Final Environmental Impact Statement

Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015

October 2008

NHTSA
www.nhtsa.gov

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

1200 New Jersey Avenue SE.
Washington, DC 20590

October 10, 2008

TO THE PARTY ADDRESSED:

I am pleased to enclose a copy of the National Highway Traffic Safety Administration (NHTSA) Final Environmental Impact Statement (FEIS) for new Corporate Average Fuel Economy (CAFE) standards required by the Energy Independence and Security Act of 2007. NHTSA recently proposed standards for model year (MY) 2011-2015 passenger cars and light trucks (Notice of Proposed Rulemaking; 73 *Federal Register* 24,352, May 2, 2008).

The FEIS compares the environmental impacts of the agency's Preferred Alternative and reasonable alternatives, including a "No Action" Alternative, pursuant to the National Environmental Policy Act (NEPA), 42 U.S.C. §§ 4321-4347, and implementing regulations issued by the Council on Environmental Quality (CEQ) and the U.S. Department of Transportation. The FEIS considers direct, indirect, and cumulative impacts and describes these impacts to inform decisionmakers and the public of the environmental impacts of the various alternatives.

Among other potential impacts, NHTSA analyzed the direct and indirect impacts related to fuel and energy use, emissions, including carbon dioxide (CO_2) and its effects on temperature and climate change, air quality, natural resources, and the human environment. NHTSA also considered the cumulative impacts of the proposed standards for MY 2011-2015 passenger cars and light trucks, together with estimated impacts of NHTSA's implementation of the CAFE program through MY 2010 and NHTSA's future CAFE rulemaking for MY 2016-2020, as prescribed by the Energy Policy and Conservation Act (EPCA), as amended by the Energy Independence and Security Act of 2007.

In developing the proposed fuel economy standards and reasonable alternatives, NHTSA considered the four EPCA factors underlying the statutory requirement for "maximum feasible" standards (technological feasibility, economic practicability, the effect of other Government standards on fuel economy, and the need of the Nation to conserve energy) and relevant environmental and safety considerations. NHTSA used a computer model that, for any given model year, applies technologies to a manufacturer's fleet until the manufacturer achieves compliance with the standard under consideration. In light of the EPCA factors, NHTSA assigned monetary values to relevant externalities (both energy security and environmental externalities, including the benefits of reductions in CO_2 emissions).

NHTSA is mailing this EIS to approximately 300 interested parties, including Federal, State, and local agencies, elected officials, environmental and public interest groups, Native American tribes, and other interested individuals.

Chapter 1 of the enclosed FEIS describes the public comment process. Comments on the DEIS and NHTSA's responses to those comments are provided in Chapter 10 of this FEIS. Written comments and the public hearing transcript can be viewed in their entirety in Appendix D of this FEIS. The transcript from the public hearing and written comments submitted to the agency are also a part of the administrative record, and are available on the Federal Docket, which can be found on the web at http://www.regulations.gov, Reference Docket No.: NHTSA-2008-0060.

No sooner than 30 days after the Environmental Protection Agency publishes a Notice of Availability of the FEIS in the *Federal Register*, NHTSA will publish a final CAFE rule and Record of Decision.

The FEIS has been placed in NHTSA's public files and is available for distribution and public inspection at:

DOT Library, W12-300
1200 New Jersey Avenue, SE
West Building
Washington, DC 20590

A limited number of hard copies and CD-ROMs of the DEIS and this FEIS are available from the DOT Library. The DEIS and this FEIS are also available for public viewing on the CAFE Web site at http://www.nhtsa.dot.gov. NHTSA is mailing copies of the FEIS to parties on its CAFE NEPA mailing list, including Federal, State, and local agencies; representatives of Native American tribes, industry, and public-interest groups; and individuals who requested a copy of the DEIS or provided comments during the EIS scoping period or the DEIS public comment period.

Additional information about the project is available from NHTSA's Fuel Economy Division, Office of International Policy, Fuel Economy and Consumer Programs, at 1-202-366-5206 or on the NHTSA CAFE Web site identified above. For assistance, please contact NHTSA through the following Website: https://www.nhtsa.dot.gov/email.cfm or toll free at 1-888-327-4236 (for TTY, contact 1-800-424-9153). The NHTSA CAFE Web site also provides access to the texts of formal NHTSA documents, such as orders, notices, and rulemakings.

Sincerely yours,

David Kelly

David Kelly
Acting Administrator

Enclosure

Summary

S.1 FOREWORD

The National Highway Traffic Safety Administration (NHTSA) prepared this Final Environmental Impact Statement (FEIS) to analyze and disclose the potential environmental impacts of Corporate Average Fuel Economy (CAFE) standards for the total fleet of passenger and non-passenger automobiles (later referred to as cars and light trucks, respectively) and reasonable alternative standards for the NHTSA CAFE Program pursuant to Council on Environmental Quality (CEQ) National Environmental Policy Act (NEPA) implementing regulations, U.S. Department of Transportation (DOT) Order 5610.1C, and NHTSA regulations.[1] This FEIS compares the potential environmental impacts of alternative mpg levels that will be considered by NHTSA for the final rule, including the Preferred Alternative and a No Action Alternative. It also analyzes direct, indirect, and cumulative impacts and analyzes impacts in proportion to their significance. A broad and comprehensive analysis of the alternatives, varied by economic inputs and sensitivities, and likely environmental impacts are included in this FEIS for decisionmakers.

S.2 BACKGROUND

The Energy Policy and Conservation Act of 1975 established a program to regulate automobile fuel economy and provided for the establishment of average fuel economy standards for passenger cars and separate standards for light trucks. As part of that Act, the CAFE Program was established to reduce national energy consumption by increasing the fuel economy of cars and light trucks. The Act directs the Secretary of Transportation to set and implement fuel economy standards for cars and light trucks sold in the United States. NHTSA is delegated responsibility for implementing the Energy Policy and Conservation Act fuel economy requirements assigned to the Secretary of Transportation.

In December 2007, the Energy Independence and Security Act of 2007 amended Energy Policy and Conservation Act CAFE Program requirements and granted DOT additional rulemaking authority. Pursuant to the Energy Independence and Security Act, on April 22, 2008, NHTSA proposed CAFE standards for model year (MY) 2011-2015 passenger cars and light trucks in a Notice of Proposed Rulemaking issued on May 2, 2008.

S.3 PURPOSE AND NEED FOR THE PROPOSED ACTION

The Energy Independence and Security Act sets forth extensive requirements for the rulemaking, and those requirements form the purpose of and need for the standards. The requirements also were the basis for establishing the range of alternatives considered in this FEIS. Specifically, the Energy Policy and Conservation Act requires the Secretary of Transportation to establish average fuel economy standards for each model year at least 18 months before the beginning of that model year and to set them at "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year." When setting maximum feasible fuel economy standards, the Secretary is required to "consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy." NHTSA interprets the statutory factors as including environmental issues and permitting the consideration of other relevant societal issues, such as safety. The purpose of this FEIS is to disclose and

[1] NEPA is codified at 42 U.S.C. § 4321-4347. CEQ NEPA implementing regulations are codified at 40 Code of Federal Regulations (CFR) Parts 1500-1508. NHTSA NEPA implementing regulations are codified at 49 CFR Part 520.

analyze the potential environmental impacts of the standards and alternatives for consideration by the NHTSA decisionmaker.

The Energy Independence and Security Act further directs the Secretary, after consultation with the Secretary of Energy and the Administrator of the U.S. Environmental Protection Agency (EPA), to establish separate average fuel economy standards for passenger cars and for light trucks manufactured in each model year beginning with MY 2011 "to achieve a combined fuel economy average for MY 2020 of at least 35 miles per gallon for the total fleet of passenger and non-passenger automobiles manufactured for sale in the United States for that model year." In this FEIS, passenger and non-passenger are also referred to as the car and light truck fleet. In so doing, the Secretary of Transportation is to adopt "annual fuel economy standard increases," but in any single rulemaking, standards may be established for not more than 5 model years. This FEIS covers the initial 5-year rulemaking and also considers the cumulative impacts of reaching the 35-miles-per-gallon (mpg) total fleet requirement during the second 5-year period, MY 2016-2020.

S.4 ALTERNATIVES

NEPA requires an agency to compare the potential environmental impacts of its proposed action and a reasonable range of alternatives. The Energy Policy and Conservation Act fuel economy requirements, including the four factors NHTSA must consider in determining maximum feasible CAFE levels – technological feasibility, economic practicability, the need to conserve energy, and the effect of other standards of the Government on fuel economy – form the purpose of and need for the MY 2011-2015 CAFE standards and, therefore, inform the range of alternatives for consideration in this NEPA analysis. NHTSA recognizes that several alternative CAFE levels are conceivable and that the alternatives represent several points on a continuum of alternatives. The NHTSA decision process must balance the four Energy Policy and Conservation Act factors and be informed by the environmental considerations of NEPA. In developing its reasonable range of alternatives, NHTSA identified alternative stringencies that represent the full spectrum of potential environmental impacts and safety considerations. The Draft Environmental Impact Statement (DEIS) and this FEIS analyze the impacts of six "action" alternatives and the impacts that would be expected if NHTSA imposed no new requirements (the No Action Alternative).

In response to public comments on the DEIS, this FEIS also examines how these alternatives are affected by variations in the economic assumptions input to the computer model NHTSA uses to calculate the costs and benefits of various CAFE standards (the Volpe model). NHTSA calculated and analyzed mpg standards and environmental impacts associated with each alternative under several model input scenarios. The "Reference Case" uses as model inputs the Energy Information Administration's reference case fuel price forecast and a domestic social cost of carbon. The "High Scenario" uses as model inputs the Energy Information Administration's high case for fuel price forecast and a global social cost of carbon. Values for the domestic and social costs of carbon have been updated from the DEIS, as have those for the costs of oil externalities. NHTSA also examined two other input scenarios, Mid-1 and Mid-2 Scenarios, to show how input values between those used in the Reference Case and the High Scenario result in mpg that falls between the mpg associated with the Reference Case and the High Scenario. All input scenarios use a 3-percent discount rate to calculate the current value of carbon emissions reductions. The High Scenario also uses a 3-percent discount rate to calculate the current value of other costs and benefits, while the Reference Case and Mid-1 and Mid-2 Scenarios use a 7-percent discount rate to calculate the current value of costs and benefits other than future carbon reductions.

NHTSA's Preferred Alternative is the Optimized Alternative (Alternative 3), which establishes optimized mpg standards that yield the greatest net benefits of all feasible alternatives. As mpg standards are increased beyond this optimized level, manufacturers would be forced to apply technologies that entail higher incremental costs than benefits, thereby reducing total net benefits.

The most stringent alternative NHTSA analyzed is the Technology Exhaustion Alternative (Alternative 7), which represents the level at which vehicle manufacturers apply all feasible technologies, while recognizing that some must still be installed as part of a vehicle freshening or redesign. Alternative 7 would yield negative net benefits. Another specific alternative NHTSA analyzed was the Total Costs Equal Total Benefits Alternative (Alternative 6), the second most stringent alternative, under which manufacturers would be forced to apply technologies until total costs equal total benefits, yielding zero net benefits. Three other alternatives NHTSA analyzed (Alternatives 2, 4, and 5) illustrate how costs, benefits, and net benefits vary across other possible CAFE standards between the No Action Alternative (Alternative 1) and the Total Costs Equal Total Benefits Alternative (Alternative 6).

As shown in Table S-1, the 50 Percent Above Optimized Alternative would generate a 2015 mpg standard half way between the Optimized and Total Costs Equal Total Benefits Alternatives. The 25 Percent Above Optimized Alternative would generate a 2015 mpg standard halfway between the Optimized and 50 Percent Above Optimized Alternatives, and the 25 Percent Below Optimized Alternative would generate a 2015 standard that falls below the Optimized Alternative by the same absolute amount by which the 25 Percent Above Optimized Alternative exceeds the Optimized Alternative.

Table S-1

Reference Case Alternative CAFE Standards in MY 2015 MPG

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Cars	27.5	33.3	33.4	33.5	33.7	33.9	47.1
Trucks	23.4	25.8	26.0	26.2	26.5	27.0	37.2

The specific mpg standards associated with each alternative in Table S-1 reflect the Reference Case input values for fuel prices, the social cost of carbon, the discount rate, and oil import externalities. Table S-2 lists the Reference Case and High Scenario values for key economic model inputs. Table S-3 shows how the mpg standards associated with each alternative would change with this combination of inputs. Chapter 2 of this FEIS provides a more detailed description of the Input Scenarios used in the analysis**.**

The alternatives in Tables S-1 and S-3 are both defined by the same relationship between costs and benefits calculated by the economic model. The specific mpg standards associated with the alternatives in Tables S-1 and S-3 differ because model input values affect the relationship between costs and benefits. For example, the Optimized Alternative that yields the greatest net benefits is associated with the specific mpg standards of 33.4 for cars and 26.0 for trucks in MY 2015, as shown in Table S-1, based on the Reference Case inputs in Table S-2. For the High Scenario, the Optimized Alternative that yields the greatest net benefits is associated with the specific mpg standards of 37.7 for cars and 29.6 for trucks in MY 2015, as shown in Table S-3.

Table S-2

Reference Case and High Scenario Economic Model Inputs

	Value of Carbon Dioxide (CO_2) (2007 $/ton)	Oil Import Externalities (2007 $/gallon)	*Annual Energy Outlook 2008* a/ Fuel Price	Discount Rate
Reference Case	$2.00 (domestic)	$0.326	$2.41 (reference)	3% CO_2 – 7% Other
High Scenario	$33.00 (global)	$0.116	$3.33 (high)	3% CO_2 – 3% Other

a/ Both the Reference and High *Annual Energy Outlook* fuel price vary by year. Price shown is the average 2011-2030 price for gasoline expressed in 2007 dollars.

Table S-3

High Scenario Alternative CAFE Standards in MY 2015 MPG

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized (Preferred)	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Passenger Cars	27.5	37.2	37.7	38.2	38.8	39.8	47.1
Light Trucks	23.4	28.9	29.6	30.3	31.0	32.3	37.2

An infinite number of mpg standards could theoretically be defined along a continuum from the least to the most stringent levels of CAFE standards. NHTSA selected the specific alternatives analyzed to illustrate cost and benefit characteristics along this continuum. A vast number of model input values also could be used to analyze costs and benefits (along a continuum from low to high values for fuel price, carbon dioxide (CO_2), oil import externalities, and the discount rate), serving as model parameters to these existing alternatives and generating additional mpg levels for analysis.[2] These model parameters are estimated forecasts of future economic circumstances. NHTSA acknowledges that these estimates are subject to uncertainty and debate. Many who commented on the DEIS noted that a combination of different model input values would result in substantially higher mpg standards associated with the Optimized Alternative. In this FEIS, NHTSA addresses uncertainty about model input values by presenting analytical results for the Reference Case and High Scenario model inputs, and for two other scenarios with model inputs that fall between these (the Mid-1 and Mid-2 Scenarios).

The resource sections in Chapters 3 and 4 of this FEIS discuss the analysis of alternatives for the Reference Case model inputs under the heading "Environmental Consequences." The Reference Case discussions are followed by sections entitled "Input Scenarios," which discuss the impacts for the same alternatives under the High Scenario, and for other scenarios that have model inputs and outputs that fall between those of the Reference Case and High Scenario (the Mid-1 and Mid-2 Scenarios). This analytical structure is designed to fully inform decisionmakers and the public about the potential environmental impacts of any combination of economic inputs into the model, across the range of feasible alternatives.

[2] CEQ guidance instructs that "[w]hen there are potentially a very large number of alternatives, only a reasonable number of examples, covering the full spectrum of alternatives, must be analyzed and compared in the EIS." CEQ, *Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations*, 46 *FR* 18026, 18027, March 23, 1981 (emphasis in original).

S.5 POTENTIAL ENVIRONMENTAL CONSEQUENCES

This FEIS describes potential environmental impacts to a variety of resources. The resource areas that warrant the most detailed analysis are energy resources, air quality, and climate and resources that might be affected by changes in climate. Tables and figures in this section summarize the direct, indirect, and cumulative effects of the CAFE alternatives on energy, air quality, and climate. NHTSA recognizes the national interest in global climate change issues, particularly as related to the Country's use of automobiles and light trucks. "Global climate change" refers to long-term fluctuations in global surface temperatures, precipitation, sea level, cloud cover, ocean temperatures and currents, and other climatic conditions. Scientific research has shown that in the past century, Earth's surface temperature has risen by an average of about 1.3 degrees Fahrenheit (°F) (0.74 degree Celsius[°C]) (IPCC 2007c) and sea levels have risen 6.7 inches (0.17 meter) (IPCC 2007c).

Most scientists now agree that climate change is very likely due to greenhouse gas (GHG) emissions from human activities (IPCC 2007d). Most GHGs are naturally occurring, including CO_2, methane (CH_4), nitrous oxide (N_2O), water vapor, and ozone (O_3). Human activities, such as the combustion of fossil fuel, the production of agricultural commodities, and the harvesting of trees, can contribute to increased concentrations of these gases in the atmosphere.

Levels of atmospheric CO_2 have been rising rapidly. For about 10,000 years prior to the Industrial Revolution, atmospheric CO_2 levels were 280 ppm (plus or minus 20 ppm). Since the Industrial Revolution, CO_2 levels have risen to 367 ppm in 1999 and to 379 ppm in 2005. In addition, other GHGs have been on the increase. Direct atmospheric measurements since 1970 have detected a 150 percent decrease in CH_4 and an 18 percent increase in N_2O (IPCC 2007c).

Contributions to the build-up of GHG in the atmosphere vary greatly from country to country, and depend heavily on the level of industrial and economic activity. Emissions from the United States accounted for approximately 15 to 20 percent of global GHG emissions in the year 2000. With more than one-quarter of these U.S. emissions due to the combustion of petroleum fuels in the transportation sector, CO_2 emissions from the United States transportation sector represent approximately 4 percent of all global GHG emissions. Emissions from passenger cars and light trucks account for about 60 percent of emissions from the U.S. transportation sector.[3]

Throughout this FEIS, NHTSA has relied extensively on findings of the United Nations Intergovernmental Panel on Climate Change (IPCC) and the U.S. Climate Change Science Program (USCCSP). Our discussion relies heavily on the most recent, thoroughly peer-reviewed, and credible assessments of global climate change and its impact on the United States: the IPCC Fourth Assessment Report Working Group I[4] and II[5] Reports,[6] and reports by the USCCSP that include *Scientific Assessments of the Effects of Global Climate Change on the United States* and Synthesis and Assessment Products.[7] This FEIS cites these sources and the studies they review frequently. For these reasons, NHTSA encourages readers to read the Synthesis Report: Summary for Policymakers of the IPCC Fourth

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[3] Estimation of this number is complicated by the fact that greenhouse gas inventories are taken by EPA, but EPA uses different definitions of passenger cars and light trucks than EPCA.
[4] *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC.* ISBN 978 0521 88009-1 Hardback; 978 0521 70596-7. *See* http://www.ipcc.ch/ipccreports/ar4-wg1.htm.
[5] *Climate Change 2007 – Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC.* (978 0521 88010-7 Hardback; 978 0521 70597-4 Paperback). *See* http://www.ipcc.ch/ipccreports/ar4-wg2.htm.
[6] *See generally* http://www.ipcc.ch/ipccreports/assessments-reports.htm.
[7] *See generally* http://www.climatescience.gov/.

Assessment Report before reading this FEIS.[8] This relatively short document summarizes the key findings of the IPCC Fourth Assessment Report.

Because of the link between the transportation sector and GHG emissions, NHTSA recognizes the need to consider the possible impacts on climate and global climate change in the analysis of the effects of these fuel economy standards. NHTSA also recognizes the difficulties and uncertainties involved in such an impact analysis. Accordingly, consistent with CEQ regulations on addressing incomplete or unavailable information in environmental impact analyses, NHTSA has reviewed existing credible scientific evidence which is relevant to this analysis and summarized it in this FEIS. NHTSA has also employed and summarized the results of research models generally accepted in the scientific community.

NHTSA emphasizes that the action of setting fuel economy requirements does not directly regulate emissions from passenger cars and light trucks. NHTSA's authority to promulgate new fuel economy standards is a limited authority and does not allow it to regulate other factors affecting emissions, including society's driving habits. The proposed action before NHTSA is to establish the CAFE standards for MY 2011-2015 passenger cars and light trucks, which has a primary goal of energy conservation. At the same time, the reduction of CO_2 emissions is a substantial by-product of that conservation. Further, the stringency of the fuel economy standards is based on the valuation of both direct (fuel savings) and indirect (*e.g.*, the reduction of CO_2 emissions) benefits. To the extent that the CAFE standards reduce fuel consumption, they play a role in reducing vehicle emissions that would have occurred absent such conservation. Consequently, as discussed in this FEIS, the proposed action will indirectly contribute to reducing impacts on and associated with the ongoing process of global climate change.

Although the alternatives have the potential to substantially decrease GHG emissions, they do not prevent climate change, but only result in reductions in the anticipated increases in CO_2 concentrations, temperature, precipitation, and sea level. They would also to a small degree delay the point at which certain temperature increases and other physical effects stemming from increased GHG emissions would occur. As discussed below, NHTSA presumes that these reductions in climate effects will be reflected in reduced impacts on affected resources.

NHTSA informed the public through notices in the *Federal Register* of its intent to prepare a DEIS for this proposed action. The purpose of these notices was to request from the public its views and comments on the scope of the NEPA analysis, including the impacts and alternatives the DEIS should address, and to inform NHTSA of any available studies that would assist in the impact analysis for global climate-change issues. NHTSA reviewed and considered the public scoping comments and the studies commenters suggested. The predominant request by commenters during the scoping process was that NHTSA focus the DEIS on the standards' possible impacts on both air quality and global climate change.

EPA issued the Notice of Availability of the DEIS on July 3, 2008, which initiated a 45-day public comment period. NHTSA held a public hearing on the DEIS in Washington, DC, on August 4, 2008. The DEIS public comment period ended on August 18, 2008. NHTSA received 66 written comment documents from interested stakeholders. In addition, 44 private citizens and organizations provided oral statements at the public hearing.

[8] IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22, *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf.

Commenters urged NHTSA to consider standards that would go beyond the Energy Independence and Security Act's minimum requirement to reach 35 mpg by the year 2020. NHTSA has analyzed a full range of alternatives, the most stringent of which exceed the 35 mpg target by 2015. Commenters also noted that environmental impacts could depend on the choice of economic inputs used in the Volpe model. NHTSA has addressed these concerns by analyzing the full range of environmental impacts that result under varying economic inputs for each alternative. Finally, commenters requested that the FEIS discuss the appropriate context of this action in relation to other large-scale actions that reduce GHGs, and NHTSA has included such a discussion in this FEIS.

NHTSA consulted with various federal agencies in the development of this FEIS, including the EPA, the Centers for Disease Control and Prevention, the National Oceanic and Atmospheric Administration, the U.S. Fish and Wildlife Service, the National Park Service, and the U.S. Forest Service.

While the main focus of this FEIS is the quantification of impacts to energy, air quality, and climate, and qualitative analysis of cumulative impacts resulting from climate change, it also addresses other potentially affected resources. NHTSA conducted a qualitative review of the related direct, indirect, and cumulative impacts, positive or negative, of the alternatives on other potentially affected resources (water resources, biological resources, land use, hazardous materials, safety, noise, historic and cultural resources, and environmental justice). Effects of the alternatives on these resources would be too small to address quantitatively. Impacts to biological resources could include reductions in habitat disturbance, decreased impacts from acid rain on water and terrestrial habitats from decreases in petroleum production, and increased agricultural-related disturbances and runoff due to biofuel production. Impacts to land use and development could include increased agricultural land use. Impacts to safety could include downweighting of vehicles and increased vehicle miles traveled, resulting in increased traffic injuries and fatalities. Impacts to hazardous materials could include overall reductions in the generation of air and oil production related wastes, and increases in agricultural wastes due to biofuel production. Impacts to historic and cultural resources could include reductions in acid rain related damage. Noise impacts could include increased noise levels in some areas due to higher vehicle miles traveled. Impacts to environmental justice populations could include increased air toxics in some areas as a result of higher vehicle miles traveled. No impacts are expected to natural areas protected under Section 4(f) of the Department of Transportation Act. In addition, NHTSA has determined a Section 7 review under the Endangered Species Act is not required.

The effects of the alternatives on climate – CO_2 concentrations, temperature, precipitation, and sea-level rise – can translate into impacts on key resources, including freshwater resources, terrestrial ecosystems, coastal ecosystems, land use, human health, and environmental justice. Although the alternatives have the potential to substantially decrease GHG emissions, they do not prevent climate change from occurring. However, the magnitudes of the changes in these climate effects under the alternatives – a few parts per million of CO_2, one or two one-hundredths of a degree Celsius difference in temperature, a small percentage change (0.02 percent to 0.03 percent) in the rate of precipitation increase, and 1 or 2 millimeters of sea-level change – are too small to meaningfully address quantitatively in terms of their impacts on resources. Given the enormous resource values at stake, these distinctions could be important – very small percentages of huge numbers can still yield substantial results – but they are too small for current quantitative techniques to resolve. Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but rather provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change.[9]

[9] *See* 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures … which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40

NHTSA examined the impacts resulting from global climate change due to all global emissions on the U.S. and global scale. Impacts to freshwater resources could include changes in precipitation patterns, decreasing aquifer recharge in some locations, changes in snowpack and time of snowmelt, salt-water intrusion from ocean rise, changes in weather patterns resulting in flooding or drought in certain regions, increased water temperature, and numerous other changes to freshwater systems that disrupt human use and natural aquatic habitats. Impacts to terrestrial ecosystems could include shifts in species range and migration patterns, potential extinctions of sensitive species unable to adapt to changing conditions, increases in the occurrence of forest fires and pest infestation and intensity, and changes in habitat productivity because of increased atmospheric CO_2. Impacts to coastal ecosystems, primarily from predicted sea-level rise, could include the loss of coastal areas due to submersion and erosion, additional impacts from severe weather and storm surges, and increased salinization of estuaries and freshwater aquifers. Impacts to land use could include flooding and severe-weather impacts to coastal, floodplain and island settlements, extreme heat and cold waves, increases in drought in some locations, and weather/sea-level related disruptions of the service, agricultural, and transportation sectors. Impacts to human health could include increased mortality and morbidity due to excessive heat, increases in respiratory conditions due to poor air quality, increases in water and food-borne diseases, changes to the seasonal patterns of vector-borne diseases, and increases in malnutrition. Impacts to environmental justice populations could come from any of the above.

S.5.1 Direct and Indirect Effects

Under NEPA, direct effects “are caused by the action and occur at the same time and place” (40 CFR § 1508.8). CEQ regulations define indirect effects as those that “are caused by the action and are later in time or farther removed in distance but are still reasonably foreseeable. Indirect effects may include … effects on air and water and other natural systems, including ecosystems” (40 CFR § 1508.8). Below is a description of the direct and indirect effects of the CAFE alternatives on energy, air quality, and climate.

S.5.1.1 Energy – Reference Case

Table S-4 shows the impact on annual fuel consumption under the Reference Case for passenger cars and light trucks from 2020 through 2060,[10] a period during which an increasing volume of the fleet will be MY 2011-2015 vehicles. The table shows annual total fuel consumption (both gasoline and diesel) under the No Action Alternative and the six action alternatives for the Reference Case. Fuel consumption under the No Action Alternative is 264.9 billion gallons in 2060. Consumption falls to under 256.3 billion gallons under the Optimized Alternative and would fall to 214.3 billion gallons under the Technology Exhaustion Alternative.

CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1984), *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (recognizing that agencies are sometimes “limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood” or cannot be quantified).

[10] NHTSA uses 2060 as the end point for the analysis because it is the time at which 98 percent or more of the operating fleet would be made up of MY 2011-2015 or newer vehicles, thus achieving the maximum fuel savings under this rule.

Table S-4

Reference Case Passenger Car and Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons)

Calendar Year	Alternative CAFE Standards for MY 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Fuel Consumption							
2020	151.8	149.4	149.2	148.7	148.4	147.8	134.9
2030	172.4	167.7	167.2	166.5	165.8	164.9	141.8
2040	198.5	192.8	192.1	191.3	190.4	189.3	161.1
2050	229.7	222.9	222.2	221.2	220.1	218.7	185.9
2060	264.9	257.1	256.3	255.1	253.8	252.3	214.3
Fuel Savings Compared to No Action							
2020	--	2.4	2.6	3.1	3.4	3.9	16.9
2030	--	4.7	5.2	5.8	6.6	7.5	30.5
2040	--	5.8	6.4	7.2	8.2	9.2	37.4
2050	--	6.8	7.4	8.5	9.5	10.8	43.8
2060	--	7.8	8.6	9.7	11.0	12.5	50.5

S.5.1.2 Energy – Input Scenarios

In response to public comments, and to test how different economic assumptions could affect estimates of fuel consumption, NHTSA examined scenarios that varied cost inputs used in the Volpe model. NHTSA modeled three additional scenarios – High, Mid-1, and Mid-2 – and compared the results to the Reference Case. Table S-5 lists the impact on annual fuel consumption under the High Scenario in the Volpe model for passenger cars and light trucks from 2020 through 2060. The High Scenario uses the economic inputs described in Table S-2. Table S-5 lists annual total fuel consumption for passenger cars and light trucks, both gasoline and diesel, under the No Action Alternative and the six action alternatives. Fuel consumption under the No Action Alternative will reach 230.8 billion gallons by 2060, when the entire fleet is likely to be composed of MY 2011 or newer cars. With the assumption of higher fuel prices, lower consumption is expected across the alternatives. Consumption totals 210.2 billion gallons under the High Scenario Optimized Alternative in 2060, compared to 256.3 billion gallons under the Reference Case Optimized Alternative.

Table S-5

High Scenario Passenger Car and Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons)

Calendar Year	Alternative CAFE Standards for MY 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Fuel Consumption							
2020	139.1	133.4	132.4	131.4	130.5	129.6	123.7
2030	155.4	144.4	142.6	140.8	139.5	138.2	127.8
2040	177.2	163.7	161.6	159.5	157.7	156.3	143.8
2050	202.6	187.0	184.6	182.1	180.1	178.5	164.0
2060	230.8	213.0	210.2	207.4	205.1	203.1	186.7

Table S-5 (cont'd)							
High Scenario Passenger Car and Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons)							
	Alternative CAFE Standards for MY 2011-2015						
	Alt. 1	**Alt. 2**	**Alt. 3**	**Alt. 4**	**Alt. 5**	**Alt. 6**	**Alt. 7**
Calendar Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Cost Equal Total Benefit**	**Technology Exhaustion**
Fuel Savings Compared to No Action							
2020	--	5.6	6.7	7.8	8.6	9.4	15.5
2030	--	11.0	12.8	14.6	15.9	17.2	27.5
2040	--	13.5	15.6	17.8	19.4	20.9	33.4
2050	--	15.5	18.0	20.6	22.5	24.2	38.6
2060	--	17.8	20.6	23.4	25.6	27.6	44.1

S.5.1.3 Air Quality – Reference Case

Table S-6 summarizes the total national criteria and air toxic pollutant emissions in 2035[11] for the seven alternatives under the Reference Case, left to right in order of increasing fuel economy requirements. At the national level, most emissions analyzed in this FEIS are reduced by the Alternatives under the Reference Case, regardless of analysis year. The No Action Alternative has the highest emissions of all the alternatives for oxides of nitrogen (NO_x), fine particulate matter ($PM_{2.5}$), sulfur oxides (SO_x), volatile organic compounds (VOCs), acetaldehyde, 1,3-butadiene, and diesel particulate matter. Alternative 3 has the highest emissions of all the alternatives for CO and benzene, indicating slight increases over the No Action Alternative. Alternative 7 has the highest emissions of all the alternatives for acrolein and formaldehyde.

S.5.1.4 Air Quality - Input Scenarios

In response to public comments, and to test how different economic assumptions might affect estimates of air quality impacts, NHTSA modeled three additional scenarios – High, Mid-1, and Mid-2 – and compared the results to the Reference Case. Table S-7 summarizes the national criteria and air toxic pollutant emissions in 2035 for the seven alternatives for the High Scenario. For the High Scenario, emissions under each alternative are generally lower than for the Reference Case. At the national level, most emissions are reduced from the No Action Alternative under the High Scenario, but acetaldehyde and formaldehyde demonstrate increases in some localized cases. These localized increases slightly offset the reductions achieved by implementation of Clean Air Act (CAA) requirements, motor vehicle emissions standards, and related programs. All of the alternatives would reduce adverse health outcomes and health costs related to motor vehicle air pollution, and thus would have beneficial health effects that would not need mitigation.

[11] NHTSA uses 2035 as the latest projection year because by 2035 almost all passenger cars and light trucks in operation would meet at least the MY 2011-2015 standards, and the impact of the standards would start to come only from VMT growth rather than further tightening of the standards. NHTSA believes the year 2035 is a practical maximum for impacts of criteria and toxic air pollutants to be considered reasonably foreseeable rather than speculative.

Table S-6

Reference Case Alternative CAFE Standards Nationwide Criteria Pollutant Emissions and Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year, Calendar Year 2035)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Criteria Pollutant Emissions							
Carbon monoxide (CO)	19,745,847	19,809,449	19,866,650	19,460,737	19,411,428	19,219,623	11,050,380
Nitrogen oxides (NO_x)	1,369,135	1,360,018	1,360,519	1,347,773	1,344,759	1,336,616	1,057,996
Particulate matter ($PM_{2.5}$)	99,707	98,692	98,625	98,064	97,853	97,861	91,101
Sulfur oxides (SO_x)	265,792	259,517	258,951	257,164	255,984	254,228	203,047
Volatile organic compounds (VOCs)	1,906,119	1,894,399	1,896,272	1,869,506	1,863,351	1,844,280	1,205,722
Toxic Air Pollutant Emissions							
Acetaldehyde	8,209	8,206	8,208	8,198	8,197	8,165	7,733
Acrolein	351	354	353	367	369	378	720
Benzene	47,515	47,428	47,517	46,703	46,570	46,154	29,324
1,3-butadiene	3,885	3,834	3,834	3,818	3,815	3,781	3,231
Diesel particulate matter (DPM)	119,499	116,161	115,786	115,400	114,858	114,592	104,644
Formaldehyde	13,035	12,949	12,915	13,122	13,142	13,169	16,745

Table S-7

High Scenario Alternative CAFE Standards Nationwide Criteria Pollutant Emissions and Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year, Calendar Year 2035)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Criteria Pollutant Emissions							
Carbon monoxide (CO)	17,713,991	16,946,492	17,052,955	16,475,978	16,127,830	15,629,753	9,913,291
Nitrogen oxides (NO_x)	1,228,251	1,181,455	1,180,414	1,159,073	1,146,599	1,129,532	949,127
Particulate matter ($PM_{2.5}$)	89,447	86,654	86,251	86,389	85,756	85,318	81,727
Sulfur oxides (SO_x)	238,442	221,475	219,361	215,533	212,881	209,978	182,153
Volatile organic compounds (VOCs)	1,709,979	1,620,442	1,621,526	1,572,211	1,546,659	1,507,558	1,081,653
Toxic Air Pollutant Emissions							
Acetaldehyde	7,364	7,318	7,326	7,244	7,239	7,211	6,938
Acrolein	315	356	353	379	393	412	646
Benzene	42,626	40,639	40,753	39,588	38,860	37,822	26,306
1,3-butadiene	3,885	3,815	3,821	3,790	3,754	3,709	3,231
Diesel particulate matter (DPM)	107,203	99,856	98,495	98,385	97,499	96,932	93,876
Formaldehyde	11,694	11,933	11,878	12,000	12,178	12,394	15,022

S.5.1.5 Climate – Reference Case GHG Emissions

Table S-8 shows total GHG emissions and emissions reductions from new passenger cars and light trucks from 2010-2100[12] under each of the seven alternatives for the Reference Case. While GHG emissions from this sector will continue to rise over the period (absent other reduction efforts), the effect of the alternatives is to slow this increase by varying amounts. Compared to the No Action Alternative, projections of emissions reductions over the 2010 to 2100 time frame due to other MY 2011-2015 alternative CAFE standards ranged from 5,922 to 28,047 million metric tons of CO_2 ($MMTCO_2$).[13] Over this period, this range of alternatives would reduce global CO_2 emissions (from all sources) by about 0.1 to 0.6 percent (based on global emissions of 4,850,000 $MMTCO_2$).

Table S-8

Reference Case Emissions and Emissions Reductions Due to the MY 2011-2015 CAFE Standards from 2010-2100 ($MMTCO_2$)

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	221,258	0
2 25 Percent Below Optimized	215,337	5,922
3 Optimized	214,643	6,616
4 25 Percent Above Optimized	214,144	7,114
5 50 Percent Above Optimized	213,254	8,004
6 Total Costs Equal Total Benefits	212,345	8,913
7 Technology Exhaustion	193,212	28,047

S.5.1.6 Climate - Reference Case CO_2 Concentration and Global Mean Surface Temperature

This FEIS uses a climate model to estimate the changes in CO_2 concentrations, global mean surface temperature, and changes in sea level for each alternate CAFE standard, and uses increases in global mean surface temperature combined with an approach and coefficients from the IPCC Fourth Assessment Report (IPCC 2007a) to estimate changes in global precipitation. NHTSA used MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change) Version 5.3 (Wigley 2003 to 2008) to estimate changes in key direct and indirect effects. The application of MAGICC version 5.3 uses the emissions estimates from the Volpe model, which include CO_2, CH_4, and N_2O from both direct fuel combustion and upstream sources, as well as SO_2, NO_x, CO, and VOCs. NHTSA performed sensitivity analyses to examine the relationship among various CAFE alternatives, climate sensitivities, and scenarios of global emissions paths and the associated direct and indirect effects for each combination. These relationships can be used to infer the effect of the emissions associated with the regulatory alternatives on direct and indirect climate effects.

[12] The global climate change models NHTSA used for this FEIS analysis use 2100 because we believe that, given the present state of the science, 2100 is a practical maximum for impacts of climate change to be considered reasonably foreseeable rather than speculative.
[13] The values here are summed from 2010 through 2100, and therefore are considerably higher than the value of 520 $MMTCO_2$ cited in the Notice of Proposed Rulemaking for the Optimized Alternative. The latter value is the reduction in CO_2 emissions by only MY 2011-2015 passenger cars and light trucks over their lifetimes resulting from the optimized CAFE standards, measured as a reduction from the Notice of Proposed Rulemaking baseline of extending the CAFE standards for MY 2010 to apply to MY 2011-2015.

Table S-9 shows mid-range estimated CO_2 concentrations, increase in global mean surface temperature, and sea-level rise in 2030, 2060, and 2100 under the No Action Alternative and the six action alternatives. There is a fairly narrow band of estimated CO_2 concentrations as of 2100, from 714.6 parts per million under the Technology Exhaustion Alternative to 717.2 parts per million under the No Action Alternative. Because CO_2 concentrations are the key driver of climate effects, this narrow range implies that the differences among alternatives are difficult to distinguish. These estimates include considerable uncertainty due to a number of factors, of which the climate sensitivity is the most important. The IPCC Fourth Assessment Report estimates a range of climate sensitivity from 2.5 to 4.0 °C with a mid point of 3.0 °C which directly relates to the uncertainty in estimated global mean surface temperature.

Table S-9

Reference Case MY 2011-2015 Alternative CAFE Standards Impact on CO_2 Concentration, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC (A1B a/)

	CO_2 Concentration (parts per million)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (centimeters)		
	2030	2060	2100	2030	2060	2100	2030	2060	2100
Totals by Alternative									
1 No Action (A1B-AIM)	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.5	573.4	716.7	0.873	1.943	2.957	7.99	19.29	37.08
3 Optimized	455.5	573.4	716.6	0.873	1.943	2.956	7.99	19.29	37.08
4 25 Percent Above Optimized	455.5	573.4	716.6	0.873	1.943	2.956	7.99	19.29	37.08
5 50 Percent Above Optimized	455.5	573.4	716.5	0.873	1.943	2.956	7.99	19.29	37.08
6 Total Costs Equal Total Benefits	455.4	573.3	716.4	0.873	1.943	2.956	7.99	19.28	37.07
7 Technology Exhaustion	455.3	572.5	714.6	0.872	1.938	2.946	7.99	19.25	36.99
Reductions under Alternative CAFE Standards									
2 25 Percent Below Optimized	0.0	0.3	0.5	0.000	0.001	0.002	0.00	0.01	0.02
3 Optimized	0.0	0.3	0.6	0.000	0.001	0.002	0.00	0.01	0.02
4 25 Percent Above Optimized	0.0	0.3	0.6	0.000	0.001	0.003	0.00	0.01	0.02
5 50 Percent Above Optimized	0.0	0.3	0.7	0.000	0.001	0.003	0.00	0.01	0.02
6 Total Costs Equal Total Benefits	0.1	0.4	0.8	0.000	0.002	0.003	0.00	0.02	0.03
7 Technology Exhaustion	0.2	1.2	2.6	0.002	0.007	0.013	0.00	0.05	0.11

a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

For all alternatives, the temperature increase is about 0.87 °C for 2030, 1.94 °C for 2060, and 2.96 °C for 2100. The differences among alternatives are small. For 2100, the reduction in temperature increase in relation to the No Action Alternative ranges from 0.002 °C to 0.013 °C.

S.5.1.7 Climate - Reference Case Global Mean Precipitation

The action alternatives reduce temperature increases slightly in relation to the No Action Alternative, and thus reduce increases in precipitation slightly, as shown in Table S-10. As shown in the table, there is a fairly narrow band of estimated reductions in precipitation increase in the mid-range estimates as of 2090, from 4.49 percent to 4.51 percent, and there is very little difference between the alternatives. Uncertainty in these numbers results from uncertainty in the increase in the global mean surface temperature and uncertainty in the global mean precipitation change.

Table S-10

Reference Case MY 2011-2015 CAFE Alternatives: Impact on Reductions in Global Mean Precipitation based on A1B a/ SRES Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC

Scenario	2020	2055	2090
Global Mean Precipitation Change			
	1.45	1.51	1.63
Global Temperature above Average 1980-1999, Mid-level Results (^oC)			
1 No Action	0.560	1.764	2.765
2 25 Percent Below Optimized	0.560	1.763	2.763
3 Optimized	0.560	1.763	2.763
4 25 Percent Above Optimized	0.560	1.763	2.762
5 50 Percent Above Optimized	0.560	1.763	2.762
6 Total Costs Equal Total Benefits	0.560	1.763	2.762
7 Technology Exhaustion	0.560	1.758	2.753
Reduction in Global Temperature, Mid-level Results, Compared to No Action (^oC)			
2 25 Percent Below Optimized	0.000	0.001	0.002
3 Optimized	0.000	0.001	0.002
4 25 Percent Above Optimized	0.000	0.001	0.002
5 50 Percent Above Optimized	0.000	0.001	0.003
6 Total Costs Equal Total Benefits	0.000	0.001	0.003
7 Technology Exhaustion	0.000	0.006	0.011
Global Mean Precipitation Change, Mid-level Results (%)			
1 No Action	0.81	2.66	4.51
2 25 Percent Below Optimized	0.81	2.66	4.50
3 Optimized	0.81	2.66	4.50
4 25 Percent Above Optimized	0.81	2.66	4.50
5 50 Percent Above Optimized	0.81	2.66	4.50
6 Total Costs Equal Total Benefits	0.81	2.66	4.50
7 Technology Exhaustion	0.81	2.65	4.49
Reduction in Global Mean Precipitation Change, Mid-level Results, Compared to No Action (%)			
2 25 Percent Below Optimized	0.00	0.00	0.00
3 Optimized	0.00	0.00	0.00
4 25 Percent Above Optimized	0.00	0.00	0.00
5 50 Percent Above Optimized	0.00	0.00	0.00
6 Total Costs Equal Total Benefits	0.00	0.00	0.00
7 Technology Exhaustion	0.00	0.01	0.02

a/ The A1B scenario is the SRES marker scenario used by IPCC Working Group I to represent the SRES A1B (medium) storyline.

S.5.1.8 Climate - Reference Case Impact on Sea-level Rise

The IPCC Fourth Assessment Report identifies four primary components of sea-level rise: thermal expansion of ocean water; melting of glaciers and ice caps; loss of land-based ice in Antarctica; and loss of land-based ice in Greenland. Ice-sheet discharge is an additional factor that could influence sea level over the long term. The MAGICC model calculates the oceanic thermal expansion component of global mean sea-level rise, using a non-linear temperature- and pressure-dependent expansion coefficient. It also addresses the other three primary components through ice-melt models for small glaciers and the Greenland and Antarctic ice sheets, and excludes non-melt sources, which the IPCC Fourth Assessment Report also excluded.

Table S-9 lists the impact on sea-level rise under the scenarios and shows sea-level rise in 2100 ranging from 37.10 centimeters under the No Action Alternative to 36.99 centimeters under the

Technology Exhaustion Alternative, for a maximum reduction of 0.11 centimeter by 2100 from under the CAFE alternatives for the Reference Case.

S.5.1.9 Climate - Input Scenarios

In response to public comments, and to test how different economic assumptions might affect estimates of emissions reductions and resulting climate effects, NHTSA modeled three additional scenarios – High, Mid-1, and Mid-2 – and compared the results to the Reference Case. Variables that were altered include fuel price, the social cost of carbon, oil import externalities, and the discount rate for other benefits Tables S-11 and S-12 list the results for the High Scenario.

As shown in Table S-11, compared to the Reference Case, total emissions under the High Scenario were lower for all alternatives. The primary reason for this difference is the lower forecast for vehicle miles traveled under the High Scenario. Emissions reductions for all alternatives compared to the No Action Alternative were greater under the High Scenario than under the Reference Case, except for the emissions reduction resulting from the Technology Exhaustion Alternative. There was a greater emissions reduction resulting from the Technology Exhaustion Alternative under the Reference Case than under the High Scenario.

Table S-11

High Scenario Emissions and Emissions Reductions Due to the MY 2011-2015 CAFE Standards from 2010-2100 ($MMTCO_2$)

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	195,501	0
2 25 Percent Below Optimized	182,890	12,611
3 Optimized	180,591	14,910
4 25 Percent Above Optimized	179,079	16,422
5 50 Percent Above Optimized	177,669	17,832
6 Total Costs Equal Total Benefits	176,736	18,765
7 Technology Exhaustion	170,829	24,672

Table S-12 shows the resulting effects on CO_2 concentration, global mean surface temperature, and sea-level rise. Under the High Scenario, the resulting CO_2 concentration, global mean surface temperature, and sea-level rise were lower than under the Reference Case for all action alternatives except the Technology Exhaustion Alternative. Thus, the differences for the action alternatives compared to the No Action Alternative are greater for the High Scenario than the Reference Case, except for the Technology Exhaustion Alternative.

Table S-12

High Scenario 2011-2015 CAFE Alternatives Impact on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC (A1B a/)

Totals by Alternative	CO_2 Concentration (parts per million)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (centimeters)		
	2030	2060	2100	2030	2060	2100	2030	2060	2100
1 No Action	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.4	573.2	716.1	0.873	1.942	2.954	7.99	19.28	37.06
3 Optimized	455.4	573.1	715.8	0.873	1.942	2.953	7.99	19.28	37.05
4 25 Percent Above Optimized	455.4	573.0	715.7	0.873	1.941	2.953	7.99	19.28	37.04
5 50 Percent Above Optimized	455.4	572.9	715.6	0.873	1.941	2.952	7.99	19.27	37.04
6 Total Costs Equal Total Benefits	455.3	572.9	715.5	0.873	1.940	2.951	7.99	19.27	37.03
7 Technology Exhaustion	455.3	572.6	714.9	0.872	1.938	2.948	7.99	19.26	37.00
Reduction under CAFE Alternatives									
2 25 Percent Below Optimized	0.1	0.5	1.1	0.001	0.002	0.005	0.00	0.02	0.04
3 Optimized	0.1	0.6	1.4	0.001	0.003	0.006	0.00	0.02	0.05
4 25 Percent Above Optimized	0.1	0.7	1.5	0.001	0.003	0.006	0.00	0.02	0.06
5 50 Percent Above Optimized	0.1	0.8	1.6	0.001	0.004	0.007	0.00	0.03	0.06
6 Total Costs Equal Total Benefits	0.2	0.8	1.7	0.001	0.004	0.008	0.00	0.03	0.07
7 Technology Exhaustion	0.2	1.1	2.3	0.002	0.006	0.011	0.00	0.04	0.10

a/ The A1B scenario is the SRES marker scenario used by IPCC Working Group I to represent the SRES A1B (medium) storyline.

S.5.2 Cumulative Effects

CEQ identifies the impacts that must be addressed and considered by federal agencies in satisfying the requirements of NEPA. These include permanent, temporary, direct, indirect, and cumulative impacts. CEQ regulations implementing the procedural provisions of NEPA define cumulative impacts as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions." 40 CFR § 1508.7. Below is a description of the cumulative effects of the CAFE alternatives on energy, air quality, and climate.

S.5.2.1 Energy – Reference Case

The seven alternatives examined for CAFE standards will result in different future levels of fuel use, total energy, and petroleum consumption, which will in turn have an impact on emissions of GHG and criteria air pollutants. Table S-13 presents the cumulative fuel consumption and fuel savings of passenger-car and light-truck fleets from the onset of the new CAFE standards for the Reference Case.

Table S-13

Reference Case Passenger Car and Light Truck Cumulative Annual Fuel Consumption and Cumulative Fuel Savings (billion gallons)

Calendar Year Range	Alternative CAFE Standards for MY 2011-2020						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Cumulative Fuel Consumption							
2010-2020	1,601.3	1,583.2	1,581.8	1,579.5	1,577.7	1,574.5	1,510.9
2010-2030	3,229.6	3,083.6	3,076.0	3,063.1	3,051.9	3,038.5	2,786.4
2010-2040	5,092.6	4,731.3	4,714.0	4,684.5	4,658.6	4,630.4	4,125.8
2010-2050	7,245.2	6,620.1	6,591.1	6,541.1	6,497.2	6,451.1	5,647.9
2010-2060	9,733.2	8,800.2	8,757.5	8,683.5	8,618.6	8,551.6	7,401.6
Cumulative Fuel Savings							
2010-2020	--	18.1	19.5	21.8	23.6	26.7	90.3
2010-2030	--	146.0	153.7	166.5	177.7	191.1	443.2
2010-2040	--	361.3	378.6	408.1	434.0	462.2	966.8
2010-2050	--	625.1	654.1	704.1	748.0	794.1	1,597.2
2010-2060	--	933.1	975.7	1,049.8	1,114.6	1,181.6	2,331.7

S.5.2.2 Energy - Input Scenarios

To illustrate how different economic assumptions could affect estimates of fuel consumption, NHTSA examined scenarios that varied economic inputs used in the Volpe model. NHTSA modeled three additional scenarios – High, Mid-1, and Mid-2 – and compared the results to the Reference Case. Table S-14 lists the cumulative impact on fuel consumption under the High Scenario in the Volpe model for passenger cars and light trucks from the onset of the new CAFE standards. The High Scenario uses the economic inputs described in Table S-2. The table lists total fuel consumption for passenger cars and light trucks, both gasoline and diesel, under the No Action Alternative and the six action alternatives.

Table S-14

High Scenario Passenger Car and Light Truck Cumulative Annual Fuel Consumption and Cumulative Fuel Savings (billion gallons)

Calendar Year Range	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Cost Equal Total Benefit	Alt. 7 Technology Exhaustion
	Alternative CAFE Standards for MY 2011-2020						
Cumulative Fuel Consumption							
2010-2020	1,498.6	1,464.8	1,458.8	1,452.6	1,447.8	1,443.0	1,415.4
2010-2030	2,971.5	2,738.3	2,709.5	2,683.5	2,660.0	2,643.7	2,569.1
2010-2040	4,641.6	4,086.9	4,024.5	3,970.4	3,919.4	3,888.5	3,769.9
2010-2050	6,550.8	5,608.3	5,506.0	5,418.6	5,334.6	5,287.1	5,119.9
2010-2060	8,731.1	7,341.4	7,193.3	7,067.6	6,945.6	6,879.3	6,656.6
Cumulative Fuel Savings							
2010-2020	--	33.9	39.9	46.0	50.9	55.6	83.3
2010-2030	--	233.2	262.0	288.0	311.4	327.8	402.4
2010-2040	--	554.7	617.1	671.2	722.2	753.2	871.8
2010-2050	--	942.6	1,044.9	1,132.3	1,216.2	1,263.8	1,430.9
2010-2060	--	1,389.6	1,537.8	1,663.5	1,785.5	1,851.8	2,074.5

S.5.2.3 Air Quality – Reference Case

Table S-15 summarizes the cumulative national toxic and criteria pollutants in 2035, showing that the Reference Case No Action Alternative has the highest cumulative emissions of all the alternatives for all pollutants except CO, acetaldehyde, acrolein, and formaldehyde. Alternative 3 has the highest emissions of CO and acetaldehyde. Alternative 7 has the highest emissions of all the alternatives for acrolein[14] and formaldehyde.

S.5.2.4 Air Quality - Input Scenarios

In response to public comments, and to test how different economic assumptions could affect air quality by examining scenarios with varied economic inputs used in the Volpe model, NHTSA modeled three additional scenarios – High, Mid-1, and Mid-2 – and compared the results to the Reference Case. Table S-16 summarizes the cumulative national criteria and air toxic pollutant emissions in 2035 for the seven alternatives for the High Scenario. For the High Scenario, emissions under each alternative are generally lower than under the Reference Case. There could be localized increases in criteria and toxic air pollutant emissions in some nonattainment areas as a result of implementation of the CAFE standards under the alternatives. These localized increases slightly offset the reductions being achieved by implementation of CAA standards, motor-vehicle emissions standards, and related programs. All of the alternatives would reduce adverse health outcomes and health costs related to motor-vehicle air pollution, and thus would have beneficial health effects that would not need mitigation.

[14] Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

Table S-15

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on Nationwide Criteria Pollutant Emissions and Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year, Calendar Year 2035)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Criteria Pollutant Emissions (Calendar Year 2035)							
Carbon monoxide (CO)	19,745,847	20,068,580	20,145,455	19,664,457	19,615,715	19,406,046	11,524,825
Nitrogen oxides (NO_x)	1,369,135	1,335,125	1,335,545	1,318,678	1,314,728	1,305,570	1,048,518
Particulate matter ($PM_{2.5}$)	99,707	95,588	95,468	94,650	94,333	94,305	89,788
Sulfur oxides (SO_x)	265,792	240,446	239,437	236,567	234,662	232,370	183,541
Volatile organic compounds (VOC)	1,906,119	1,861,129	1,862,621	1,832,904	1,825,138	1,803,935	1,196,950
Toxic Air Pollutant Emissions (Calendar Year 2035)							
Acetaldehyde	8,209	8,224	8,229	8,211	8,214	8,183	7,974
Acrolein	351	362	361	377	381	392	758
Benzene	47,515	47,256	47,364	46,405	46,251	45,791	29,613
1,3-butadiene	3,885	3,852	3,854	3,839	3,839	3,803	3,331
Diesel particulate matter (DPM)	119,499	105,773	105,131	104,372	103,457	102,999	94,643
Formaldehyde	13,035	12,717	12,677	12,899	12,924	12,961	17,034

Table S-16

High Scenario MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impacts on Nationwide Criteria Pollutant Emissions and Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year, Calendar Year 2035)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Criteria Pollutant Emissions (Calendar Year 2035)							
Carbon monoxide (CO)	17,713,991	17,102,067	17,249,166	16,551,203	16,107,699	15,482,276	10,338,916
Nitrogen oxides (NO_x)	1,228,251	1,147,887	1,145,748	1,120,053	1,102,988	1,082,932	940,625
Particulate matter ($PM_{2.5}$)	89,447	83,017	82,423	82,542	81,642	81,247	80,549
Sulfur oxides (SO_x)	238,442	198,158	194,471	189,553	185,397	182,149	164,654
Volatile organic compounds (VOCs)	1,709,979	1,575,147	1,574,616	1,518,089	1,486,823	1,440,609	1,073,784
Toxic Air Pollutant Emissions (Calendar Year 2035)							
Acetaldehyde	7,364	7,351	7,372	7,282	7,278	7,255	7,153
Acrolein	315	374	374	406	424	450	680
Benzene	42,626	40,169	40,301	38,917	37,990	36,721	26,566
1,3-butadiene	3,885	3,833	3,846	3,810	3,766	3,713	3,331
Diesel particulate matter (DPM)	107,203	87,624	85,380	85,166	83,729	83,295	84,904
Formaldehyde	11,694	11,783	11,730	11,897	12,127	12,433	15,281

S.5.2.5 Climate - Reference Case Cumulative GHG Emissions

Table S-17 lists total emissions reductions from MY 2010-2100 new passenger cars and light trucks under each of the seven alternatives for the Reference Case. Projections of emissions reductions over the 2010 to 2100 time frame due to the MY 2011-2020 CAFE standards ranged from 24,321 to 49,157 $MMTCO_2$. Compared to global emissions of 4,850,000 $MMTCO_2$ over this period (projected by the IPCC A1B-medium scenario), the incremental impact of this rulemaking is expected to reduce global CO_2 emissions by about 0.5 to 1.0 percent.

Table S-17

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 CAFE Standards Cumulative Emissions and Emissions Reductions Due to the Projected for 2010-2100 ($MMTCO_2$)

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	221,258	0
2 25 Percent Below Optimized	196,937	24,321
3 Optimized	195,816	25,442
4 25 Percent Above Optimized	194,057	27,201
5 50 Percent Above Optimized	192,478	28,780
6 Total Costs Equal Total Benefits	191,073	30,185
7 Technology Exhaustion	172,101	49,157

S.5.2.6 Climate - Reference Case CO_2 Concentration and Global Mean Surface Temperature

The mid-range results of MAGICC model simulations for the No Action Alternative and the six alternatives in terms of CO_2 concentrations and increase in global mean surface temperature in 2030, 2060, and 2100 are presented in Table S-18 and Figures S-1 through S-4. As Figures S-3 and S-4 show, the impact on the growth in CO_2 concentrations and temperature is just a fraction of the total growth in CO_2 concentrations and global mean surface temperature. However, the relative impact of the CAFE alternatives is illustrated by the reduction in growth of both CO_2 concentrations and temperature under the Technology Exhaustion Alternative, which is nearly double that of the 25 Percent Below Optimized Alternative, as shown in Figures S-5 to S-6.

As shown in the table and figures, there is a fairly narrow band of estimated CO_2 concentrations as of 2100, from 712.6 parts per million under the most stringent alternative to 717.2 parts per million under the No Action Alternative. Because CO_2 concentrations are the key driver climate effects, this narrow range implies that the differences among alternatives are difficult to distinguish. The MAGICC model simulations of mean global surface air temperature increases are also shown in Table S-18. For all alternatives, the temperature increase is about 0.87 °C as of 2030, 1.93 to 1.94 °C as of 2060, and 2.94 to 2.96 °C as of 2100. The differences among alternatives are small. As of 2100, the reduction in temperature increase, in relation to the No Action Alternative, ranges from 0.009 °C to 0.02 °C. These estimates include considerable uncertainty due to a number of factors, of which climate sensitivity is the most important. The IPCC Fourth Assessment Report estimates a range of the climate sensitivity from 2.5 to 4.0 °C with a mid-point of 3.0 °C, which directly relates to the uncertainty in the estimated global mean surface temperature.

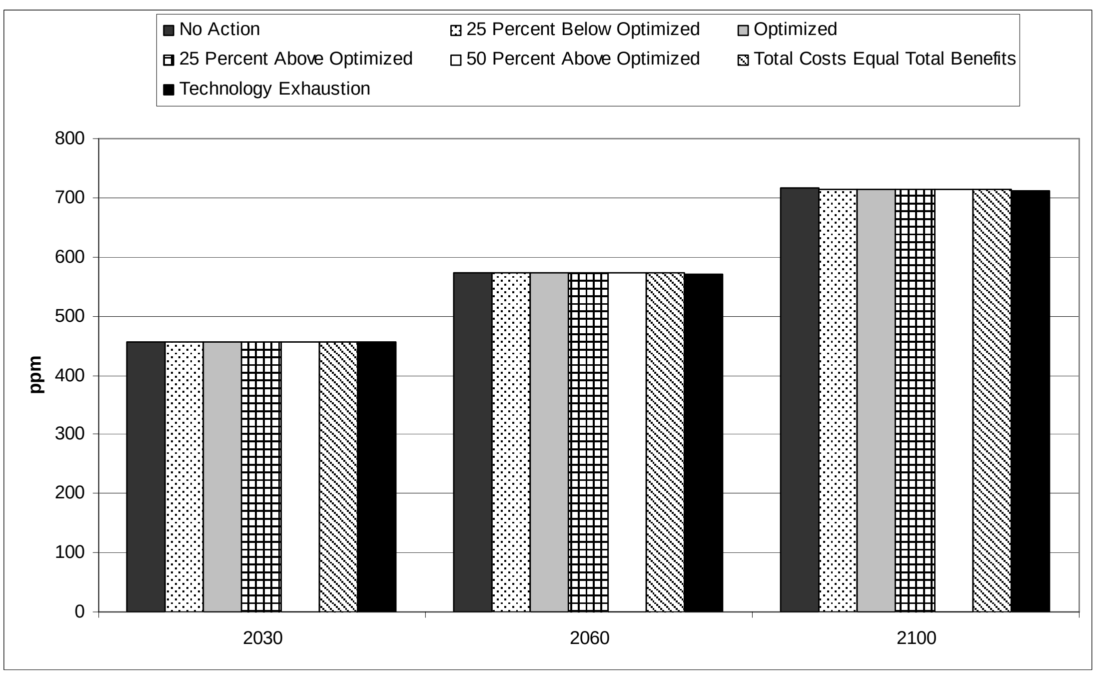
Table S-18

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on CO_2 Concentrations, Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC (A1B a/)

	CO_2 Concentration (parts per million)			Surface Temperature Increase (°C)			Sea-level Rise (centimeters)		
	2030	**2060**	**2100**	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**
Totals by Alternative									
1 No Action (A1B-AIM)	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.4	572.7	714.9	0.873	1.940	2.950	7.99	19.27	37.02
3 Optimized	455.4	572.7	714.8	0.873	1.940	2.950	7.99	19.27	37.02
4 25 Percent Above Optimized	455.3	572.6	714.7	0.873	1.940	2.949	7.99	19.27	37.01
5 50 Percent Above Optimized	455.3	572.5	714.5	0.873	1.940	2.948	7.99	19.27	37.01
6 Total Costs Equal Total Benefits	455.3	572.5	714.4	0.873	1.939	2.948	7.99	19.26	37.00
7 Technology Exhaustion	455.1	571.7	712.6	0.871	1.934	2.938	7.99	19.23	36.92
Reduction Compared to No Action									
2 25 Percent Below Optimized	0.1	1.0	2.3	0.001	0.004	0.009	0.00	0.03	0.08
3 Optimized	0.1	1.0	2.4	0.001	0.004	0.009	0.00	0.03	0.08
4 25 Percent Above Optimized	0.2	1.1	2.5	0.001	0.005	0.010	0.00	0.03	0.09
5 50 Percent Above Optimized	0.2	1.2	2.7	0.001	0.005	0.011	0.00	0.03	0.09
6 Total Costs Equal Total Benefits	0.2	1.2	2.8	0.001	0.005	0.011	0.00	0.04	0.10
7 Technology Exhaustion	0.4	2.0	4.6	0.002	0.010	0.020	0.00	0.07	0.18

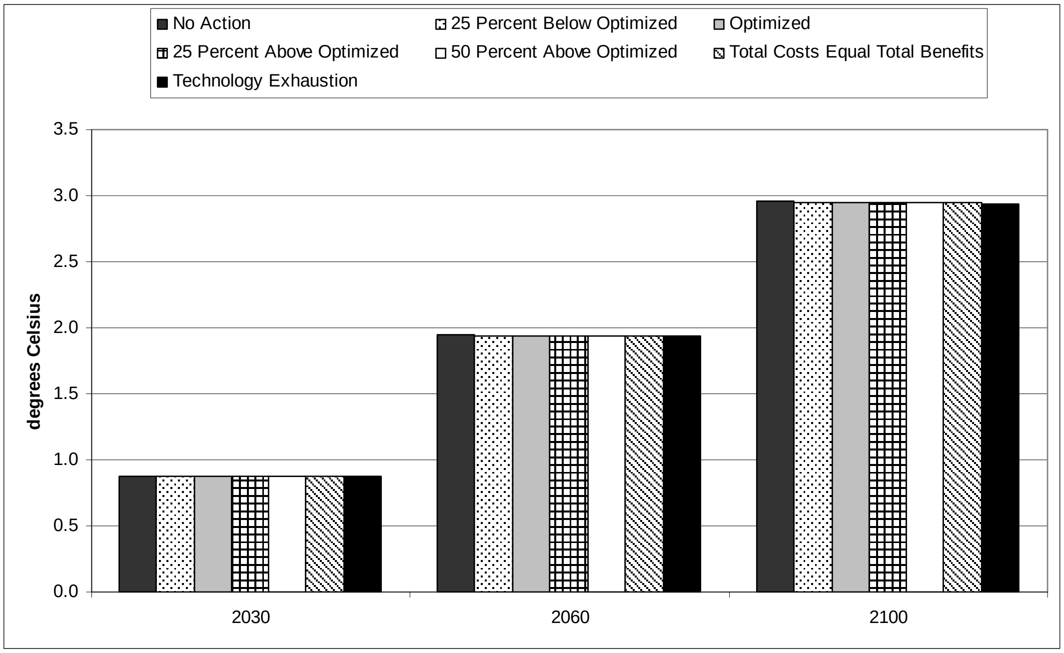
a/ The A1B scenario is the SRES marker scenario used by IPCC Working Group I to represent the SRES A1B (medium) storyline.

Figure S-1. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on CO_2 (ppm) Concentrations Using MAGICC (A1B a/)



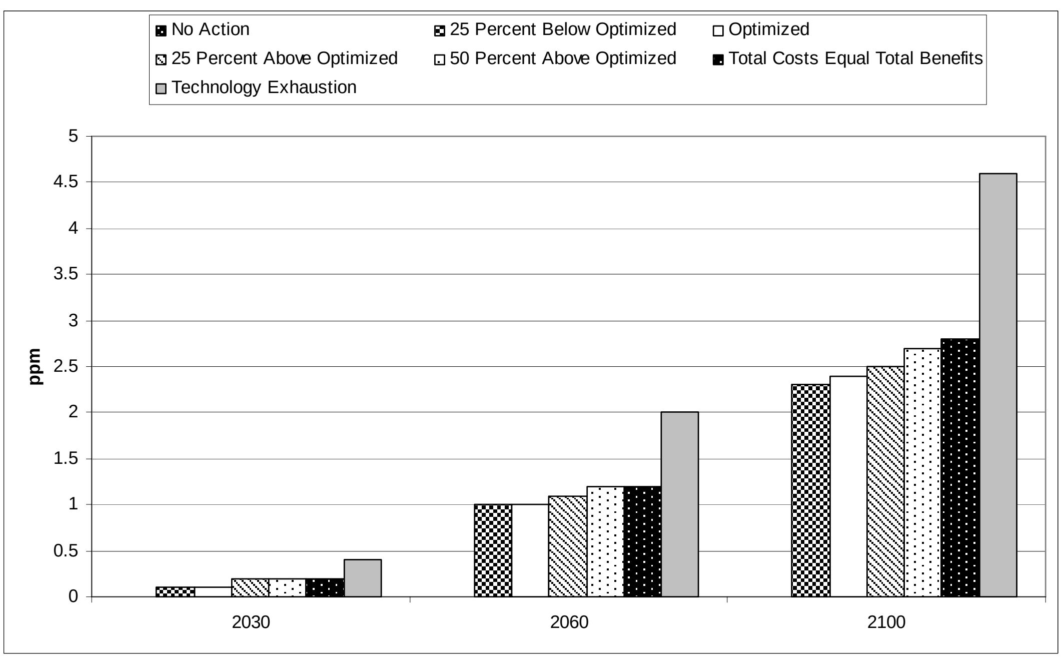
a/ The A1B scenario is the SRES marker scenario used by IPCC Working Group I to represent the SRES A1B (medium) storyline.

Figure S-2. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on Global Mean Surface Temperature Increase (°C) Using MAGICC (A1B a/)



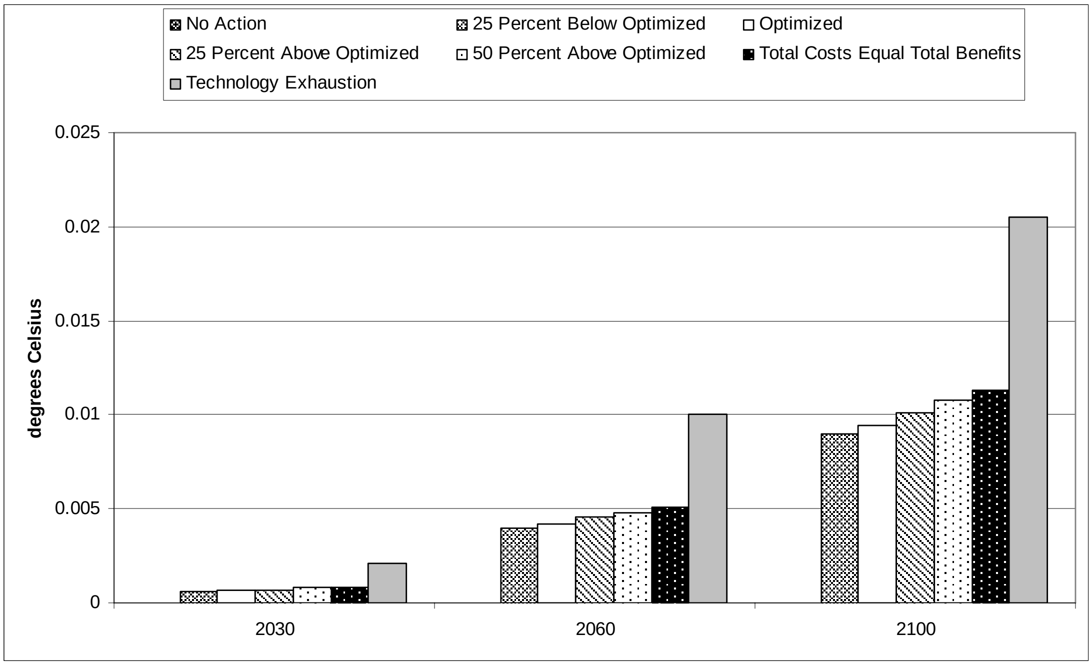
a/ The A1B scenario is the SRES marker scenario used by IPCC Working Group I to represent the SRES A1B (medium) storyline.

Figure S-3. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on the Reduction in the Growth of CO_2 Concentrations (ppm) Using MAGICC (A1B a/)



a/ The A1B scenario is the SRES marker scenario used by IPCC Working Group I to represent the SRES A1B (medium) storyline.

Figure S-4. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on the Reduction in the Growth of Global Mean Temperature (°C) Using MAGICC (A1B a/)



a/ The A1B scenario is the SRES marker scenario used by IPCC Working Group I to represent the SRES A1B (medium) storyline.

S.5.2.7 Climate - Reference Case Global Mean Precipitation

The action alternatives reduce temperature increases slightly compared to the No Action Alternative. Thus, the action alternatives also reduce predicted increases in precipitation slightly, as shown in Table S-19. As shown in the table, there is a fairly narrow band of mid-range estimated reductions in precipitation increase as of 2100, from 4.48 percent to 4.51 percent, and there is very little difference between the alternatives. Uncertainty in these numbers results from uncertainty in the increase in global mean surface temperature and uncertainty about the change in global mean precipitation.

S.5.2.8 Climate - Reference Case Impact on Sea-level Rise

The IPCC Fourth Assessment Report identifies four primary components of sea-level rise: thermal expansion of ocean water; melting of glaciers and ice caps; loss of land-based ice in Antarctica; and loss of land-based ice in Greenland. Ice-sheet discharge is an additional factor that could influence sea level over the long term. The MAGICC model calculates the oceanic thermal expansion component of global mean sea-level rise, using a non-linear temperature- and pressure-dependent expansion coefficient. It also addresses the other three primary components through ice-melt models for small glaciers and the Greenland and Antarctic ice sheets, and excludes non-melt sources, which the IPCC Fourth Assessment Report also excluded.

Table S-18 lists the impact on sea-level rise associated with the Reference Case for each alternative and shows sea-level rise in 2100 ranging from 37.10 centimeters under Alternative 1 (No Action) to 36.92 centimeters under the Technology Exhaustion Alternative (Alternative 7), for a maximum reduction of 0.18 centimeters by 2100 from the CAFE alternatives.

Table S-19

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards
Cumulative Impact on Reductions in Global Mean Precipitation Based on A1B a/ SRES Scenario, Using Increases in Global Mean Surface Temperature Simulated by MAGICC

Scenario	2011–2030/2020	2046–2065/2055	2080–2099/2090
Global Mean Precipitation Change			
	1.45	1.51	1.63
Global Temperature Above Average 1980-1999 Levels (°C) for the A1B Scenario by 2100, Mid-level Results			
1 No Action	0.560	1.764	2.765
2 25 Percent Below Optimized	0.560	1.759	2.753
3 Optimized	0.560	1.758	2.752
4 25 Percent Above Optimized	0.560	1.758	2.751
5 50 Percent Above Optimized	0.560	1.757	2.750
6 Total Costs Equal Total Benefits	0.560	1.757	2.750
7 Technology Exhaustion	0.559	1.756	2.749
Reduction in Global Temperature (°C) for the A1B Scenario, Mid-level Results			
2 25 Percent Below Optimized	0.000	0.005	0.011
3 Optimized	0.000	0.006	0.013
4 25 Percent Above Optimized	0.000	0.006	0.014
5 50 Percent Above Optimized	0.000	0.007	0.015
6 Total Costs Equal Total Benefits	0.000	0.007	0.015
7 Technology Exhaustion	0.000	0.008	0.016
Mid-level Global Mean Precipitation Change by 2100 (%)			
1 No Action	0.81	2.66	4.51
2 25 Percent Below Optimized	0.81	2.66	4.49
3 Optimized	0.81	2.65	4.49
4 25 Percent Above Optimized	0.81	2.65	4.48
5 50 Percent Above Optimized	0.81	2.65	4.48
6 Total Costs Equal Total Benefits	0.81	2.65	4.48
7 Technology Exhaustion	0.81	2.65	4.48
Reduction in Global Mean Precipitation (%)			
2 25 Percent Below Optimized	0.00	0.01	0.02
3 Optimized	0.00	0.01	0.02
4 25 Percent Above Optimized	0.00	0.01	0.02
5 50 Percent Above Optimized	0.00	0.01	0.02
6 Total Costs Equal Total Benefits	0.00	0.01	0.02
7 Technology Exhaustion	0.00	0.01	0.03

a/ The A1B scenario is the SRES marker scenario used by IPCC Working Group I to represent the SRES A1B (medium) storyline.

In summary, the impacts of the MY 2011-2020 CAFE alternatives on global mean surface temperature, sea-level rise, and precipitation are relatively small in the context of the expected changes associated with the emissions trajectories in the Special Report on Emission Scenarios (SRES). This is due primarily to the global and multi-sectoral nature of the climate problem. Emissions of CO_2, the primary gas driving the climate effects, from the United States passenger-car and light-truck fleet represented about 2.5 percent of total global emissions of GHGs in the year 2000.[15] While a substantial source, this is a still small percentage of global emissions, and the relative contribution of CO_2 emissions

[15] CO_2 emissions from passenger cars and light trucks were obtained from EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks. 1990–2006*, which can be found at http://www.epa.gov/climatechange/emissions/usinventoryreport.html. Global GHG emissions were obtained from the World Resources Institute's Climate Analysis Indicators Tool (CAIT) Version 5.0. http://cait.wri.org.

from the U.S. passenger car and light truck fleet is expected to decline in the future, due primarily to rapid growth of emissions from developing economies, which are due in part to growth in emissions from the global transportation sector.

S.5.2.9 Cumulative Impacts - Input Scenarios

In response to public comments, and to test how different economic assumptions might affect estimates of cumulative emissions reductions and resulting climate effects, NHTSA modeled three additional scenarios – High, Mid-1, and Mid-2 – and compared the results to the Reference Case. Variables that were altered include fuel price, the social cost of carbon, oil import externalities, and the discount rate for other benefits. Tables S-20 and S-21 lists the results for the High Scenario.

As shown in Table S-20, compared to the Reference Case, total cumulative emissions under the High Scenario were lower for all alternatives. The primary reason for this difference is the lower vehicle miles traveled forecast under the High Scenario. Cumulative emissions reductions for Alternatives 2 through 7 compared to the No Action Alternative were all higher under the High Scenario than under the Reference Case, except the Technology Exhaustion Alternative. Emissions reductions were greater under the Technology Exhaustion Alternative for the Reference Case than for the High Scenario.

Table S-20

High Scenario Alternative CAFE Standards Cumulative Emissions and Emissions Reductions Due to the MY 2011-2015 Standards and Potential MY 2016-2020 Standards for 2010 through 2100 ($MMTCO_2$)

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	195,501	0
2 25 Percent Below Optimized	160,903	34,598
3 Optimized	157,088	38,413
4 25 Percent Above Optimized	154,618	40,884
5 50 Percent Above Optimized	151,781	43,721
6 Total Costs Equal Total Benefits	150,919	44,583
7 Technology Exhaustion	152,290	43,211

Table S-21 shows the resulting effects on CO_2 concentration, global mean surface temperature, and sea-level rise. Under the High Scenario, the resulting CO_2 concentration, global mean surface temperature, and sea-level rise were lower for all alternatives except the Technology Exhaustion Alternative. Thus, the differences for the action alternatives compared to the No Action Alternative are greater for the High Scenario than the Reference Case, except for the Technology Exhaustion Alternative.

S.5.3 Other Potential Environmental Consequences

While the main focus of this FEIS is on the quantification of impacts to energy, air quality, climate, and qualitative cumulative impacts resulting from climate change, this FEIS also addresses other potentially affected resources. NHTSA conducted a qualitative review of the non-climate change related direct, indirect, and cumulative effects, either positive or negative, of the alternatives on other potentially affected resources. These resource areas included water resources, biological resources, land use, hazardous materials, safety, noise, historic and cultural resources, and environmental justice. Effects of the alternatives on these resources were too small to address quantitatively. Impacts to biological resources could include reductions in habitat disturbance, decreased impacts from acid rain on water and terrestrial habitats from decreases in petroleum production and increased agricultural disturbances and

Table S-21

High Scenario MY 2011-2015 Standards and Potential MY 2016-2020 Standards
Cumulative Impact on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC (A1B a/)

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
Totals by Alternative	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**
1 No Action	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.3	572.3	714.0	0.873	1.938	2.946	7.99	19.26	36.99
3 Optimized	455.2	572.1	713.6	0.872	1.937	2.944	7.99	19.25	36.97
4 25 Percent Above Optimized	455.2	572.0	713.4	0.872	1.937	2.943	7.99	19.25	36.96
5 50 Percent Above Optimized	455.2	571.9	713.1	0.872	1.936	2.942	7.99	19.25	36.95
6 Total Costs Equal Total Benefits	455.2	571.9	713.0	0.872	1.936	2.942	7.99	19.24	36.95
7 Technology Exhaustion	455.2	571.9	713.1	0.872	1.935	2.941	7.99	19.24	36.94
Reduction under CAFE Alternatives									
2 25 Percent Below Optimized	0.2	1.4	3.2	0.001	0.006	0.013	0.00	0.04	0.11
3 Optimized	0.3	1.6	3.6	0.001	0.007	0.015	0.00	0.05	0.13
4 25 Percent Above Optimized	0.3	1.7	3.8	0.001	0.007	0.016	0.00	0.05	0.14
5 50 Percent Above Optimized	0.3	1.8	4.1	0.001	0.008	0.017	0.00	0.05	0.15
6 Total Costs Equal Total Benefits	0.3	1.8	4.2	0.002	0.008	0.017	0.00	0.06	0.15
7 Technology Exhaustion	0.3	1.8	4.1	0.002	0.009	0.018	0.00	0.06	0.16

a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

runoff due to biofuel production. Impacts to land use and development could include increased agricultural land use. Impacts to safety could include downweighting of vehicles and increased VMT, resulting in increased traffic injuries and fatalities. Impacts to hazardous materials could include overall reductions in the generation of air and oil production related wastes, and increases in agricultural wastes due to biofuel production. Impacts to historic and cultural resources could include reductions in acid rain related damage. Noise impacts could include increased noise levels in some areas due to higher VMT. The non-climate related impact from increased atmospheric CO_2 could, in conjunction with other environmental factors and changes in plant communities, potentially alter growth, abundance, and respiration rates of some soil microbes and impact coral reef and other marine ecosystems from ocean acidification.

Impacts to environmental justice populations could include increased air toxics in some areas as a result of higher VMT. No impacts are expected to resources protected under Section 4(f), and a Section 7 Review under the Endangered Species Act is not required.

S.5.4 Mitigation Measures and Unavoidable Adverse Impacts

Each of the six action alternatives, under any Input Scenario, would result in a decrease in CO_2 emissions and associated climate change impacts, a general decrease in criteria air pollutant emissions and toxic air pollutant emissions, and a decrease in energy consumption as compared to the No Action Alternative. Based on our current understanding of global climate change, certain effects are likely to occur due to the sum total of GHG emissions entering the atmosphere. Any of the alternatives presented here would not prevent these effects. They may diminish the effects of climate change and contribute to global GHG reductions. Under the No Action alternative, CO_2 emissions and energy consumption would continue to increase; thus, any of the alternatives (other than the No Action Alternative) would have a beneficial effect that would not need mitigation.

Increases in national CO emissions could occur under the Optimized Alternative of the Reference Case. While nominally high, these increases are just 0.6 percent of the CO emissions of the No Action Alternative. Furthermore, no violations of the CO standard have been demonstrated since 2002, making any potential increase in these emissions less likely to affect human health even if they were to occur. Localized increases in criteria and toxic air pollutant emissions could occur in some non-attainment areas as a result of implementation of the CAFE standards under the alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of CAA standards. The Federal Highway Administration has funds dedicated to the reduction of air pollution in nonattainment areas, providing state and local authorities the ability to mitigate for localized increases in levels of criteria and toxic air pollutants in nonattainment areas that might be observed under the standards. Further, EPA has the authority to continue to improve vehicle emissions standards.

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List of Appendices

The appendices to this Draft Environmental Impact Statement (DEIS) have been provided electronically on the accompanying CD.

List of Tables

List of Figures

List of Acronyms and Abbreviations

$\mu g/m^3$	micrograms per cubic meter of air
APA	Administrative Procedures Act
AEO	Annual Energy Outlook
AER	Annual Energy Review
AAM	Alliance of Automobile Manufacturers
AMFA	Alternative Motor Fuels Act
AMOC	Atlantic Meridional Overturning Circulation
AMT	Automated Shift Manual Transmission
AOGCM	atmospheric-ocean general circulation models
BTU	British thermal unit
CAA	Clean Air Act
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
CBD	Center for Biological Diversity
CDC	Centers for Disease Control and Prevention
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CH_4	methane
cm	centimeter
CMAQ	Congestion Mitigation and Air Quality Improvement
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DEIS	Draft Environmental Impact Statement
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPM	diesel particulate matter
EA	environmental assessment
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EISA	Energy Independence and Security Act
ENSO	El Niño Southern Oscillation
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPCA	Energy Policy and Conservation Act
EU	European Union
EV	electric vehicle
FAO	United Nations Food and Agriculture Organization
FEIS	Final Environmental Impact Statement
FFV	flexible fuel vehicle
FONSI	Finding of No Significant Impact
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FR	Federal Register
FRIA	Final Regulatory Impact Analysis
FTA	Federal Transit Administration
GAO	General Accounting Office

GDP	Gross Domestic Product
GHG	greenhouse gases
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
GtC/year	gigatons carbon per year
GWP	global warming potential
HEV	hybrid electric vehicle
HFC	hydrofluorocarbons
HOP	high oil price
LNG	liquefied natural gas
IEO	International Energy Outlook
IPCC	Intergovernmental Panel on Climate Change
ka	kiloannum
LDV	light-duty vehicles
LTV	light trucks and vans
MAGICC	Model for Assessment of Greenhouse Gas-induced Climate Change
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
mm	millimeter
$MMTCO_2$	million metric tons of carbon dioxide
MOC	Meridional Overturning Circulation
MOP	moderate oil price
mpg	miles per gallon
MSAT	mobile source air toxics
MTBE	methyl tertiary butyl ether
MY	model year
N_2	nitrogen
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NADA	National Automobile Dealers Association
NCD	National County Database
NEPA	National Environmental Policy Act
NESCCAF	Northeast States Center for a Clean Air Future
NESCAUM	Northeast States for Coordinated Air Use Management
NERA	National Environmental Research Associates
NGO	non-governmental organization
NHTSA	National Highway Traffic Safety Administration
NMIM	National Mobile Inventory Model
NO	nitric oxide
NO_2	nitrogen dioxide
NOI	Notice of Intent
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NPRM	Notice of Proposed Rulemaking
NRDC	Natural Resources Defense Council
NYSDOT	New York State Department of Transportation
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries
OMB	Office of Management and Budget
PFC	perfluorocarbons
PHEV	Plug-In Hybrid Electric Vehicle
PM	particulate matter

PM10	particulate matter10 microns diameter or less
PM2.5	particulate matter 2.5 microns diameter or less
ppm	parts per million
PRIA	Preliminary Regulatory Impact Analysis
RFS	Renewable Fuels Standard
RGGI	Regional Greenhouse Gas Initiative
RIA	Regulatory Impact Analysis
RPE	retail price equivalent
SAP	Synthesis and Assessment Product
SCC	social cost of carbon
SF_6	sulfur hexafluoride
SIP	State Implementation Plan
SO	sulfur oxide
SO_x	sulfur oxides
SO_2	sulfur dioxide
SRES	Special Report on Emission Scenarios
SUV	sport utility vehicle
T&S&D	Transportation, Storage, and Distribution
TB	total benefits
TC	total cost
THC	thermohaline circulation
U.S.C.	United States Code
UCS	Union of Concerned Scientists
UMD	University of Maryland
USCCSP	United States Climate Change Science Program
USGS	United States Geological Survey
VMT	vehicle-miles traveled
VOC	volatile organic compound
Volpe Center	Volpe National Transportation Systems Center
WCI	Western Climate Initiative
WGI	IPCC Work Group I
WGII	IPCC Work Group II
WHO	World Health Organization
WMO	World Meteorological Organization

Glossary

To help readers more fully understand this Final Environmental Impact Statement, NHTSA has provided the following list of definitions for technical and scientific terms, as well as plain English terms used differently in the context of this FEIS.

Term	Definition
25 Percent Above Optimized Alternative (Alternative 4)	Alternative regulatory measure reflecting standards that exceed the Optimized Alternative by 25 percent of the interval between the Optimized Alternative and an alternative based on applying technologies until total costs equal total benefits.
25 Percent Below Optimized Alternative (Alternative 2)	Alternative regulatory measure reflecting standards that fall below the Optimized Alternative by the same absolute amount by which the 25 percent above Optimized Alternative exceeds the Optimized Alternative.
50 Percent Above Optimized Alternative (Alternative 5)	Alternative regulatory measure reflecting standards that exceed the Optimized Alternative by 50 percent of the interval between the Optimized Alternative and an alternative based on applying technologies until total costs equal total benefits.
Adaptation	Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, including anticipatory and reactive, private and public, and autonomous and planned.
Afforestation	Planting of new forests on lands that historically have not contained forests (for at least 50 years).
Anthropogenic	Resulting from or produced by human beings.
Aquaculture	Farming of plants and animals that live in water.
Baseline Alternative	See “No Action Alternative.”
Benthic	Describing habitat or organisms occurring at the bottom of a body of water.
Biosphere	The part of the Earth system comprising all ecosystems and living organisms, in the atmosphere, on land (terrestrial biosphere) or in the oceans (marine biosphere), including dead organic matter, such as litter, soil organic matter, and oceanic detritus.
Carbon sink	Any process, activity, or mechanism that removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas or aerosol from the atmosphere.
Coral bleaching	The paling in color that results if a coral loses its symbiotic, energy providing, organisms.
Criteria pollutants	Carbon monoxide (CO), airborne lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and fine particulate matter (PM).
Cryosphere	The portion of Earth’s surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.

Term	Definition
Dansgaard-Oeschger events	Very rapid climate changes—up to 7 °C in some 50 years—during the Quaternary geologic period, and especially during the most recent glacial cycle.
Ecosystem	A system of living organisms interacting with each other and their physical environment. The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study. Thus, the extent of an ecosystem may range from very small spatial scales to, ultimately, the entire Earth.
El Nińo-Southern Oscillation	The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. It has since become identified with a basinwide warming of the tropical Pacific east of the international dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, with preferred time scales of two to about seven years, is collectively known as El Niño-Southern Oscillation, or ENSO. During an ENSO event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds.
Emission rates	Rate at which contaminants are discharged from a particular source, usually in weight unit per time period.
Endemic	Restricted to a region.
EPCA factors for setting "maximum feasible" CAFE standards	Technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need of the Nation to conserve energy.
Eutrophication	Enrichment of a water body with plant nutrients.
Evapotranspiration	The combined process of water evaporation from the Earth's surface and transpiration from vegetation.
GREET model	Model developed by Argonne National Laboratory that provides estimates of the energy and carbon contents of fuels as well as energy use in various phases of fuel supply.
High Scenario	Model input scenario that uses the Energy Information Administration's high fuel price forecast of $3.33 per gallon, a global social cost of carbon of $33.00 per ton with a 3 percent discount rate, a 3 percent overall discount rate, and a value of $0.116 per gallon for oil import externalities.
Hydrology	The science dealing with the occurrence, circulation, distribution, and properties of the Earth's water.
Hydrosphere	The component of the climate system comprising liquid surface and subterranean water, such as oceans, seas, rivers, freshwater lakes, and underground water.
Kiloannum	A unit of time equal to 1000 years. Abbreviated symbol is "ka."
Lake stratification	The layering of warmer, less dense water over colder, denser water.

Term	Definition
Lifetime fuel consumption	Total volume of fuel used by a vehicle over its lifetime.
Maximum lifetime of vehicles	The age after which less than 2 percent of the vehicles originally produced during a model year remains in service.
Mid-1 Scenario	An intermediate model input scenario that uses a fuel price forecast of $3.33 per gallon, a global social cost of carbon of $33.00 per ton with 3 percent discount rate, a 7 percent discount rate overall, and a value of $0.116 per gallon for oil import externalities.
Mid 2 Scenario	An intermediate model input scenario that uses a fuel price forecast of $3.33 per gallon, a domestic social cost of carbon of $2.00 per ton with a 3 percent discount rate, a 7 percent overall discount rate, and a value of $0.382 per gallon for oil import externalities.
MOBILE6.2	EPA's motor vehicle emission factor model.
NEPA scoping process	An early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action.
No Action Alternative (Alternative 1)	The No Action Alternative assumes that NHTSA would not issue a rule regarding CAFE standards. The No Action Alternative assumes that average fuel economy levels in the absence of CAFE standards beyond 2010 would equal the higher of a manufacturer's product plans or the manufacturer's required level of average fuel economy for MY 2010. The MY 2011 fuel economy in mpg (27.5 mpg and 23.3 mpg for passenger cars and light trucks, respectively) represents the standard the agency believes manufacturers would continue to achieve, assuming that the agency does not issue a rule.
Nonattainment area	Regions where concentrations of criteria pollutants exceed federal standards. Nonattainment areas are required to develop and implement plans to comply with the National Ambient Air Quality Standards within specified time periods.
Ocean acidification	A decrease in the pH of sea water due to the uptake of anthropogenic carbon dioxide.
Optimized Alternative (Alternative 3)	Alternative regulatory measures reflecting the optimized standards.
Optimized standards	Standards set at levels such that the cost of the last technology application (using the Volpe model) equals the benefits of the improvement in fuel economy resulting from that application, thereby maximizing net benefits (benefits minus costs).
Overexploitation of species	Exploitation of species to the point of diminishing returns.
Paleoclimatology	The study of climate change through the physical evidence left on earth of historical global climate change (prior to the widespread availability of records to temperature, precipitation, and other data).
Pathways of fuel supply	Imports to the United States of refined gasoline and other transportation fuels, domestic refining of fuel using imported petroleum as a feedstock, and domestic fuel refining from crude petroleum produced within the United States.

Term	Definition
Permafrost	Ground (soil or rock and included ice and organic material) that remains at or below zero degrees Celsius for at least two consecutive years.
Phenology	The study of natural phenomena in biological systems that recur periodically (development stages, migration) and their relationship to climate and seasonal changes.
Rebound effect	A situation in which improved fuel economy reduces the fuel cost of driving and leads to additional use of passenger cars and light trucks and thus increased emissions of criteria pollutants by passenger cars and light trucks.
Reference Case	Model input scenario that uses the Energy Information Administration's reference case fuel price forecast of $2.41 per gallon, a domestic social cost of carbon of $2.00 per ton with a 3 percent discount rate, a 7 percent overall discount rate, and a value of $0.326 per gallon for oil import externalities.
Reformed CAFE Program	Consists of two basic elements: (1) a process that sets fuel economy targets for different values of vehicle footprint; and (2) a Reformed CAFE standard for each manufacturer, which is equal to the production-weighted harmonic average of the fuel economy targets corresponding to the footprint values of each light truck model it produces.
Saltwater intrusion	Displacement of fresh surface water or groundwater by the advance of saltwater due to its greater density. This process usually occurs in coastal and estuarine areas due to reducing land-based influence (either from reduced runoff and associated groundwater recharge, or from excessive water withdrawals from aquifers) or increasing marine influence (relative sea-level rise).
Silviculture	The management of forest resources.
Survival rate	The proportion of vehicles originally produced during a model year that are expected to remain in service at the age they will have reached during each subsequent year.
Thermohaline circulation	The physical driving mechanism of ocean circulation, resulting from fluxes of heat and freshwater across the sea surface, subsequent interior mixing of heat and salt, and geothermal heat sources.
Total Costs Equal Total Benefits Alternative (Alternative 6)	Alternative reflecting standards based on applying technologies until total costs equal total benefits (zero net benefits).
Technologies	Engine technologies, transmission, vehicle, electrification/accessory and hybrid technologies that influence fuel economy.
Technology Exhaustion Alternative (Alternative 7)	Alternative in which NHTSA applied all feasible technologies by progressively increasing the stringency of the standard in each model year until every manufacturer (among those without a history of paying civil penalties) exhausted technologies estimated to be available during MY 2011-2015.

Term	Definition
Thermohaline circulation	This term refers to the physical driving mechanism of ocean circulation, resulting from fluxes of heat and freshwater across the sea surface, subsequent interior mixing of heat and salt, and geothermal heat sources.
Tipping point	A situation where the climate system reaches a point at which is there is a strong and amplifying positive feedback from only a moderate additional change in a driver, such as CO_2 or temperature increase.
Total vehicle miles	Total number of miles each vehicle will be driven over its lifetime.
Track width	The lateral distance between the centerlines of the base tires at ground, including the camber angle.
Transpiration	Water loss from plant leaves.
Turbidity	A decrease in the clarity of water due to the presence of suspended sediment.
Vehicle footprint	The product of track width times wheelbase divided by 144.
Vehicle miles traveled	Total number of miles driven.
Volpe model	CAFE Compliance and Effects Model developed by the U.S. Department of Transportation's Volpe Center, that, for any given year, applies technologies to the manufacturer's fleet until the manufacturer achieves compliance with the standard under consideration.
Wheelbase	The longitudinal distance between front and rear wheel centerlines.

Chapter 1 Purpose and Need for the Proposed Action

1.1 INTRODUCTION

The Energy Policy and Conservation Act of 1975[1] (EPCA) established a program to regulate automobile fuel economy and provided for the establishment of average fuel economy standards for passenger cars and light trucks. As part of that Act, the Corporate Average Fuel Economy (CAFE) Program was established to reduce national energy consumption by increasing the fuel economy of passenger cars and light trucks. EPCA directs the Secretary of Transportation to set and implement fuel economy standards for passenger cars and light trucks sold in the United States. The National Highway Transportation Safety Administration (NHTSA) is delegated responsibility for implementing EPCA fuel economy requirements assigned to the Secretary of Transportation.[2]

In December 2007, the Energy Independence and Security Act of 2007 (EISA)[3] amended EPCA's CAFE Program requirements, granting the U.S. Department of Transportation (DOT) additional rulemaking authority and responsibilities.[4] Pursuant to EISA, NHTSA recently proposed CAFE standards for model year (MY) 2011-2015 passenger cars and light trucks in a Notice of Proposed Rulemaking[5] (NPRM) (NHTSA 2008b).[6]

Under the National Environmental Policy Act[7] (NEPA), a federal agency must analyze environmental impacts if the agency implements a proposed action, provides funding for an action, or issues a permit for that action. Specifically, NEPA directs that "to the fullest extent possible," federal agencies proposing "major federal actions significantly affecting the quality of the human environment" must prepare "a detailed statement" on the environmental impacts of the proposed action (including alternatives to the proposed action). NHTSA submits this Final Environmental Impact Statement (FEIS) to disclose its evaluation of the potential environmental impacts of adopting CAFE standards for MY 2011-2015.

1.2 NEPA PROCESS

To inform its development of the new CAFE standards required under EPCA, as amended by EISA, NHTSA prepared this FEIS to analyze and disclose the potential environmental impacts of our preferred alternative and other alternative standards pursuant to Council on Environmental Quality (CEQ)

[1] EPCA was enacted for the purpose of serving the Nation's energy demands and promoting conservation methods when feasibly obtainable. EPCA is codified at 49 United States Code (U.S.C.) 32901 *et seq.*
[2] 49 Code of Federal Regulations (CFR) §§ 1.50, 501.2(a)(8). In addition, the U.S. Environmental Protection Agency (EPA) calculates the average fuel economy for each automobile manufacturer that sells vehicles in the United States.
[3] EISA amends and builds on the Energy Policy and Conservation Act by setting out a comprehensive energy strategy for the 21st Century addressing renewable fuels and CAFE standards. EISA is Public Law 110-140, 121 Stat. 1492 (December 19, 2007).
[4] Accordingly, the Secretary of Transportation, DOT, and NHTSA are used interchangeably in this section of the FEIS.
[5] 73 *Federal Register* (*FR*) 24352 (May 2, 2008).
[6] At the same time, NHTSA requested updated product plan information from the automobile manufacturers. *See* Request for Product Plan Information, Passenger Car Average Fuel Economy Standards—Model Years 2008-2020 and Light Truck Average Fuel Economy Standards—Model Years 2008-2020, 73 *FR* 21490, May 2, 2008.
[7] 42 U.S.C. § 4332(2)(C).

NEPA implementing regulations, DOT Order 5610.1C, and NHTSA regulations.[8] This FEIS compares the potential environmental impacts among alternatives, including a no action alternative. It also analyzes direct, indirect, and cumulative impacts and discusses impacts in proportion to their significance.

1.3 PURPOSE AND NEED

NEPA requires that a proposed action's alternatives be developed based on the action's purpose and need. The purpose and need statement explains why the action is needed and the action's intended purpose, and serves as the basis for developing the range of alternatives to be considered in the NEPA analysis. In accordance with EPCA, as amended by EISA, the purpose of the rulemaking action is to establish MY 2011-2015 CAFE standards at "the maximum feasible average fuel economy level that the Secretary of Transportation decides the manufacturers can achieve in that model year." When setting "maximum feasible" fuel economy standards, the Secretary is required to "consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy."[9] NHTSA interprets these statutory factors to include environmental and safety concerns.[10]

As explained in the NPRM:

- "Technological feasibility" means whether a particular method of improving fuel economy can be available for commercial application in the model year for which a standard is being established.
- "Economic practicability" means whether a standard is one within the financial capability of the industry, but not so stringent as to lead to adverse economic consequences, such as significant job losses or unreasonable elimination of consumer choice.
- "The effect of other motor vehicle standards of the Government on fuel economy" means the unavoidable adverse effects on fuel economy of compliance with emission, safety, noise, or damageability standards.
- "The need of the United States to conserve energy" means the consumer cost, national balance of payments, environmental, and foreign policy implications of the Nation's need for large quantities of petroleum, especially imported petroleum.

EPCA, as amended by EISA, requires that the CAFE standards for passenger cars and light trucks must increase ratably to at least the levels necessary to meet 35 mpg requirements for MY 2020. EPCA further directs the Secretary, after consultation with the Secretary of Energy and the Administrator of the Environmental Protection Agency (EPA), to establish separate average fuel economy standards for passenger cars and for light trucks manufactured in each model year beginning with MY 2011, "to achieve a combined fuel economy average for model year 2020 of at least 35 miles per gallon for the total fleet of passenger and non-passenger automobiles manufactured for sale in the United States for that model year."[11] In so doing, the Secretary of Transportation is to adopt "annual fuel economy standard

[8] NEPA is codified at 42 U.S.C. §§ 4321-4347. CEQ NEPA implementing regulations are codified at 40 CFR Parts 1500-1508, and NHTSA's NEPA implementing regulations are codified at 49 CFR Part 520.

[9] 49 U.S.C. §§ 32902(a), 32902(f).

[10] *See, e.g.*, *Competitive Enterprise Inst. v. NHTSA*, 956 F.2d 321, 322 (D.C. Cir. 1992) (citing *Competitive Enterprise Inst. v. NHTSA*, 901 F.2d 107, 120 n.11 (D.C. Cir. 1990)), and 73 *FR* 24,352, 24,364, May 2, 2008.

[11] 49 U.S.C. §§ 32902(b)(1), 32902(b)(2)(A).

increases."[12] The standards for passenger cars and light trucks must be "based on one or more vehicle attributes related to fuel economy." In any single rulemaking, standards may be established for not more than 5 model years.[13] EPCA also mandates a minimum standard for domestically manufactured passenger cars.[14]

1.3.1 Notice of Intent and Scoping

In March 2008, NHTSA issued a Notice of Intent (NOI) to prepare an EIS for the MY 2011-2015 CAFE standards. The NOI described the statutory requirements for the standards, provided initial information about the NEPA process, and initiated scoping[15] by requesting public input on the scope of the environmental analysis to be conducted.[16] Two important purposes of scoping are identifying the substantial environmental issues that merit in-depth analysis in the EIS, and identifying and eliminating from detailed analysis the environmental issues that are not substantial and therefore require only a brief discussion in the EIS.[17] Scoping should "deemphasize insignificant issues, narrowing the scope of the environmental impact statement process accordingly."[18]

Consistent with NEPA and its implementing regulations, on April 10 and 11, 2008, NHTSA mailed the NOI to:

- 78 contacts at federal agencies having jurisdiction by law or special expertise with respect to the environmental impacts involved, or authorized to develop and enforce environmental standards, including other modes within DOT;
- the Governors of every state and U.S. territory;
- 23 organizations representing state and local governments;
- 14 Native American tribal organizations and academic centers that had issued reports on climate change and tribal communities; and
- 92 contacts at other stakeholder organizations that NHTSA reasonably expected to be interested in the NEPA analysis for the MY 2011-2015 CAFE standards, including auto industry organizations, environmental organizations, and other organizations that had expressed interest in prior CAFE rules.

NHTSA used its letters transmitting the NOI to develop a mailing list for future notices about the NEPA process for the CAFE standards. For instance, NHTSA asked each Governor to, "share [the] letter and the enclosed [NOI] with the appropriate environmental agencies and other offices within your administration and with interested local jurisdictions or local government organizations within your State." NHTSA further requested that each Governor ask their representative to provide contact information for the state's lead office on the CAFE EIS by returning a mailing list form to NHTSA or by

[12] 49 U.S.C. § 32902(b)(2)(C).
[13] 49 U.S.C. §§ 32902(b)(3)(A), 32902(b)(3)(B).
[14] 49 U.S.C. § 32902(b)(4).
[15] Scoping, as defined under NEPA, is an early and open process for determining the scope of issues to be addressed in an EIS and for identifying the significant issues related to a proposed action. 40 CFR § 1501.7.
[16] *See* Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 73 *FR* 16615, March 28, 2008.
[17] 40 CFR §§ 1500.4(g), 1501.7(a).
[18] 40 CFR § 1500.4(g).

sending NHTSA an e-mail containing the information requested on the form. NHTSA asked federal agency contacts to share the NOI with other interested parties within their organizations. NHTSA asked contacts at other stakeholder organizations to let NHTSA know whether they wished to remain on the agency's NEPA mailing list for the CAFE EIS by returning a mailing list form or sending NHTSA an e-mail containing the information requested on the form. NHTSA indicated that organizations that did not return the form would be removed from the NEPA mailing list.

1.3.1.1 Supplemental Notice of Public Scoping

In April 2008, NHTSA issued a supplemental notice of public scoping providing additional information about:

- participating in the scoping process;
- the proposed standards; and
- the alternatives NHTSA expected to consider in its NEPA analysis.[19]

NHTSA outlined its plans for its NEPA analysis for the MY 2011-2015 CAFE standards, explaining that it would:

> …consider the direct, indirect and cumulative environmental impacts of the proposed standards and those of reasonable alternatives. Among other potential impacts, NHTSA will consider direct and indirect impacts related to fuel and energy use, emissions, including Carbon Dioxide (CO_2) and their effects on temperature and climate change, air quality, natural resources, and the human environment. NHTSA also will consider the cumulative impacts of the proposed standards for MY 2011-2015 automobiles together with estimated impacts of NHTSA's implementation of the CAFE program through MY 2010 and NHTSA's future CAFE rulemaking for MY 2016-2020, as prescribed by EPCA, as amended by EISA…[20]

NHTSA also acknowledged that it "anticipate[d] considerable uncertainty in estimating and comparing the potential environmental impacts of the proposed standards and the alternatives relating to climate change in particular."[21]

In preparing the supplemental scoping notice, NHTSA consulted with CEQ and EPA. In that notice, NHTSA again invited all stakeholders to submit written comments on the appropriate scope of NHTSA's NEPA analysis for CAFE standards for MY 2011-2015 passenger cars and light trucks. To help identify and narrow the issues for analysis in the EIS, NHTSA specifically requested comments, peer-reviewed scientific studies, and other information addressing the potential impacts of the standards and reasonable alternatives relating to climate change.[22]

Following its publication in the *Federal Register* on April 28, 2008, NHTSA sent copies of the supplemental scoping notice directly to:

- 46 Governors from whom NHTSA had not received a lead State NEPA contact in response to the agency's initial letters;

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[19] Supplemental Notice of Public Scoping for an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 73 *FR* 22913, April 28, 2008.
[20] *Id.* at 22916.
[21] *Id.* at 22916.
[22] *Id.* at 22917.

- 24 state and local government NEPA contacts that had responded to the agency's initial letters;
- 11 administrators or other officials at other DOT agencies and offices;
- 62 NEPA contacts at other federal agencies; and
- 42 other stakeholders that asked to remain or be included on NHTSA's NEPA mailing list.

During the first week of May 2008, NHTSA mailed the supplemental scoping notice to Governors and stakeholders who had indicated a preference for receiving NHTSA's NEPA communications by U.S. mail. NHTSA e-mailed the supplemental scoping notice to all other stakeholders on May 6 and 7, 2008.

During the first week of May, NHTSA also mailed copies of the NOI and the supplemental scoping notice to more than 580 federally recognized Native American tribes, inviting them to submit written comments on the scope of NHTSA's NEPA analysis for the CAFE standards. In letters transmitting the two notices, NHTSA asked contacts at each tribe to let NHTSA know whether they wished to remain on the agency's NEPA mailing list for the CAFE EIS by returning a mailing list form or sending NHTSA an e-mail containing the information requested on the form. NHTSA indicated that tribes that did not return the form would be removed from the NEPA mailing list.

NHTSA's letters transmitting the NOI also explained our plans for communicating primarily by e-mail throughout the EIS process unless stakeholders indicated a preference for communications by U.S. mail. Representative copies of NHTSA's letters transmitting the NOI and the supplemental scoping notice to the stakeholders described above are available in the docket for this FEIS, Docket No. NHTSA-2008-0060, at http://www.regulations.gov.

In June 2008, NHTSA contacted various federal and state agencies and held meetings in person or by telephone to discuss the potential effects of the actions to be taken under EPCA and EISA. These agencies included Office of Protected Resources, National Oceanic and Atmospheric Administration (NOAA); Endangered Species Program, U.S. Fish and Wildlife Service; Cultural Resources, National Park Service; Advisory Council on Historic Preservation; Forest Health Monitoring Program and Forest Legacy Program, U.S. Forest Service; Division of Emergency and Environmental Health Services, Centers for Disease Control and Prevention (CDC); NEPA Compliance and Health Effects, Benefits, and Toxics Center, EPA; NEPA Oversight, CEQ; and Historical and Cultural Programs, Maryland Historical Trust. Comments received from these agencies were incorporated into the Draft Environmental Impact Statement (DEIS).

1.3.2 Summary of Scoping Comments and NHTSA's Responses

NHTSA received 1,748 comment letters in response to its two scoping notices. All but 11 of these letters were a form letter similar in content and sent by individuals. The non-form letters were provided by federal and state agencies, automobile trade associations, environmental advocacy groups, and two individuals.

Several commenters addressed the issues on which NHTSA specifically sought comment in its supplemental scoping notice and helped the agency identify and narrow the environmental issues for analysis. Other commenters questioned NHTSA's decision to prepare an EIS instead of an environmental assessment (EA). Still other commenters raised issues that are more properly addressed outside the NEPA process in other rulemaking documents. For example, some commenters raised economic and social issues, and courts have generally held that such issues are appropriate for consideration under NEPA only if they directly interrelate to the effects on the physical environment.[23] Other commenters made suggestions about the process to follow or the factors to be considered in setting CAFE standards – issues that are germane to the NPRM and other supporting documents.

Note that Sections 1.3.2.1 through 1.3.2.6 restate our responses to scoping comments. Specifically, they respond to those comments that spoke to the scope of NHTSA's NEPA analysis for the MY 2011-2015 CAFE standards. For this reason, the responses often are stated in terms of references or discussions appearing in the DEIS or refer specifically to the DEIS.

1.3.2.1 Federal Agencies

Federal agencies that provided scoping comments included EPA (Docket No. NHTSA-2008-0060-0016) and the Department of Health and Human Services, CDC (Docket No. NHTSA-2008-0060-0010 and NHTSA-2008-0060-0140). After receiving scoping comments from EPA and CDC, NHTSA conducted a telephone conference with CDC on June 12, 2008, and met with EPA officials at the EPA Washington, DC, headquarters on June 17, 2008, to discuss each agency's respective scoping comments. NHTSA also consulted with NOAA, the U.S. Fish and Wildlife Service, the U.S. National Park Service, and the U.S. Forest Service.

EPA indicated that some of the factors that affect air quality, such as meteorology and atmospheric processes, will not be taken into account when evaluating environmental impacts and that this limitation should be acknowledged. NHTSA agrees with EPA's suggestion, and this limitation is acknowledged in Chapters 3 and 4.

In addition to the regulatory scenarios that NHTSA developed using the Volpe model, EPA suggested that NHTSA evaluate reasonable alternative scenarios by using other combinations of inputs, including fuel prices, manufacturer compliance costs, economic discount rates, the projected benefits of greenhouse gas (GHG) emission reductions (including assumptions about the social cost of carbon (SCC) emissions), and the likely manufacturer and consumer response to the footprint curve embedded in the proposed rule. The NHTSA benefit-cost analysis did include several sensitivity analyses to examine the impact of different model input assumptions, such as the values of economic and environmental externalities and the price of gasoline. NHTSA presented the results of the sensitivity analyses in the Preliminary Regulatory Impact Analysis (PRIA), and discussed them in Chapter 3 of the DEIS (NHTSA 2008a).

EPA also stated that NHTSA should consider the impacts of each alternative on air toxics emissions. NHTSA conducted these suggested analyses; *see* Chapters 3 and 4.

EPA additionally recommended that the projected impacts of the EPCA program components that provide alternative means for manufacturers to demonstrate compliance with CAFE standards be analyzed, because EPA believes that these components of the program can be expected to lower compliance costs and reduce projected fuel savings. As explained in Chapters 3 and 4, although NHTSA expects that manufacturers' use of CAFE-related flexibilities will lead to higher fuel consumption and emissions than presented in this analysis, NHTSA does not currently have a reasonable basis to develop specific quantitative estimates of such effects. NHTSA will reevaluate the potential to do so after

[23] *See, e.g.*, *Ashley Creek Phosphate Co. v. Norton*, 420 F.3d 934, 944 (9th Cir. 2005); *Hammond v. Norton*, 370 F. Supp. 2d 226, 243 (D.D.C. 2005).

reviewing the updated product plans it has requested of vehicle manufacturers and related comments in response to the NPRM.

The Department of Health and Human Services, CDC, suggested that NHTSA relate projected changes in fleet emissions, fuel consumption, and fleet design to human health outcomes. It indicated that the levels of automobile emissions such as ozone-forming emissions, nitrogen oxides, and hydrocarbons, are affected by the CAFE standards and in turn directly affect human health. Consequently, CDC requested that potential health effects be analyzed for all of the alternatives, including an economic analysis of the associated health costs. It also suggested that transportation-related emissions contribute to climate change with resulting environmental impacts that directly affect human health worldwide, so NHTSA should also evaluate the health impacts of climate change.

NHTSA's analysis of alternative CAFE standards incorporates the economic value of reduced damages to human health that would result from the reductions in emissions of criteria air pollutants and GHGs estimated to result from each alternative. These reductions in damages to human health are valued using estimates of damage costs per unit of emissions of each pollutant that specifically reflect the chemical composition and geographic distribution of emissions generated by motor-vehicle use and by production and distribution of transportation fuels. These estimates were developed by EPA for use in its analysis of benefits from regulations that would reduce emissions from motor vehicle use and from the production and distribution of transportation fuels. Human health is further discussed in Chapters 3 and 4.

The CDC suggested that crash-related injuries be considered, including effects on other transportation-system users, because it believes that changing CAFE standards would affect fleet design and have the potential to increase or decrease crash-related injuries. It added that decreasing vehicle fleet disparities in size and weight can decrease crash-related injuries to those driving lighter-weight vehicles. In addition, two commenters requested consideration of lightweight vehicle materials as a fuel-saving technology. As discussed in the NPRM, NHTSA's analysis does include the potential to improve fuel economy through greater utilization of lightweight materials on heavier vehicles for which doing so would be unlikely to compromise highway safety. Further, NHTSA expects that basing CAFE standards on vehicle footprint would discourage manufacturers from reducing vehicle size. Therefore, although it does not have a reliable basis to estimate changes in crash frequency or severity, NHTSA expects that attribute-based standards would tend to improve, rather than degrade, highway safety.

Finally, the CDC recommended that NHTSA's analysis of potential health impacts be conducted in collaboration with public health officials. NHTSA discussed the CDC scoping comments with CDC officials on June 12, 2008. NHTSA appreciates the suggestion and the effort CDC took to submit scoping comments. After a thorough discussion, NHTSA believes it reached a high degree of understanding and assured CDC that health impacts would be included in various ways in the DEIS. NHTSA is confident that the consultants retained to assist in the analysis and development of the DEIS, along with its own staff, have the requisite knowledge and skills to effectively incorporate health issues into the document.

1.3.2.2 States

NHTSA received a number of comments representing the interests of states, including comments from the New York State Department of Transportation (Docket No. NHTSA-2008-0060-0012), the Washington State Department of Transportation (Docket No. NHTSA-2008-0060-0177), and the Minnesota Pollution Control Agency (Docket No. NHTSA-2008-0060-0011). NHTSA received a single, combined comment letter from the Attorneys General of the States of California, Connecticut, New Jersey, New Mexico, Oregon, and Rhode Island, the Commonwealth of Pennsylvania Department of

Environmental Protection, and the New York City Corporation Counsel (Docket No. NHTSA-2008-0060-0007.1).

The New York and Washington DOTs suggested that NHTSA consider the serious impacts of climate change and the consequent need for accelerated national fuel economy standards to be implemented both sooner than the year 2020 and to cover a greater number of vehicle types. They encouraged NHTSA to work with states and vehicle manufacturers to meet the common goals of economic stability and reduced transportation-related GHG emissions in an expedited way, including promoting the production of fuel-efficient vehicles and vehicles capable of using alternative fuels and advanced biofuels, and thereby advance the development of hybrid-electric, battery-electric, cleaner-diesel, and fuel-cell technologies. NHTSA appreciates the New York and Washington DOTs' interest in the development of new CAFE standards. As in other CAFE rulemakings, NHTSA will give careful consideration to comments from states, vehicle manufacturers, and other stakeholders. We also note that we engage regularly with other countries on matters related to vehicle research and regulation.

In response to the first comment regarding accelerated CAFE standards, as proposed in the NPRM and the DEIS, NHTSA is considering the environmental impacts of several alternatives covering a range of stringency for MY 2011-2015. The CAFE level required under the standards identified in the NPRM increases at an average annual rate of 4.5 percent – a rate fast enough to, if extended through 2020, exceed the 35 mile-per-gallon (mpg) requirement established in the EISA. The NPRM and the DEIS also include more stringent CAFE alternatives than those that would be established by the proposed standards. The proposed standards result in the maximum difference between benefits and costs, or net benefits. Each of the alternatives that would establish higher CAFE standards would result in larger fuel savings and emission reductions than those resulting from the proposed standards. But they would also result in lower net benefits than the proposed standards due to higher costs to society and could, therefore, fail to meet one or more of the statutory criteria applicable under EPCA.

The New York State DOT asked how Alternative 7, Technology Exhaustion, compares to the other alternatives under study. Alternative comparisons can be found in Section 2.5.

The Minnesota Pollution Control Agency suggested that the EIS discuss the incremental change in emissions for each alternative over the projected lifetime of the model year vehicles affected, the respective changes in atmospheric concentrations of GHGs in terms of CO_2 equivalents, and the direct and indirect impacts of these changes in concentrations. The comment further included the recommendation that changes in concentrations be incorporated into the range of emission scenarios prepared by the Intergovernmental Panel on Climate Change (IPCC), including other reasonably foreseeable U.S. emissions changes. This analysis is presented in Chapters 3 and 4.

The Minnesota Pollution Control Agency also recommended the use of the published marginal cost estimates found in the economics literature for the next emitted ton of CO_2 to provide a basis for assessing the cumulative environmental impacts of releases as monetized damages that might contribute to a larger global problem. Detailed estimates of economic benefits and costs of establishing alternative CAFE standards are presented in the PRIA (NHTSA 2008a). As that document explains, consistent with its treatment of pollutants such as nitrogen oxides, NHTSA's analysis applies an estimate representing damage costs, not marginal avoidance costs. As Chapter VIII of the PRIA describes, these estimates utilize the value recommended in a survey of nearly 100 published estimates of the social cost of carbon as a basis for assessing the monetized benefits of the reductions in CO_2 emissions projected to result from alternative CAFE standards.

The joint letter from the Attorneys General of California and several other states stated that the EIS must do more than simply present raw data on tons of GHGs emitted from the relevant sources. The letter stated that the EIS must also educate the public about the scientific consensus on climate change and explain how the contribution made by the emissions from the standard, coupled with emissions from other foreseeable sources, would affect global warming (*i.e.*, cumulative emissions should be modeled to determine a potential change in temperature, and this change should be compared to climate scenarios outlined by the IPCC).

This NEPA document informs the public about the scientific consensus on climate change and explains how the incremental contribution made by the emissions from the standards, coupled with emissions from other foreseeable sources, would affect global warming. *See* Sections 3.4 and 4.4.

In another comment, the Attorneys General suggested that for each alternative, NHTSA report not only the emissions that would result if each manufacturer meets the standard, but the emissions that would result if a series of other reasonably foreseeable events occur. NHTSA should report a range of emissions based on how the standard might operate in the real world. EPA made a similar comment, and NHTSA's response is included above under the EPA comments.

The Attorneys General also referenced what they state to be significant new studies and research on the health-related effects, both direct and indirect, of global warming, and requested that NHTSA take these into account. NHTSA reviewed those studies and research and incorporated them as appropriate in Chapters 3 and 4.

The Attorneys General also requested that NHTSA describe and discuss the potential "tipping points" associated with global warming "that could create unstoppable, large-scale, disastrous impacts for the planet." The term tipping point refers to a situation in which the climate system reaches a point at which there is a strong and amplifying positive feedback from only a moderate additional change in driver, such as CO_2 or temperature increase. These tipping points could result in abrupt climate change, defined in Committee on Abrupt Climate Change (2002) (as cited in Meehl *et al.* 2007) to "occur when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause."

While climate models do take positive (and negative, *i.e.*, dampening) feedback mechanisms into account, the magnitude of their effect and the threshold at which a tipping point is reached might not be well understood in some cases. In fact, MacCracken *et al.* (2008) notes that existing climate models may not include some critical feedback loops, and Hansen *et al.* (2007) states that the predominance of positive feedbacks in the climate system has the potential to cause large, rapid fluctuations in climate change effects. Therefore, it is important to discuss these mechanisms and the possibility of reaching points that could bring about abrupt climate change. The existence of these mechanisms and other evidence has led some climate scientists including Hansen *et al.* (2007) to conclude that a CO_2 level exceeding about 450 parts per million (ppm) is "dangerous."[24] Overall, however, the IPCC concludes that these abrupt changes are unlikely to occur this century…" (Meehl *et al.* 2007). Whether these tipping points exist and the levels at which they occur are still a matter of scientific investigation.

Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). In this case, the DEIS acknowledges that information on tipping points or abrupt climate change is incomplete, and the state of the science does not allow for a characterization of how the CAFE alternatives influence these risks, other than to say that the greater the emission reductions, the lower the risk of abrupt climate change.

[24] Defined as more than 1 degree Centigrade (°C) above the level in 2000.

1.3.2.3 Automobile Trade Associations

Automobile trade associations that provided scoping comments on the proposal included the National Automobile Dealers Association (NADA) (Docket No. NHTSA-2008-0060-0013) and the Alliance of Automobile Manufacturers (AAM) (Docket No. NHTSA-2008-0060-DRAFT-0033.1[1]). They noted that NHTSA is not responsible for GHG emissions, because vehicle usage is a voluntary choice, and that the scope of NHTSA's environmental analysis should be restricted to impacts that can clearly be attributed to the standards, with other factors, including fuel prices, manufacturer competition, and consumer preferences, held constant. EPA's comment on the same topic noted that fuel price was an important input into the setting of the standards which could have an effect on the environmental benefits estimated.

As indicated in its response to EPA, NHTSA agrees that fuel price can have an impact on the environmental benefits and, thus, should be considered. Reformed CAFE, and the process used to set the standards ensure that consumer preferences are maintained. The first step in setting standards involves collecting confidential manufacturers' product plan data. Vehicle manufacturers operate in a competitive environment. As profit-maximizing firms, they make product plans to reflect their forecast of what consumers want to buy. In the standard-setting process, NHTSA adds technologies at the individual vehicle-specific level to improve fleet-wide fuel economy. In order to preserve consumer preferences as predicted by vehicle manufacturers, the number and attributes of the vehicles, including their performance, are not altered. Reformed CAFE allows manufacturers to compete by producing a mix of vehicles they think consumers want to buy. No longer do manufacturers have to average out large vehicles with small ones to meet CAFE standards.

NADA also asked that all assumptions regarding the impacts on the rate of vehicle fleet turnover be provided, and that NHTSA forecast the introduction of vehicles meeting the standards into the fleet.

NHTSA's approach to analyzing the rate of vehicle fleet turnover is set forth in the NPRM. *See* 73 *FR* 24352, 24406-24407 (May 2, 2008).

Additionally, NADA requested that NHTSA consider any unique environmental impacts associated with the manufacturing and maintenance of vehicles affected by the proposed action, including alternative fuel vehicles. *See* Section 3.5 for an explanation of these issues.

The AAM stated that it disputes NHTSA's definition of the No Action Alternative as the alternative of maintaining CAFE standards at MY 2010 levels, because it believes that the baseline for comparison of the alternatives under NEPA should be set based on the scope of legal authority NHTSA has under EISA. The AAM recommended that NHTSA redefine the No Action Alternative to be consistent with the minimum CAFE standard increases needed to achieve a combined fuel economy level of 35 mpg by MY 2020. The AAM stated that such redefinition of the No Action Alternative would change NHTSA's calculation of the magnitude of the environmental impacts of the rulemaking, and might also change the agency's assessment of the significance of those effects. Accordingly, the AAM stated that it might be more appropriate for NHTSA to prepare a less elaborate EA, rather than a more-searching EIS.[25]

NEPA requires that NHTSA examine a no action alternative that reflects the state of the environment if the action were not taken. Even though NHTSA is required under EISA to set new fuel economy standards, we must analyze a scenario in which NHTSA does not take this action, which serves

[25] *Id.* at 18-22.

as a baseline against which to compare the other alternatives (*see* Section 1.3.2.6 concerning NHTSA's decision to prepare an EIS).

Another issue raised by the AAM was the extent of NHTSA's analysis of global effects associated with CO_2 emissions. The AAM stated that it agrees with NHTSA's statement in the May 2008 NPRM that "the appropriate value to be placed on changes [in] climate damages caused by carbon emissions should be ones that reflect the change in damages to the United States alone."[26] The AAM interpreted this statement in the NPRM as a proposal by NHTSA "to limit analysis undertaken in connection with the rulemaking to effects within the United States' own borders."[27] The AAM stated that this conclusion should carry over to the NEPA analysis, and that it believes NHTSA should scale back the estimated harms in any studies of the global effects associated with carbon emissions.

NHTSA agrees in part regarding the estimates employed for SCC, as discussed in the NPRM. NHTSA disagrees, however, with the AAM's characterization of NHTSA's statement in the NPRM as being a proposal to limit the agency's environmental impact analysis under NEPA. Potential environmental impacts are global in this instance, and the analysis must look beyond the borders of the United States. The section of the NPRM preamble quoted by the AAM discussed valuation of SCC as an input into the Volpe model. NHTSA has an obligation under NEPA to "recognize the worldwide and long-range character of environmental problems."[28]

NHTSA has considered the AAM's comment on the issue of the global effects of the agency's action. In the NPRM, NHTSA also requested "comment on its tentative conclusions for the value of the SCC emissions, the use of a domestic versus global value for the economic benefit of reducing CO_2 emissions, the rate at which the value of the SCC grows over time, the desirability of and procedures for incorporating benefits from reducing emissions of GHGs other than CO_2, and any other aspects of developing a reliable SCC value for purposes of establishing CAFE standards." *Id.* at 24414-24415.

Furthermore, an appropriate discussion of global climate change does not make sense if NHTSA limits analysis to the effects within the United States, because this environmental problem is inherently global in nature. Climate science focuses on accumulations of carbon emissions in the global atmosphere because the atmospheric concentration of GHGs is basically uniform across the globe (IPCC 1997). That is, carbon emissions from one nation disperse into the global atmosphere and have impacts in other nations, and conversely, benefits from emissions reductions in one nation are felt in all nations for the same reason. That said, NHTSA considers the AAM's comment as a suggestion to focus on environmental impacts within the United States, and agrees that this type of national rulemaking warrants specific discussion of regional U.S. impacts and how global climate change specifically affects the United States. Accordingly, NHTSA devoted a substantial section of the DEIS to such discussion.

The AAM argued in its comments that "the principal cumulative effects on which NHTSA's NEPA analysis should focus are those associated with the additive effects over the last decade or more of CAFE standards on the light-truck side, combined with those for this proposed rulemaking, which increases CAFE standards for both passenger cars and trucks." The AAM was primarily disputing the Ninth Circuit's decision in *Center for Biological Diversity v. NHTSA*, 508 F.3d 508, 550 (9th Cir. 2007),

[26] *See* 73 *FR* 24352, 24414.
[27] Alliance Comments, *supra* at 29.
[28] 42 U.S.C. § 4332(f). *See also* CEQ, *Council on Environmental Quality Guidance on NEPA Analyses for Transboundary Impacts* (July 1, 1997), at 3, *available at* http://ceq.hss.doe.gov/nepa/regs/transguide.html (last visited June 16, 2008) (stating that "agencies must include analysis of reasonably foreseeable transboundary effects of proposed actions in their [NEPA] analysis of proposed actions in the United States.").

in which the Court concluded that "by allowing particular fuel economy levels … NHTSA's regulations are the proximate cause of [tailpipe GHG] emissions."

In response to the AAM's comment, NHTSA notes that the CEQ regulations define "cumulative impacts" as "the impacts on the environment which result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." 40 CFR § 1508.7.

In the DEIS, NHTSA addresses the cumulative impacts (through 2100) of MY 2011-2015 standards, NHTSA's implementation of the CAFE Program through MY 2010, and "assumed" CAFE standards for MY 2016-2020. NHTSA has reviewed the available research and literature and has estimated the cumulative impacts on energy, air quality, and climate change. Our analysis considers both physical effects and resource impacts due to the cumulative impacts on climate change. Physical effects include changes in temperature, precipitation, and sea-level rise. Resource impacts include cumulative weather-based impacts on freshwater and terrestrial ecosystems and on human health and land-use patterns, and non-weather impacts. Our cumulative impacts analysis accounts for uncertainty and is consistent with CEQ regulations.

To this end, while this NEPA analysis considers some of the issues suggested by the AAM, including an analysis of the cumulative emissions impacts resulting from the CAFE Program since its inception (*see* Chapter 3) and an analysis of the standards and cumulative air quality impacts (in terms of criteria pollutant emissions, for example) on human health and the environment, NHTSA believes that the cumulative impacts analysis suggested by the AAM comments might be too narrow for our purposes.

1.3.2.4 Environmental Advocacy Groups

The Environmental Defense Fund (Docket No. NHTSA-2008-0060-0015) commented on the scope of NHTSA's NEPA analysis in conjunction with the Northern Health Impact Resource Group, Physicians for Social Responsibility, American Public Health Association, and the Johnson County Health Department. The commenters suggested a framework and methodology for analyzing the potential health impacts of climate change related to the CAFE standards and suggested that NHTSA request technical assistance from agencies with special expertise in this area. They suggested that the health benefits of the reduction of the emissions of pollutants regulated under the Clean Air Act, including criteria pollutants, and generated at every stage of the fuel cycle (*i.e.*, fuel production, refining, transport, storage, and combustion in vehicle engines) be quantified using traditional risk assessment. The commenters asserted that proper quantification of the economic benefits of reducing these adverse health impacts might justify adoption of more stringent fuel economy standards.

The commenters also suggested that NHTSA consider the policy alternatives under consideration as conforming to (as one example) no action, moderate action, and stringent action pathways. These pathways might be comparable to the different emissions scenarios employed by the IPCC, and they are also consistent with NHTSA's proposed categorization of alternative policy options. Assessment of health impacts could then be conducted for the degree of reductions in national or global GHG emissions associated with the relative stringency of each pathway, to provide decisionmakers with some useful insight into the health consequences of the various degrees of stringency associated with specific CAFE alternatives. Estimates of changes in incidence or prevalence of climate-sensitive health outcomes could be performed at 5-year intervals into the future, and inflation-adjusted costs associated with those health outcomes could also be calculated as a means of valuing the incremental contribution of the alternatives.

NHTSA has listed the alternatives in order of increasing stringency, as indicated by the mpg estimates associated with each. NHTSA has presented a full range of alternatives, from no action through a full consideration and exhaustion of the technological approaches NHTSA believes are currently available to increase CAFE (without regard to cost) consistent with the commenters' concerns. Further, the analysis included in the DEIS employs three IPCC scenarios to estimate the changes in CO_2 concentrations and temperature that are due to the alternatives. These scenarios (A2, A1B, and B1) represent a high, moderate, and low estimate of what future emissions levels might be. There is a great deal of uncertainty associated with estimating emissions levels in the year 2100, and the IPCC treats these scenarios (along with the other four scenarios) as equally probable. Given this uncertainty in the emission scenarios and in the analysis generally, it is not productive to estimate final impacts on human health or on other environmental areas because the range of error would obscure any reported differences in the alternatives. For these reasons, human health and environmental outcomes resulting from the CAFE alternatives are qualitatively assessed, and NHTSA's analysis includes a sense of the direction of the impacts and the relative magnitude by alternative, which will inform NHTSA's decisions on the standards.[29] Attempts to quantify impacts, including estimating health outcomes, would provide an unrealistic sense of precision that would not, in NHTSA's opinion, provide useful information for the decisionmaker or the public.

In the DEIS, NHTSA has analyzed both the criteria pollutants and mobile source air toxics (MSATs) by estimating the emissions levels of each generated under the CAFE alternatives. Upstream emissions[30] are included to the extent possible. (Upstream emissions of acrolein are not available.) Transportation conformity[31] does not apply because neither the Federal Highway Administration (FHWA) nor the Federal Transit Administration (FTA) is taking the action. General conformity[32] provides an explicit exception for rulemaking activities. Consequently, there is no requirement to analyze concentrations for the criteria pollutants. *See* the discussion of conformity in Chapter 3 for more information.

NHTSA's approach regarding MSATs follows that of the FHWA guidance on MSATs analysis issued in February 2006 and the approach generally followed by the Federal Aviation Administration. The FHWA stated that uncertainties associated with the exposure and health risk assessments, in addition to the fact that uncertainties are inherent in the emissions modeling process, raised concerns about the utility of studying MSATs beyond an emissions burden analysis. In addition, the NHTSA analysis demonstrates an overall reduction at the national level of both MSATs and criteria air pollutants, which should reduce health risk, making any further level of analysis of marginal benefit.

[29] *See* 42 U.S.C. § 4332(2)(B) (directing agencies to "insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations"); *see* also 40 CFR § 1502.22.

[30] Emissions associated with extraction, refining, storage, and distribution of the fuel.

[31] The Transportation Conformity Rules (40 CFR 51 Subpart T), which apply to transportation plans, programs, and projects funded under title 23 U.S.C. or the Federal Transit Act. Highway and transit infrastructure projects funded by the Federal Highway Administration or the Federal Transit Administration usually are subject to transportation conformity.

[32] The General Conformity Rules (40 CFR 51 Subpart W), which apply to all other federal actions not covered under transportation conformity. The General Conformity Rules established emissions thresholds, or *de minimis* levels, for use in evaluating the conformity of a project. If the net emission increases due to the project are less than these thresholds, then the project is presumed to conform and no further conformity evaluation is required. If the emission increases exceed any of these thresholds, then a conformity determination is required. The conformity determination could entail air quality modeling studies, consultation with EPA and state air quality agencies, and commitments to revise the State Implementation Plan or to implement measures to mitigate air quality impacts.

Health costs are already included in the modeling process by which NHTSA analyzes alternatives for the CAFE standard. Using a process that maximizes net benefits, NHTSA assesses the societal costs and benefits associated with each of the alternatives. Included in the societal costs are damages to health.

Finally, NHTSA received scoping comments from CDC and EPA and has consulted with each agency. NHTSA has also retained a nationally recognized consulting firm to assist with the analysis. NHTSA believes that we have or have retained the requisite expertise and knowledge to address the health and environmental impacts as required under NEPA.

1.3.2.5 Individuals

Scoping comments from individuals included approximately 1,737 letters that were similar in form and content. These letters recommended that NHTSA base the new standards on what the commenters considered more realistic gas prices and encourage the domestic automobile manufacturers to speed up the production of more fuel-efficient automobiles.

NHTSA's analysis of alternative CAFE standards relies on fuel price forecasts reported in the U.S. Energy Information Administration's (EIA's) *Annual Energy Outlook*, an official U.S. Federal Government forecast that is widely relied upon by federal agencies in their analysis of proposed regulations. The alternative CAFE standards analyzed in the NPRM and the PRIA were developed and evaluated using fuel price forecasts from EIA's *Annual Energy Outlook 2008 Revised Early Release*, and NHTSA will consider any subsequent revisions in the final edition of *Annual Energy Outlook 2008* in preparing the Final Rule and Final Regulatory Impact Analysis (FRIA). Extensive tests of the effect of higher fuel prices on the stringency of the optimized CAFE standards, as well as upon the resulting fuel savings, reductions in CO_2 emissions, and total economic benefits are reported in Tables IX-5a and IX-5b of the PRIA. As to the timeline for production of more fuel-efficient vehicles, the standards NHTSA proposed increase at a rate that, if sustained through 2020, would exceed the 35 mpg minimum average requirement specified by EISA.

Comments from private individuals included a letter from Susan and Yuli Chew (the Chews) (Docket No. NHTSA-2008-0060-0014) suggesting that the fuel price assumptions used by NHTSA are out of date. This comment is similar to the comments of other individuals and is addressed above.

The Chews also suggested that the assumptions of the buyer's payback calculation are flawed. This comment appears to refer to the 4.7- and 4.2-year payback periods for the passenger-car and light-truck CAFE standards reported in PRIA Table IX-10, p. IX-14. These payback periods are calculated from the increases in fuel economy, annual fuel savings, and value per gallon of fuel saved at forecast retail fuel prices for the standards. They are thus empirical estimates of the actual time required for buyers of new vehicles to recoup the higher purchase prices of those vehicles in the form of fuel cost savings, rather than assumptions about buyers' time horizons for valuing fuel savings.

The Chews also questioned the "carry-forward" and "carry-back" credits. While NHTSA cannot precisely estimate the potential environmental impacts of discounting credits, NHTSA believes its analysis of how the various compliance flexibilities might affect the potential environmental impacts of the standards spans the likely range of impacts that would be associated with discounting credits. The requirements covering the use of credits for alternatively fueled vehicles are explained in the EPCA. NHTSA does not have discretion to discount credits in future years. The point, however, will become moot as these credits are being phased out under the EISA, as noted by the commenter. They will no longer be allowed at all for MY 2020 vehicles.

The Chews suggested that the effect of ethanol is not properly discussed in terms of air quality and natural and human resources and that the benefit of alternative-fuel vehicles has been magnified, as only small portions of Midwest states have any E85[33] infrastructure in place.

In setting CAFE standards, NHTSA sets the fuel economy targets manufacturers are required to meet but does not specify the technologies required to meet those targets. Companies are provided credits under the Alternative Motor Fuels Act, but Congress is phasing out those credits. Even if the manufacturers employ the production of vehicles that can run on 85 percent ethanol in their strategies to meet the new targets, the existence of these vehicles does not necessarily change the production of ethanol, because consumers would have to choose to fill their vehicles with E85 fuel, and also have it available at their fueling stations.

NHTSA believes that the extent to which ethanol will actually be used as a transportation fuel will primarily be determined by its availability at retail fueling stations and its retail price in relation to that of gasoline. Because the availability of ethanol and its price in relation to that of gasoline are unlikely to be affected substantially by the stringency of CAFE standards, the use of ethanol is similarly unlikely to differ substantially among the alternative CAFE standards considered for MY 2011-2015. Thus, while the volume of ethanol that is produced, distributed, and consumed could substantially affect total emissions from the production and use of transportation fuels, this effect is not likely to differ substantially among alternative CAFE standards. As a consequence, the extent of ethanol use is unlikely to affect the changes in total emissions from production and use of transportation fuels resulting from alternative CAFE standards, or the environmental impacts associated with those changes in emissions.

The Chews also stated that the benefits are almost twice as much as the costs for MY 2011-2015, so the target should be adjusted to be more aggressive than planned. Regarding these benefits, NHTSA's NPRM reflects the best information available to NHTSA when the analysis was performed, and the standards reflect those benefits. NHTSA has requested comment on its estimate of benefits and costs, and on its analytical methods. After reviewing these comments, which are due on July 1, 2008, NHTSA will revisit its analysis in preparing the final rule.

The Chews suggested that the phasing out of the fuel economy incentives by dual-fuel vehicles (*e.g.*, E85) is welcomed and overdue. Dual-fuel vehicles are designed to run on gasoline or an alternative fuel. By law, manufacturers of these vehicles can lower their CAFE requirements by a certain amount within the limits specified in statute. To assess the environmental impacts of in-use operation of dual-fuel vehicles, data detailing the operation of the vehicle using the alternative fuel would be necessary. Unfortunately, such data depend on each individual's use of the dual-fuel vehicle, and are not available.

1.3.2.6 Other Comments

There were several comments submitted that go beyond the scoping process under NEPA or address regulatory issues within the NPRM or the PRIA.

The AAM (Docket No. NHTSA-2008-0060-DRAFT-0033.1[1]) submitted comments suggesting that an EIS is not warranted, and that an EA would be adequate.

NHTSA's rationale for preparing an EIS is explained in its NOI to prepare an EIS.[34]

[33] Automobile fuel that is 85 percent denatured ethanol and 15 percent gasoline.
[34] 73 *FR* 16615, 16616 (March 28, 2008).

The AAM also stated its belief that because the setting of CAFE standards under EPCA involves consideration of environmental factors, the "functional equivalence doctrine" applies to NHTSA's mandate for setting CAFE standards.[35] The AAM maintains that the functional equivalence doctrine is applied by courts to eliminate the need for an agency to perform NEPA analysis where the agency's Congressional mandate already involves specific procedures for considering the environment that offer the functional equivalent of an EIS.[36] According to the AAM, courts have ruled that EPA regulation under the Clean Air Act is the functional equivalent of NEPA analysis, making separate application of NEPA by EPA unnecessary.

In those instances where courts have found an agency exempt from NEPA requirements via the functional equivalence doctrine, the doctrine has been narrowly drawn. For example, the D.C. Circuit has repeatedly described the functional equivalence doctrine as a narrow exemption that is applicable "when the agency's organic legislation mandates procedures for considering the environment that are 'functional equivalents' of the NEPA process."[37] Other circuit courts have adopted even more narrow interpretations of the functional equivalence doctrine, construing it to mean that one process requires the same steps as another.[38] Although NHTSA considers environmental impacts when setting CAFE standards, EPCA does not require explicit consideration of environmental impacts; rather, the analysis is one that the agency has conducted in the context of evaluating the Nation's need to conserve energy.[39] EPCA does not require a level of environmental analysis commensurate with the requirements of NEPA. Moreover, courts have long held that NEPA applies except in limited circumstances.[40] Consequently, NHTSA declines to adopt the AAM's suggestion, and has prepared a DEIS to consider the environmental impacts of the standards in the context of NHTSA's CAFE Program. The DEIS will aid the agency in completing a robust analysis of the environmental impacts of the rulemaking for MY 2011-2015 CAFE standards.

The AAM also suggested that NHTSA consider an alternative tied to the "least capable manufacturer" approach that was applied prior to the advent of Reformed CAFE. NHTSA does not adopt this approach for the following reasons. NHTSA's earlier "Unreformed CAFE" standards specified a "one size fits all" (uniform) level of CAFE that applied to each manufacturer and that was set with particular regard to the lowest projected level of CAFE among the manufacturers that have a substantial

[35] Comments of the Alliance of Automobile Manufacturers, Document ID No. NHTSA-2008-0600-0176, 12-15 (June 2, 2008).
[36] *Id.* at 5-6.
[37] *American Trucking Assns. v. EPA*, 175 F.3d 1027, 1042 (D.C. Cir. 1999) (quoting *Izaak Walton League of America v. Marsh*, 655 F.2d 346, 367 n.51 (D.C. Cir. 1981)); *Amoco Oil Co.*, 501 F.2d at 749 (quoting *Int'l Harvester Co. v. Ruckelshaus*, 478 F.2d, 615, 650 n.130 (D.C. Cir. 1973)); *Portland Cement Assn.*, 486 F.2d at 384-387 (describing the functional equivalence doctrine as a narrow exemption); *Environmental Defense Fund v. EPA*, 489 F.2d 1247, 1256 (D.C. Cir. 1973).
[38] *Douglas County v. Babbitt*, 48 F.3d 1495, 1504 n.10 (9th Cir. 1995); *see* also *State of Wyoming v. Hathaway*, 525 F.2d 66, 73-74 (10th Cir. 1976) (affirming the trial court's finding of no functional equivalence).
[39] *See Center for Biological Diversity v. NHTSA*, 508 F.3d 508, 547 (9th Cir. 2007) (describing as complementary EPCA's goal of energy conservation and NEPA's goal of helping public officials make decisions that are based on an understanding of environmental consequences); *Massachusetts v. EPA*, 127 S. Ct. 1438, 1462 (2007) (categorizing EPCA's requirement to set CAFE standards as "DOT's mandate to promote energy efficiency" and distinguishing this mandate as "wholly independent" of the Clean Air Act's command that EPA protect the public's health and welfare); *see* also *Center for Auto Safety v. NHTSA*, 793 F.2d 1322, 1324-1325 n.12 (D.C. Cir. 1986) (listing the four statutory factors NHTSA is to consider when determining "maximum feasible" fuel economy, and noting approvingly that NHTSA interpreted the "need of the Nation to conserve energy" factor as requiring consideration of, among other issues, the "environmental … implications of our need for large quantities of petroleum").
[40] *See Pacific Legal Foundation v. Andrus*, 657 F.2d 829, 833 (6th Cir. 1981); *Calvert Cliffs' Coordinating Committee, Inc. v. U.S. Atomic Energy Commission*, 449 F.2d 1109, 1114-1115 (D.C. Cir. 1971).

share of the market. The manufacturer with the lowest projected CAFE level is typically known as the "least capable" manufacturer. However, NHTSA's 2006 CAFE standards for light trucks adopted a different "Reformed CAFE" approach. (71 *FR* 17566 [April 6, 2006]). EISA recently codified that approach, requiring that all CAFE standards be based on one or more vehicle attributes. (49 U.S.C. § 32902(b)(3)(A); *see* 73 *FR* 24352, 24354-24355 [May 2, 2008] [discussing NHTSA's proposal to base CAFE standards on the attribute of vehicle size, as defined by vehicle footprint].)

As NHTSA explained when proposing Reformed CAFE standards for MY 2008-2011 light trucks, "[u]nder Reformed CAFE, it is unnecessary to set standards with particular regard to the capabilities of a single manufacturer in order to ensure that the standards are technologically feasible and economically practicable for all manufacturers with a substantial share of the market. This is true both fleet wide and within any individual category of vehicles." *See* 70 *FR* 51414, 51432 (August 30, 2005). Specifically:

> There is no need under Reformed CAFE to set the standards with particular regard to the capabilities of the "least capable" manufacturer. Indeed, it would often be difficult to identify which manufacturer should be deemed the "least capable" manufacturer under Reformed CAFE. The "least capable" manufacturer approach was simply a way of implementing the guidance in the conference report [part of EPCA's legislative history][41] in the specific context of Unreformed CAFE….
>
> …The very structure of Reformed CAFE standards makes it unnecessary to continue to use that particular approach in order to be responsive to guidance in the conference report. Instead of specifying a common level of CAFE, a Reformed CAFE standard specifies a variable level of CAFE that varies based on the production mix of each manufacturer. By basing the level required for an individual manufacturer on that manufacturer's own mix, a Reformed CAFE standard in effect recognizes and accommodates differences in production mix between full- and part-line manufacturers, and between manufacturers that concentrate on small vehicles and those that concentrate on large ones.
>
> There is an additional reason for ceasing to use the "least capable" manufacturer approach. There would be relatively limited added fuel savings under Reformed CAFE if we continued to use the "least capable" manufacturer approach even though there ceased to be a need to use it….

(70 *FR* 51433).

In addition, the AAM's suggested approach would not result in the increases in fuel economy mandated by EISA – namely, 35 mpg by MY 2020.

In light of the fact that Congress recently codified the Reformed CAFE approach for both passenger cars and light trucks, and for all of the reasons stated above, NHTSA does not consider in detail an alternative tied to the historic "least capable manufacturer" approach.

Other comments, described below, suggested that NHTSA's NEPA analysis consider certain economic or social issues that are beyond the scope of NEPA.

[41] *See* 70 *FR* 51414, 51425-51426 (August 30, 2005) (discussing the conference report).

The AAM suggested that appropriate cumulative effects should include "The economic disbenefits and counterproductive/unintended consequences of CAFE standard increases," specifically including, "at a minimum, … the cumulative effects in this regard stemming from employment losses and associated health effects, for both this current proposed rule and the 2006 light truck rule. The same is true as to cumulative safety disbenefits and cumulative environmental disbenefits in terms of increased criteria pollutant emissions traceable to the fleet turnover and rebound effects."

The AAM also suggested that NHTSA consider what it characterized as additional categories of "environmental" effects in the DEIS, including the quality of life of unemployed automotive industry workers and fleet turnover.

The CDC suggested that "health and well-being"-related impacts of decreasing dependency on motor vehicle fuel, such as mental health benefits, reduced stress, and increased economic stability be evaluated in the DEIS. NHTSA discussed this comment with CDC on June 12, 2008. In particular, NHTSA and CDC discussed the potential for human health impacts in two areas – namely, the potential for social instability resulting from energy concerns and for changes in family expenditures related to energy. Further, in the discussion with CDC, the difficulty in addressing such issues was acknowledged. NHTSA agreed to examine the source provided by CDC concerning health issues related to petroleum scarcity (*see* Chapter 3).

Courts have generally held that economic and social issues need only be considered if they directly interrelate to the effects on the physical environment.[42] Because these issues raised by the AAM and CDC do not stem from effects on the physical environment, they are not addressed in this document.

The Attorneys General suggested the additional alternative of downweighting for all vehicles, not just vehicles weighing more than 5,000 pounds, and stated that there is strong evidence that downweighting of vehicles does not make them less safe. As discussed above, other comments also raised the downweighting alternative and related concerns. Chapter 2 explains NHTSA's rationale for choosing alternatives, and explains why NHTSA believes that the safety risks with downweighting preclude its selection as a reasonable alternative.

The Attorneys General also requested that NHTSA expand its analysis of reduced vehicle weight as a means of improving fuel economy. As mentioned above and discussed in the NPRM, NHTSA's analysis does include the potential to improve fuel economy through greater utilization of light-weight materials on heavier vehicles for which doing so would be unlikely to compromise highway safety.

Other comments refer to issues NHTSA expects to address in the final rule. These include comments from states concerning new technologies, comments from the AAM concerning the proper construction of the term, "ratably," and comments from individuals.

1.3.3 Summary of Public Comments on the DEIS

On June 26, 2008, NHTSA submitted to EPA a DEIS that disclosed and analyzed the potential environmental impacts of new CAFE standards and reasonable alternative standards in the context of NHTSA's CAFE Program pursuant to CEQ NEPA implementing regulations, DOT Order 5610.1C, and NHTSA regulations. On July 2, 2008, NHTSA published a *Federal Register* Notice of Availability announcing the availability of the DEIS. NHTSA's Notice of Availability also made public the date and location of a public hearing, and invited the public to participate at the hearing on August 4, 2008, in

[42] *See, e.g., Ashley Creek Phosphate Co. v. Norton*, 420 F.3d 934, 944 (9th Cir. 2005); *Hammond v. Norton*, 370 F. Supp.2d 226, 243 (D.D.C. 2005).

Washington, DC. On July 3, 2008, EPA issued its Notice of Availability for the DEIS, triggering the 45-day public comment period. In accordance with CEQ implementing regulations, the public was invited to submit written comments on the DEIS until August 18, 2008.

NHTSA mailed approximately 200 copies of the DEIS to interested parties, including federal, state, and local agencies; elected officials; environmental and public interest groups; Native American tribes; and other interested individuals, as listed in Chapter 9 of the DEIS.

A total of 44 commenters spoke at the hearing. In addition, NHTSA received 66 written comment documents from interested stakeholders, including EPA, the CDC, state and local agencies, elected officials, automobile trade associations, organizations, and private citizens. The transcript from the public hearing and written comments submitted during the public-comment period are part of the administrative record, and are available on the Federal Docket Web site at http://www.regulations.gov, Reference Docket No. NHTSA-2008-0060. Chapter 10 of this FEIS contains public comments on the DEIS and NHTSA's responses to those comments. Appendix D of this FEIS provides a copy of each written comment document and the public hearing transcript in their entirety.

Commenters raised a wide variety of issues regarding the DEIS. For example, some commenters were concerned about how NHTSA's alternatives relate to EPCA's requirement to establish the "maximum feasible average fuel economy." Other commenters had questions about how NHTSA had fulfilled its statutory requirements under NEPA, specifically in regard to public involvement and the timing of the EIS and CAFE rulemaking. A few commenters questioned the need for the agency to produce an EIS, citing the Government's (at the time) pending en banc petition for review of the Ninth Circuit Court of Appeals decision (*Center for Biological Diversity v. NHTSA*, 508 F.3d 508 [9th Cir. 2008], vacated and withdrawn, 2008 WL 3822966 [9th Cir. 2008] [denying the government's petition as moot]), while one commenter suggested that NHTSA should prepare an EA instead of an EIS.

NHTSA received a number of comments on various aspects of the Volpe model, many expressing concern about the economic assumptions that were input to the model. The most common of these input-related comments included concerns regarding the values assigned to fuel price, social cost of carbon, discount rate, and rebound effect; the technologies and vehicle attributes considered by the model and their associated costs; assumptions about the types of vehicles on the road in the future (particularly the market penetration of hybrids); and the use of auto manufacturers' product plans. Commenters also suggested that the Volpe model consider the military and national security costs associated with ensuring oil supplies, consider a different method to account for consumer demand and behavior directly, and use related changes to U.S. vehicle fleet turnover.

NHTSA received comments on the alternatives in the DEIS. Commenters questioned NHTSA's definition of the No Action Alternative (Alternative 1), specifically regarding the projected baseline mpg and other factors considered, or not considered, in its definition. Commenters also questioned how the Optimized Alternative (Alternative 3) represents an optimization of cost and benefits. Some commenters recommended that NHTSA select alternatives below Optimized, while others recommended that NHTSA use the requirement of "ratable" to derive standards that ratably increase to 35 mpg. Multiple commenters recommended that NHTSA select alternatives above Optimized, including the Total Costs Equal Total Benefits Alternative (Alternative 6). Several commenters argued for adoption of the Technology Exhaustion Alternative (Alternative 7), while others did not believe this alternative represented a true exhaustion of technological options. Some commenters stated that NHTSA did not consider a reasonable range of alternatives. In addition, there were comments regarding the alternatives' relationship to the "maximum feasible fuel economy standard." Some commenters requested that NHTSA consider new alternatives, such as alternatives that might not be within NHTSA's jurisdiction or that more aggressively raised the fuel economy standards so as to reach or exceed 35 mpg by 2015.

NHTSA received comments concerning the methodology for analyzing air quality impacts and associated health costs. Commenters noted that the DEIS did not include full-scale photochemical air quality modeling and, therefore, did not characterize the ambient air quality impacts or health outcomes associated with each alternative. Commenters also expressed concern that the dollar-per-ton values used to reflect the monetized health-related benefits associated with criteria pollutant emission reductions omitted a number of unquantified health and environmental effects.

Many commenters referenced suggestions made by the scientific community that CO_2 emissions should be reduced 80 percent by 2050 to mitigate the worst effects of climate change. Commenters suggested that this goal be used as a reference point from which to measure greenhouse gas reductions achieved through the different alternatives presented in the DEIS. Commenters stated that this contextual comparison would be more appropriate than comparing the alternatives based on their contribution to the reduction in global temperature and sea-level rise.

Other commenters suggested updated methodologies that could be employed in the FEIS. For example, some commenters recommended re-running the analysis using the revised version (5.3) of MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change). Commenters also recommended running MAGICC using a range of climate sensitivities to reflect the 2.0 to 4.5 °C range projected in the IPCC report. Many commenters questioned the accuracy of the “scaling approach” implemented in the DEIS, which assumed a linear relationship between emission levels and climate responses. Commenters further stated that the DEIS did not fully address the issue of tipping points.

A few commenters also stated that the proposed rulemaking would substantially impact endangered species and that a proper analysis of these impacts was absent from the comparison of the impacts of each alternative in the DEIS.

In addition to comments on the DEIS, NHTSA received a number of comments regarding the rulemaking. Some of these comments dealt with the issue of federal preemption of state laws, arguing that NHTSA’s rulemaking should not preempt state regulation of GHG emissions from automobiles. Other comments on the rulemaking objected to NHTSA’s vehicle footprint approach, either suggesting a more inclusive consideration of vehicle attributes, such as towing capacity, or questioning the use of a size-based system that has the built-in risk of manufacturers upsizing vehicles to achieve lower fuel economy targets.

In Chapter 10 of this FEIS, NHTSA sets forth excerpts of the comments on the DEIS, followed by NHTSA’s responses to those comments. Written comments and the public hearing transcript can be viewed in their entirety in Appendix D of this FEIS.

1.3.4 Submission of the Final EIS and Next Steps

NHTSA is mailing this FEIS to the agencies, individuals, and organizations on the distribution list provided in Chapter 9, and submitted it to EPA for formal issuance of a Notice of Availability. No sooner than 30 days after EPA publishes a Notice of Availability of the FEIS in the *Federal Register*, NHTSA will publish a final CAFE rule and Record of Decision. The Record of Decision will state and explain NHTSA’s decision and describe NHTSA’s consideration of applicable environmental laws and policies.

Chapter 2 Proposed Action and Alternatives

2.1 INTRODUCTION

The National Environmental Policy Act[1] (NEPA) requires an agency to compare the environmental impacts of its proposed action and alternatives. An agency must rigorously explore and objectively evaluate all reasonable alternatives, including a No Action Alternative. For alternatives an agency eliminates from detailed study, the agency must "briefly discuss the reasons for their having been eliminated."[2] The purpose of and need for the agency's action provides the foundation for determining the range of reasonable alternatives to be considered in its NEPA analysis.[3]

In developing the new Corporate Average Fuel Economy (CAFE) standards and possible alternatives, the National Highway Traffic Safety Administration (NHTSA) considered the four Energy Policy and Conservation Act (EPCA) factors that guide the agency's determination of "maximum feasible" standards:

- Technological feasibility
- Economic practicability
- The effect of other standards of the Government on fuel economy
- The need of the Nation to conserve energy[4]

In addition, NHTSA also considered relevant environmental and safety factors. For instance, NHTSA has placed monetary values on environmental externalities, including the benefits of reductions in carbon dioxide (CO_2) emissions. The NEPA analysis presented in NHTSA's Draft Environmental Impact Statement (DEIS) and this Final Environmental Impact Statement (FEIS) is informing the agency's action in setting final CAFE standards. During the standard-setting process, NHTSA consults with the U.S. Environmental Protection Agency (EPA) and the Department of Energy (DOE) regarding a variety of matters as required by EPCA.

2.2 STANDARDS-SETTING AND BENEFIT-COST ANALYSIS

To inform the balancing of the EPCA factors relevant to standard setting, NHTSA examined various levels of stringencies (mpg levels) to conduct a benefit-cost analysis for each level. A benefit-cost analysis weighs the expected benefits against the expected costs of specific alternatives on a societal basis, relative to a "no action" baseline. Costs of any specific CAFE alternative include the aggregate costs to increase the utilization of fuel-saving technologies, where such costs are expressed on a retail price equivalent basis. The benefits of any specific alternative include fuel savings over the operational life of new vehicles with increased fuel economy and the social benefits of reducing petroleum consumption and environmental externalities.

For each alternative under all scenarios, NHTSA calculated the costs and the benefits. This information replaces the benefit-cost information discussed in the DEIS which relied on the PRIA. The tables are entitled "FEIS Benefit-Cost Information, October 2, 2008," and are shown in Appendix C.

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[1] 42 United States Code (U.S.C.) § 4332(2)(C). NEPA is codified at 42 U.S.C. §§ 4321 *et seq.*
[2] 40 Code of Federal Regulations (CFR) §§ 1502.14(a), (d).
[3] 40 CFR § 1502.13. *Vermont Yankee Nuclear Power Corp. v. Natural Resources Defense Council*, 435 U.S. 519, 551 (1978); *City of Alexandria v. Slater*, 198 F.3d 862, 867-69 (DC Cir. 1999), cert. denied sub nom. 531 U.S. 820 (2000).
[4] 49 U.S.C. § 32902(f).

NHTSA has a long-standing practice of analyzing regulatory options based on the best available information regarding (1) the future vehicle market, (2) the technologies expected to be available during the relevant model years, and (3) the key economic factors, such as future fuel prices. Among these categories, all information except NHTSA's forecast of the future vehicle market is made available to the public. The forecast of the future vehicle market is based substantially on confidential product planning information manufacturers submit to the agency, as individual manufacturers are better able than any other entity to anticipate what mix of products they are likely to sell in the future.

2.2.1 Volpe Model

Until 2002, when NHTSA began work on CAFE standards for light trucks sold during model years 2005-2007, the agency used tools such as spreadsheets to analyze regulatory options. For that rulemaking and ensuing rulemakings, the agency has supplemented such tools with a modeling system developed specifically to assist NHTSA with applying technologies to thousands of vehicles and developing estimates of the costs and benefits of potential CAFE standards. The CAFE Compliance and Effects Modeling System, developed by DOT's Volpe National Transportation Systems Center and commonly referred to as "the Volpe model," enables the agency to efficiently, systematically, and reproducibly evaluate many more regulatory options, including attribute-based CAFE standards required by EISA, than was previously possible, and to do so much more quickly. The model assumes that manufacturers apply the most cost-effective technologies first, yielding the greatest net benefits. As more stringent fuel economy standards are evaluated, the model recognizes that manufacturers must apply less cost-effective technologies. The model then compares the discounted present value of costs and benefits for any specific CAFE standard.

Model documentation, publicly available in the rulemaking docket, explains how the model is installed, how the model inputs and outputs are structured, and how the model is used. The model can be used on any Windows-based personal computer with Microsoft Office 2003 and the Microsoft .NET framework installed (the latter available without charge from Microsoft). The executable version of the model, with all of its codes and accompanying demonstration files, is available upon request, and has been provided to manufacturers, consulting firms, academic institutions, nongovernmental organizations, research institutes, foreign government officials, and other organizations. The current version of the model was developed using Microsoft Development Environment 2003, and every line of computer code (primarily in C#.NET) has been made available to individuals who have requested the code. Many of these individuals have run the model using market forecast data that they estimated on their own.[5]

The Volpe model requires the following types of input information: (1) a forecast of the future vehicle market, (2) estimates of the availability, applicability, and incremental effectiveness and cost of fuel-saving technologies, (3) estimates of vehicle survival and mileage accumulation patterns, the rebound effect, future fuel prices, the "social cost of carbon," and many other economic factors, (4) fuel characteristics and vehicular emissions rates, and (5) coefficients defining the shape and level of CAFE curves to be examined. The model makes no *a priori* assumptions regarding inputs such as fuel prices and available technology, and does not dictate the form or stringency of the CAFE standards to be examined. The agency makes those selections and, in the case of technology assumptions, has determined that confidential product plans are a vital source of information.

Using inputs selected by the agency based on the best available information and data, NHTSA projects a set of technologies each manufacturer could apply in attempting to comply with the various levels of potential CAFE standards to be examined. The model then estimates the costs associated with

[5] Resources for the Future (RFF) has run the model and is working under contract with EPA to expand its capability.

this additional technology utilization, as well as accompanying changes in travel demand, fuel consumption, fuel outlays, emissions, and economic externalities related to petroleum consumption and other factors.

Recognizing the uncertainty inherent in many of the underlying estimates in the model, NHTSA has used the Volpe model to conduct both sensitivity analyses, by changing one factor at a time, and a probabilistic uncertainty analysis (a Monte Carlo analysis that allows simultaneous variation in these factors) to examine how key measures (*e.g.*, mpg levels of the standard, total costs, and total benefits) vary in response to change in these factors. This type of analysis is used to estimate the uncertainty of the costs and benefits of a given set of CAFE standards.

The model can also be used to fit coefficients defining an attribute-based standard, and to estimate the stringency that either (a) maximizes net benefits to society, (b) achieves a specified stringency at which total costs equal total benefits, (c) imposes a specified average required CAFE level, or (d) results in a specified total incremental cost, *etc*. The agency uses this information from the Volpe model as a tool to assist in setting standards.

Although NHTSA has used the Volpe model as a tool to inform its consideration of potential CAFE standards, the Volpe model, alone, does not determine the CAFE standards NHTSA will propose or promulgate as final regulations. NHTSA considers the results of analyses conducted using the Volpe model and external analyses, including assessments of greenhouse gases and air pollution emissions, and technologies that may be available in the long term. NHTSA also considers whether the standards could expedite the introduction of new technologies into the market, and the extent to which changes in vehicle prices and fuel economy might affect vehicle production and sales. Using all of this information, the agency considers the governing statutory factors, along with environmental issues and other relevant societal issues, such as safety, and promulgates the maximum feasible standards based on its best judgment on how to balance these factors.

2.2.2 Input Scenarios

As noted in the public comments, there is a vast number of model input values that could be used to calculate costs and benefits of the alternatives, including, but not limited to, future fuel prices, the value of carbon dioxide emissions reductions (referred to as the social cost of carbon or SCC), the discount rate, and oil import externalities.[6,7] These model parameters are estimated forecasts of future economic conditions. These estimates are subject to uncertainty and debate, and as several commenters noted, the CAFE standards and resulting environmental impacts could depend on the choice of the economic assumptions utilized by the Volpe model. These commenters urged NHTSA to examine impacts under different input scenarios.

The sensitivity analysis reported in the Preliminary Regulatory Impact Analysis (PRIA) revealed changes in required fuel economy levels due to variations in the value of CO_2, oil import externalities, the rebound effect (the estimated increase in driving due to higher fuel economy standards), and higher fuel prices. In the DEIS, NHTSA addressed these concerns in Section 3.4.4.2, "Sensitivity Analysis."

[6] For further discussion of what constitutes "oil import externalities," *see* page 24410 of the Notice of Proposed Rulemaking, Average Fuel Economy Standards (NHTSA 2008b).
[7] Council on Environmental Quality (CEQ 1981) guidance instructs that "[w]hen there are potentially a very large number of alternatives, only a reasonable number of examples, covering the full spectrum of alternatives, must be analyzed and compared in the EIS" (emphasis in original).

In this FEIS, NHTSA further addresses these concerns by presenting analytical results for the alternatives under four model input scenarios: Reference Case, High Scenario, Mid-1 Scenario, and Mid-2 Scenario. The Reference Case uses the Energy Information Administration's (EIA's) reference case fuel price forecast ($2.41 per gallon) and a domestic SCC. The High Scenario uses the EIA high fuel price forecast ($3.33 per gallon) and a global SCC. The Reference Case value for oil import externalities ($0.326 per gallon) is higher than the High Scenario input value ($0.116 per gallon) due to higher fuel price and SCC values in the High Scenario. *See* Section 10.2.2.10 for a description of the components of the oil externality values. In analyzing the benefits of future CO_2 emissions reductions, the Reference Case, High Scenario, Mid-1 Scenario, and Mid-2 Scenario all employ a 3-percent discount rate. For non-CO_2 impacts, the High Scenario uses a 3-percent discount rate, while the Reference Case and Mid-1 and Mid-2 Scenarios use a 7-percent discount rate. *See* Table 2.3-1 for a list of the different input values used in the scenarios. Sections 3.4 and 4.4 describe in detail the environmental impacts of the Reference Case and High Scenario alternatives, and briefly discuss the impacts of the Mid-1 and Mid-2 Scenarios. Appendix B shows the full analysis results for the Mid-1 and Mid-2 Scenarios.

Table 2.2-1

Economic Model Input Scenarios

	Value of CO_2 (2007$/ton)	**Oil Import Externalities (2007$/gallon)**	**AEO 2008 a/ Fuel Price**	**Discount Rate**
Reference Case	$2.00 (Domestic)	$0.326	$2.41 (Reference)	3% CO_2 – 7% Other
Mid-2 Scenario	$2.00 (Domestic)	$0.382	$3.33 (High)	3% CO_2 – 7% Other
Mid-1 Scenario	$33.00 (Global)	$0.116	$3.33 (High)	3% CO_2 – 7% Other
High Scenario	$33.00 (Global)	$0.116	$3.33 (High)	3% CO_2 – 3% Other

a/ Both the Reference and High *Annual Energy Outlook* fuel price vary by year. Price shown is the average 2011-2030 price for gasoline expressed in 2007 dollars.

The analysis of costs and benefits employed in the Volpe model reflects NHTSA's current assessment of a broad range of technologies that can be applied to passenger cars and light trucks. NHTSA consulted with EPA to develop a list of fuel-saving technologies cost and effectiveness numbers for the NPRM and DEIS. EPA published the results of this collaboration in a report (EPA 2008h). A copy of the report and other studies used in the technology update was placed in the rulemaking docket.

2.2.3 Technology Assumptions

NHTSA specifically sought comment on the estimates, which it had developed jointly with EPA, of the availability, applicability, cost, and effectiveness of fuel-saving technologies, and the order in which the technologies were applied. *See* 73 *FR* 24352, 24367. While NHTSA asked manufacturers to submit such information in the request for product plans, the agency also conducted its own independent analysis of the all the comments and data – including comments and information from entities outside the automobile manufacturing community – received through the rulemaking process. This involved hiring an international engineering consulting firm that specializes in automotive engineering, and that was used by the EPA in developing its recent advance notice of proposed rulemaking to regulate greenhouse gas emissions under the Clean Air Act (CAA).[8]

[8] 73 *FR* 44354 (July 30, 2008).

NHTSA and its consultants undertook a thorough review of the NPRM technology assumptions and all comments received on those assumptions, based on both old and new public and confidential manufacturer information. NHTSA and its consultants reviewed and compared comments on the availability and applicability of technologies, and the logical progression between them. The agency also reviewed and compared the methodologies used for determining the costs and effectiveness of the technologies as well as the specific estimates provided. Relying on the expertise of its consultants and taking into consideration all the information available, NHTSA revised its estimates of the availability and applicability of many technologies, and revised its estimate of the order in which the technologies are applied. In addition, the agency and its consultant generally agreed with commenters who said that in several cases, the technology related costs used in the NPRM and DEIS were underestimated and benefits were overestimated. The agency also agreed with commenters that both sets of estimates were not well differentiated by vehicle class and that the technology decision trees needed to be expanded and refined. NHTSA used the revised technology and effectiveness estimates in analyzing all of the alternatives and scenarios presented in this FEIS. The agency believes that the representation of technologies—that is, estimates of the availability, applicability, cost, and effectiveness of fuel-saving technologies, and the order in which the technologies are applied—used in this action is the best available.

The technologies considered by the model are briefly described below, under the five broad categories of engine, transmission, vehicle, electrification/accessory, and hybrid technologies.

Types of engine technologies that were considered under the benefit-cost analysis include the following:

- *Low-friction lubricants* – reduce fuel consumption, and more advanced engine oils are now available with improved performance and better lubrication.

- *Reduction of engine friction losses* – can be achieved through low-tension piston rings, roller cam followers, improved material coatings, more optimal thermal management, piston surface treatments, and other improvements in the design of engine components and subsystems that improve engine operation and fuel economy, and reduce friction and emissions.

- *Conversion to dual overhead cam with dual cam phasing* – as applied to overhead valves designed to increase the air flow with more than two valves per cylinder and thermal efficiencies by reducing pumping losses.

- *Cylinder deactivation* – does not inject fuel into some cylinders during light-load operation, such as coasting, and when cruise control is activated. Active cylinders combust at almost double the load required if all cylinders are operating, with pumping losses substantially reduced so long as the engine is operated in this mode.

- *Variable valve timing* – alters the timing or phase of the intake valve, exhaust valve, or both, primarily to reduce pumping losses, increase specific power, and control residual gases.

- *Discrete variable valve lift* – reduces fuel consumption by improved air flow and thermal efficiency by pumping loss reduction. Accomplished by hydraulically controlled switching between two or more cam profile lobe heights.

- *Continuous variable valve lift* – is an electromechanically controlled system in which cam period and phasing is changed as lift height is controlled. This yields a wide range of performance optimization and combustion efficiency, including enabling the engine to be valve throttled.

- *Stoichiometric gasoline direct-injection technology* – injects fuel at high pressure directly into the combustion chamber to improve cooling of the air/fuel charge within the cylinder, which allows for higher compression ratios and increased thermodynamic efficiency.

- *Combustion restart* – can be used in conjunction with gasoline direct-injection systems to enable idle-off or start-stop functionality. Similar to other start-stop technologies, additional enablers, such as electric power steering, accessory drive components, and auxiliary oil pump, might be required.

- *Turbocharging and downsizing* – increases the available airflow and specific power level, allowing a reduced engine size while maintaining or improving performance. This reduces pumping losses at lighter loads in comparison to a larger engine, while reducing net friction losses.

- *Exhaust-gas recirculation boost* – increases the exhaust-gas recirculation used in the combustion process to increase thermal efficiency and reduce pumping losses. Might require additional enablers, such as intake manifold pressure monitoring.

- *Diesel engines* – have several characteristics that give superior fuel efficiency, including reduced pumping losses due to lack of (or greatly reduced) throttling, and a combustion cycle that operates at a higher compression ratio, with a very lean air/fuel mixture, than an equivalent-displacement gasoline engine. Might require additional enablers, such as NO_x trap catalyst after-treatment or selective catalytic reduction NO_x after-treatment.

Types of transmission technologies considered under the benefit-cost analysis include:

- *Improved automatic transmission controls and externals* – optimizes shift schedule to maximize fuel efficiency under wide ranging conditions, and minimizes losses associated with torque converter slip through lock-up or modulation.

- *Six-, seven-, and eight-speed automatic transmissions* – influence the width of gear ratio spacing and transmission ratio optimization available under different operating conditions, thereby offering greater engine optimization and higher fuel economy.

- *Dual clutch or automated shift manual transmissions* – are similar to conventional transmissions, but the vehicle controls shifting and launch functions. A dual-clutch automated shift manual transmission uses separate clutches for even-numbered and odd-numbered gears, so the next expected gear is pre-selected, which allows for faster and smoother shifting.

- *Continuously variable transmission* – commonly uses V-shaped pulleys connected by a metal belt rather than gears to provide ratios for operation. Unlike manual and automatic transmissions with fixed transmission ratios, continuously variable transmissions can provide fully variable transmission ratios with an infinite number of gears, enabling finer optimization of the transmission ratio under different operating conditions so that the powertrain can operate at its optimum efficiency.

- *Manual 6-speed transmission* – like automatic transmissions, increases the number of available ratios in a manual transmission to improve fuel economy by allowing the driver to select a ratio that optimizes engine operation at a given speed.

Types of vehicle technologies considered under the benefit-cost analysis include:

- *Low-rolling-resistance tires* – have characteristics that reduce frictional losses associated with the energy dissipated in the deformation of the tires under load, therefore improving fuel economy.

- *Low-drag brakes* – reduce the sliding friction of disc brake pads on rotors when the brakes are not engaged because the brake shoes are pulled away from the rotating drum.

- *Front or secondary axle disconnect for four-wheel drive systems* – provides a torque distribution disconnect between front and rear axles when torque is not required to the non-driving axle. This results in the reduction of associated parasitic energy losses, therefore improving fuel economy.

- *Aerodynamic drag reduction* – is achieved by changing vehicle shape or frontal area, including skirts, air dams, underbody covers, and more aerodynamic side view mirrors.

- *Material substitution* – encompasses a variety of techniques that include application of lighter-weight materials, higher-strength materials, component redesign, and size matching of components.

Types of electrification/accessory technologies considered under the benefit-cost analysis include:

- *Electric power steering* – is an electrically-powered, decoupled steering system that has advantages over traditional hydraulic power steering because it draws power only when required by the operator to steer the vehicle, which is only a small percentage of vehicle operating time.

- *Improved accessories* – the technology associated with an intelligent cooling system. This ignores other electrical accessories (electrical lubrication and electrical air conditioning), which might be present in full hybrid applications.

- *Higher-voltage, Improved alternator* – provides a mechanical-to-electrical power conversion for the numerous electrical load requirements of a vehicle. Traditionally, alternators are optimized for cost. Increased conversion efficiency alternators cost more, but result in less fuel required to power the electrical loads, thus improving vehicle fuel economy.

- *12-volt micro-hybrid* – commonly implemented as a 12-volt belt-driven integrated starter-generator, this is the most basic hybrid system that facilitates idle-stop capability. Along with other enablers, this system replaces a common alternator with an enhanced power starter-alternator, both belt driven, and a unique accessory drive system.

- *Integrated starter generator* – is similar to the 12-volt micro-hybrid in function and design, except that it uses a 110- to 144-volt battery that contains greater battery capacity and maintains a smaller electric machine than other hybrid electric vehicle designs. Along with other enablers, this system replaces a common alternator with an enhanced power starter-alternator, either accessory belt driven or crank mounted, with a generator for recovering energy while slowing down.

Types of hybrid technologies considered under the benefit-cost analysis include:

- *2-mode hybrid* – is a full hybrid system that uses an adaptation of a conventional stepped-ratio automatic transmission by replacing some of the transmission clutches with two electric motors that control the ratio of engine speed to vehicle speed, while clutches allow the motors to be bypassed, which improves both the transmission torque capacity for heavy-duty applications and fuel economy at highway speeds.

- *Power-split hybrids* – is a full hybrid system that replaces the vehicle's transmission with a single planetary gear and a motor/generator. This motor/generator uses its engine torque to either charge the battery or supply additional power to the drive motor. A second, more powerful motor/generator, is permanently connected to the vehicle's final drive and always turns with the wheels. The planetary gear splits the engine's torque between the first motor/generator and the drive motor to either charge the battery or supply power to the wheels.

- *Plug-in hybrid electric vehicles* – are vehicles with the means to charge the battery packs from an outside source of electricity (usually the electric grid). These vehicles have larger battery packs with more energy storage and a greater capability to be discharged and have a control system that allows the battery pack to be substantially depleted under electric-only operation.

2.2.4 FEIS Analytical Improvements

A number of changes occurred from the NPRM and DEIS that provide analytical improvements in this FEIS. These changes explain why the CAFE levels, fuel savings, and CO_2 emissions that are attributable to each alternative and scenario in this FEIS differ from those presented in the NPRM and DEIS.

As discussed in the NPRM and the DEIS, the agency requested new product plans from manufacturers for analyzing alternative standards for the final rule. The product plans submitted in May 2007 did not take into consideration the passage of EISA and the minimum 35 mpg combined fleet requirement by 2020. In addition, during that time, the fuel prices rose substantially. The new product plans reflect those new realities in the following ways:

- Companies provided product plans that implemented some of the cost effective technologies that the agency had projected in the NPRM. This increased the baseline against which the fuel saving from the standards is measured. Some of the savings and CO_2 emission reductions attributed in the NPRM to the rulemaking action must now be attributed to improved product plans.

- The size of the overall fleet has declined from the time of the NPRM to the final rule resulting in less vehicle miles traveled.

In the NPRM, the two-wheel drive vehicles were classified in the same way they were classified by their manufacturers in their May 2007 product plans. For the purposes of this analysis and the final rule, however, they were reclassified in accordance with the discussion in the NPRM of the proper classification of those vehicles. This resulted in the shifting of slightly over one million two-wheel drive vehicles from the truck fleet to the car fleet, which lowers average car mpg due to the inclusion of vehicles previously categorized as trucks, and lowers truck mpg because the truck category now has a larger proportion of heavier trucks. Following our careful consideration of the public comments on that discussion, we reaffirm the reasoning and conclusions of that discussion.

As discussed in Section 2.2.3, NHTSA also revised the technology assumptions proposed in the NPRM based on comments and new information received during the comment period and used those assumptions for analyzing alternatives and scenarios for the FEIS and final rule. In several cases, the costs in the NPRM and DEIS were underestimated and benefits overestimated, and in most cases, these estimates were not well differentiated by vehicle class. The agency also revised its phase-in schedule of the technologies to account for lead time.

The agency, working with other agencies of the U.S. government, also updated its estimates of the domestic and global values of the SCC as well as estimates for other externalities based on comments and updated information received during the comment period. Specifically, this FEIS uses a domestic SCC of $2, which is lower than the DEIS/NPRM SCC of $7.00, but a higher global SCC at $33 as compared to $14 used in the NPRM and DEIS. These are discussed in greater detail in Chapter 10 Responses to Public Comments.

2.3 ALTERNATIVES

EPCA, as amended by EISA, requires attribute-based fuel economy standards for passenger cars and light trucks. NHTSA first employed this Reformed CAFE approach in establishing standards for MY 2008-2011 light trucks.[9] In May 2008, NHTSA proposed separate standards for MY 2011-2015 passenger cars and light trucks, again using this approach.[10] The alterations reflect the agency's best assessment based on the comments received and analyzed. Under the standards, fuel economy targets are established for vehicles of different sizes. Each manufacturer's required level of CAFE is based on its distribution of vehicles among those sizes and the fuel economy target required for each size. Size is defined by vehicle footprint.[11] The fuel economy target for each footprint reflects the technological and economic capabilities of the industry. These targets are the same for all manufacturers, regardless of the differences in their overall fleet mix. Compliance is determined by comparing a manufacturer's harmonically averaged fleet fuel economy levels in a model year with an average required fuel economy level calculated using the manufacturer's actual production levels and the targets for each footprint of the vehicles that it produces.

A large number of alternatives can be defined along a continuum from the least to the most stringent levels of CAFE. The specific alternatives NHTSA examined, described below, were selected to illustrate estimated costs and benefits. The fuel economy levels associated with the alternatives encompass a reasonable range to evaluate the potential environmental impacts of the CAFE standards and alternatives under NEPA, in view of EPCA requirements.

[9] *See* Average Fuel Economy Standards for Light Trucks, Model Years 2008-2011, 71 *FR* 17566, 17587-17625, April 6, 2006 (describing that approach).
[10] The proposed standards include light truck standards for one model year (MY 2011) that were previously covered by a 2006 final rule, Average Fuel Economy Standards for Light Trucks, Model Years 2008-2011, 71 *FR* 17566, April 6, 2006.
[11] A vehicle's footprint is generally defined as "the product of track width [the lateral distance between the centerlines of the base tires at ground, including the camber angle] … times wheelbase [the longitudinal distance between front and rear wheel centerlines] … divided by 144 …." 49 CFR § 523.2.

At one end of this range is the No Action Alternative (Alternative 1), which assumes that NHTSA would not issue a rule regarding CAFE standards. The No Action Alternative also assumes that average fuel economy levels in the absence of CAFE standards beyond 2010 would equal the higher of a manufacturer's product plans or the manufacturer's required level of average fuel economy for MY 2010. Costs and benefits of other alternatives are calculated relative to the baseline of the No Action Alternative. The No Action Alternative, by definition, would yield no incremental costs or benefits (and it would not satisfy the EPCA requirement to set standards such that the combined fleet achieves a combined average fuel economy of at least 35 mpg for MY 2020).

At the other end of the range of possible alternatives is the Technology Exhaustion Alternative (Alternative 7). This alternative would require every manufacturer to apply the maximum technology expected to be available over the period necessary to meet the statutory goals of EPCA, as amended by the EISA, without consideration of the accompanying costs. By definition, this alternative would apply all known technologies by make and model in the manufacturers' product plans while recognizing constraints associated with vehicle manufacturing and design cycles. It produces a CAFE standard that requires the use of technologies where costs exceed benefits. (*See* the NPRM for additional details on how the agency arrives at a CAFE standard, after application of the Volpe model).

NHTSA has examined five alternatives that fall between the extremes of the No Action Alternative and the Technology Exhaustion Alternative as defined below. Table 2.3-1 shows the estimated fuel economy levels for each alternative under the Reference Case.

Table 2.3-1

Reference Case Alternative CAFE Standards
MY 2015 Required MPG

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Passenger Cars	27.5	33.3	33.4	33.5	33.7	33.9	47.1
Light Trucks	23.4	25.8	26.0	26.2	26.5	27.0	37.2

Analyzing the environmental impacts of these alternatives provides information on the full spectrum of CAFE choices reasonably available to the decisionmaker. Although NEPA requires – and this FEIS analyzes – a full spectrum of alternatives, EPCA contains additional requirements and factors that NHTSA must apply in setting "maximum feasible" CAFE standards: (1) technological feasibility, (2) economic practicability, (3) the effect of other motor vehicle standards of the government on fuel economy, and (4) the need of the Nation to conserve energy.

Table 2.2-1 shows model input values for the SCC, the value of oil import externalities, fuel prices, and the discount rate for the Reference Case, High Scenario, and two intermediate scenarios – Mid-1 and Mid-2. Tables 2.3-2 and 2.3-3 show how the specific mpg standards associated with each of the seven alternatives vary across the Reference Case and the three Input Scenarios for cars and for light trucks, respectively. Table 2.3-4 shows the combined fuel economy standards for cars and light trucks for the seven alternatives for the Reference Case and the three Input Scenarios. These are the combined average fuel economy levels that would occur if each manufacturer exactly met its obligations under these standards.[12]

Table 2.3-2

MY 2015 Required MPG for Passenger Cars by Alternative and Model Input Scenario

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Input Scenario	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Reference Case	27.5	33.3	33.4	33.5	33.7	33.9	47.1
Mid-2 Scenario	27.5	36.7	37.1	37.5	37.9	38.7	47.1
Mid-1 Scenario	27.5	36.7	37.2	37.8	38.3	39.3	47.1
High Scenario	27.5	37.2	37.7	38.2	38.8	39.8	47.1

Table 2.3-3

MY 2015 Required MPG for Light Trucks by Alternative and Model Input Scenario

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Input Scenario	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Reference Case	23.4	25.8	26.0	26.2	26.5	27.0	37.2
Mid-2 Scenario	23.4	26.2	27.1	27.9	28.8	30.6	37.2
Mid-1 Scenario	23.4	29.3	29.6	29.9	30.2	30.8	37.2
High Scenario	23.4	28.9	29.6	30.3	31.0	32.3	37.2

Table 2.3-4

MY 2015 Required MPG for Passenger Cars and Light Trucks by Alternative and Model Input Scenario

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Input Scenario	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Reference Case	25.5	29.4	29.6	29.8	30.0	30.4	42.0
Mid-2 Scenario	25.5	31.1	31.8	32.5	33.2	34.6	42.0
Mid-1 Scenario	25.5	32.9	33.3	33.8	34.2	35.0	42.0
High Scenario	25.5	32.9	33.6	34.2	34.8	36.0	42.0

Tables 2.3-2 through 2.3-4 show that the estimated fuel economies under the No Action and Technology Exhaustion Alternatives are the same for the Reference Case and the three Input Scenarios. Therefore, environmental impacts for the Reference Case and the three Input Scenarios fall between the impacts of the No Action Alternative and the Technology Exhaustion Alternative.

[12] NHTSA notes that the precise level of CAFE that each manufacturer will be required to meet will be determined after the manufacturers submit final production and fleet mix figures at the end of each model year in question.

2.3.1 Preferred Alternative

The agency's Preferred Alternative is the Optimized Alternative, the level at which marginal costs equal marginal benefits. For any set of economic assumption model inputs, the Optimized Alternative yields the greatest net benefits. As fuel economy standards are increased beyond this level, manufacturers would need to apply technologies that entail higher incremental costs than benefits, thereby reducing net benefits. This alternative is described in more detail in Section 2.3.4. Table 2.2-1 lists the inputs (social cost of carbon, oil import externalities, fuel price, and discount rate) for the Reference Case and the Mid-1, Mid-2, and High Scenarios. The required fuel economy levels (combined for cars and light trucks) for the Optimized Alternative can be found in Table 2.3-4.

2.3.2 Alternative 1: No Action

The No Action Alternative assumes that NHTSA would not issue a rule regarding CAFE standards. The No Action Alternative assumes that average fuel economy levels in the absence of CAFE standards beyond 2010 would equal the higher of a manufacturer's product plans or the manufacturer's required level of average fuel economy for MY 2010. The MY 2011 fuel economy in mpg (27.5 mpg and 23.3 mpg for passenger cars and light trucks, respectively) represents the standard the agency believes manufacturers would continue to achieve, assuming that the agency does not issue a rule.[13] The No Action Alternative will yield different levels of impacts under the Reference Case and the Input Scenarios, as the Input Scenarios include the high values for fuel price. Relatively higher fuel prices serve to dampen future VMT growth and result in less fuel consumption and greenhouse gases. The air quality emissions analysis would also be different because it relies on VMT estimates and the amount of fuel produced.

NEPA requires agencies to consider a No Action Alternative in their NEPA analyses (*see* 40 CFR § 1502.14(b)), although the recent amendments to EPCA direct NHTSA to set new CAFE standards and do not permit the agency to take no action on fuel economy. In the NPRM, NHTSA refers to the No Action Alternative as the no increase or baseline alternative.

2.3.3 Alternative 2: 25 Percent Below Optimized

This alternative reflects standards that are more stringent than the No Action Alternative but less stringent than the Optimized Alternative (Alternative 3). Alternative 2 is less stringent than the Optimized Alternative by 25 percent of the difference in fuel economy between the Optimized Alternative and Alternative 6 (Total Costs Equal Total Benefits). This alternative falls below the Optimized Alternative by the same absolute amount by which the 25 Percent Above Optimized Alternative exceeds the Optimized Alternative.

As shown for passenger cars, the average required fuel economy in mpg for the industry in MY 2015 would range from 33.3 mpg for the Reference Case to 37.2 for the High Scenario. For light trucks, the average required fuel economy in mpg for the industry in MY 2015 would range from 25.8 mpg for the Reference Case to 28.9 for the High Scenario. The combined industry-wide average fuel economy for all passenger cars and light trucks would range from 29.4 mpg for the Reference Case to 32.9 for the High Scenario.

[13] *See* 40 CFR §§ 1502.2(e) and 1502.14(d).

2.3.4 Alternative 3: Optimized

The Optimized Alternative, which applies technologies until marginal benefits equal marginal costs and net benefits are maximized, is NHTSA's Preferred Alternative. For any set of economic assumption model inputs, the Optimized Alternative yields the greatest net benefits. As fuel economy standards are increased beyond this level, manufacturers would need to apply technologies that entail higher incremental costs than benefits, thereby reducing net benefits.

As shown for passenger cars, the average required fuel economy for the industry in MY 2015 would range from 33.4 mpg for the Reference Case to 37.7 for the High Scenario. For light trucks, the average required fuel economy for the industry in MY 2015 would range from 26.0 mpg for the Reference Case to 29.6 for the High Scenario. In MY 2015, the combined industry-wide average fuel economy for all passenger cars and light trucks would range from 29.6 mpg for the Reference Case to 33.6 for the High Scenario.

2.3.5 Alternative 4: 25 Percent Above Optimized

This alternative reflects standards that increase the fuel economy levels of the Optimized Alternative by 25 percent of the difference between the Optimized and the Total Costs Equal Total Benefits Alternative fuel economy levels.

As shown for passenger cars, the average required fuel economy in mpg for the industry in MY 2015 would range from 33.5 mpg for the Reference Case to 38.2 for the High Scenario. For light trucks, the average required fuel economy for the industry in MY 2015 would range from 26.2 mpg for the Reference Case to 30.3 for the High Scenario. In MY 2015, the combined industry-wide average fuel economy for all passenger cars and light trucks would range from 29.8 mpg for the Reference Case to 34.2 for the High Scenario.

2.3.6 Alternative 5: 50 Percent Above Optimized

This alternative reflects standards that increase the fuel economy levels to the Optimized Alternative level by 50 percent of the difference between the Optimized and the Total Costs Equal Total Benefits Alternative fuel economy levels.

As shown for passenger cars, the average required fuel economy for the industry in MY 2015 would range from 33.7 mpg for the Reference Case to 38.8 for the High Scenario. For light trucks, the average required fuel economy or the industry in MY 2015 would range from 26.5 mpg for the Reference Case to 31.0 for the High Scenario. In MY 2015, the combined industry-wide average fuel economy for all passenger cars and light trucks would range from 30.0 mpg for the Reference Case to 34.8 for the High Scenario.

2.3.7 Alternative 6: Total Costs Equal Total Benefits

This alternative reflects standards based on applying technologies until total costs equal total benefits. It results in zero net benefits because the benefits to society are completely offset by the costs. This is known as the Total Costs Equal Total Benefits Alternative.

As shown for passenger cars, the average required fuel economy for the industry in MY 2015 would range from 33.9 mpg for the Reference Case to 39.8 for the High Scenario. For light trucks, the average required fuel economy for the industry in MY 2015 would range from 27.0 mpg for the Reference Case to 32.3 for the High Scenario. In MY 2015, the combined industry-wide average fuel economy for all passenger cars and light trucks would range from 30.4 mpg for the Reference Case to 36.0 for the High Scenario.

2.3.8 Alternative 7: Technology Exhaustion

NHTSA developed the Technology Exhaustion Alternative by progressively increasing the stringency of the standard in each model year until every manufacturer (among those without a history of paying civil penalties) exhausted technologies estimated to be available during MY 2011-2015. Except for phase-in constraints, this analysis was performed using the same technology-related estimates (*e.g.*, incremental costs, incremental fuel savings, availability, applicability, and dependency on vehicle freshening and redesign) as used for other alternatives, such as those that maximize net benefits and those that produce total benefits approximately equal to total costs. For the Technology Exhaustion Alternative, NHTSA removed phase-in constraints in order to develop an estimate of the effects of fuel economy increases that might be achieved if manufacturers could apply as much technology as theoretically possible, while recognizing that some technologies must still be installed as part of a vehicle freshening or redesign.

In each year, NHTSA increased the stringency until the first manufacturer exhausted available technologies; beyond this stringency, NHTSA estimated that the manufacturer would be unable to comply (NHTSA is precluded from considering manufacturers' ability to use CAFE credits) and would be forced to pay civil penalties. NHTSA then increased the stringency until the next manufacturer was unable to comply, and continued to increase the stringency of the standard until every manufacturer was unable to apply enough technology to comply.

For passenger cars, the average required fuel economy for the industry would be 47.1 mpg in MY 2015 and 37.2 mpg for light trucks in MY 2015. The combined industry-wide average fuel economy for all passenger cars and light trucks would be 42.0 mpg in MY 2015.

2.4 ALTERNATIVES CONSIDERED BUT NOT ANALYZED IN DETAIL

As a result of the scoping and DEIS comment process, several suggestions were made to NHTSA regarding alternatives that should be included in this DEIS and examined in detail. NHTSA considered these alternatives and discusses them below along with the reasons why we believe these referenced alternatives do not warrant further analysis in this FEIS.

- **Downweighting Vehicles.** NHTSA was requested by commenters to consider as an alternative in the FEIS the potential for increased fuel economy by replacing heavy materials in passenger cars with lighter materials; a practice known as downweighting. As discussed in Chapter 1 and the NPRM, NHTSA's analysis does include the potential to improve fuel economy through greater utilization of lightweight materials on heavier vehicles, for which doing so would be unlikely to compromise highway safety. This request relates to specific technology choices (which CAFE standards do not require) rather than regulatory alternatives. Consequently, this comment does not warrant analysis of an additional alternative within the FEIS.

- **Least Capable Manufacturer Approach.** NHTSA's earlier Unreformed CAFE standards specified a "one size fits all" (uniform) level of CAFE that applied to each manufacturer and that was set with particular regard to the lowest projected level of CAFE among the manufacturers that have a substantial share of the market. The major manufacturer with the lowest projected CAFE level is typically known as the "least capable" manufacturer. However, NHTSA's 2006 CAFE standards for light trucks adopted a different Reformed

CAFE approach (71 *FR* 17566, April 6, 2006). EISA recently codified that approach, requiring that all CAFE standards be based on one or more vehicle attributes (49 U.S.C. § 32902(b)(3)(A); 73 *FR* 24352, 24354-24355, May 2, 2008) (discussing NHTSA's proposal to base CAFE standards on the attribute of vehicle size, as defined by vehicle footprint).

As NHTSA explained when proposing Reformed CAFE standards for MY 2008-2011 light trucks, "[u]nder Reformed CAFE, it is unnecessary to set standards with particular regard to the capabilities of a single manufacturer in order to ensure that the standards are technologically feasible and economically practicable for all manufacturers with a substantial share of the market. This is true both fleet-wide and within any individual category of vehicles" (70 *FR* 51414, 51432, August 30, 2005). Specifically:

> There is no need under Reformed CAFE to set the standards with particular regard to the capabilities of the "least capable" manufacturer. Indeed, it would often be difficult to identify which manufacturer should be deemed the "least capable" manufacturer under Reformed CAFE. The "least capable" manufacturer approach was simply a way of implementing the guidance in the conference report (part of EPCA's legislative history)[14] in the specific context of Unreformed CAFE….
>
> …The very structure of Reformed CAFE standards makes it unnecessary to continue to use that particular approach in order to be responsive to guidance in the conference report. Instead of specifying a common level of CAFE, a Reformed CAFE standard specifies a variable level of CAFE that changes based on the production mix of each manufacturer. By basing the level required for an individual manufacturer on that manufacturer's own mix, a Reformed CAFE standard in effect recognizes and accommodates differences in production mix between full- and part-line manufacturers, and between manufacturers that concentrate on small vehicles and those that concentrate on large ones.
>
> There is an additional reason for ceasing to use the "least capable" manufacturer approach. There would be relatively limited added fuel savings under Reformed CAFE if we continued to use the "least capable" manufacturer approach even though there ceased to be a need to use it…." (70 *FR* 51433, August 30, 2005).

In addition, the commenter's suggested approach would not result in the increases in fuel economy mandated by EISA – namely, 35 mpg by MY 2020. In light of the fact that Congress recently codified the Reformed CAFE approach for both passenger cars and light trucks, and for all of the reasons stated above, NHTSA declines to consider in detail an alternative tied to the historic "least capable manufacturer" approach as the commenter suggested.

2.5 COMPARISON OF ALTERNATIVES

The CEQ NEPA regulations (40 CFR Part 1500.2(e)) direct federal agencies to use the NEPA process to identify and assess the reasonable alternatives to proposed actions that would avoid or minimize adverse effects of these actions upon the quality of the human environment. CEQ regulations (40 CFR 1502.14) state:

[14] *See* 70 *FR* 51414, 51425-51426, August 30, 2005 (discussing the conference report).

> Based on the information and analysis presented in the sections on the Affected Environment (Sec. 1502.15) and the Environmental Consequences (Sec. 1502.16), it [an EIS] should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public.

This section summarizes the direct, indirect, and cumulative effects of the CAFE alternatives on energy, air quality, and climate. No quantifiable, alternative-specific effects were identified for the other resources discussed in Chapters 3 and 4. Refer to the text in Chapter 4 for qualitative discussions of the potential direct and indirect effects of the alternatives on these other resources. Reductions in fuel consumption are demonstrated for all the alternatives in Section 3.2 and 4.2. Emissions of criteria pollutants and mobile source air toxics generally show reductions although carbon monoxide emissions increase slightly under some of the alternatives. *See* Section 3.3 and 4.3. Although the alternatives have the potential to substantially decrease GHG emissions, they do not prevent climate change from occurring, but only result in reductions of less than 1 percent in the anticipated increases in CO_2 concentrations, temperature, precipitation, and sea level. As discussed below, NHTSA's presumption is that these reductions in climate effects will be reflected in reduced impacts on affected resources. The resources addressed in Chapter 4 of the FEIS include freshwater resources, terrestrial ecosystems, coastal ecosystems, land use, and human heath. However, the magnitudes of the changes in these climate effects that the alternatives produce – a few parts per million (ppm) of CO_2, one-hundredth of a degree Celsius (°C) difference in temperature, a small percentage change in the rate of precipitation increase, and 1 or 2 millimeters (mm) of sea level – are too small to address quantitatively in terms of their impacts on resources. Given the enormous resource values at stake, these distinctions may be important – very small percentages of huge numbers can still yield measurable results – but they are too small for current quantitative techniques to resolve. Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but rather provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change. Thus, there are no differences in resource impacts to report in this comparison of the alternatives.

To illustrate how different economic assumptions could affect estimates of fuel consumption, emissions reductions, and resulting health and climate effects, NHTSA examined four model input scenarios: Reference Case, High Scenario, Mid-1 Scenario, and Mid-2 Scenario. Table 2.2-1 shows the key input assumptions for these four scenarios. This section examines direct and indirect effects and cumulative effects on energy, air quality, and climate, across alternatives for the Reference Case and the High Scenario. Specific methodologies are discussed in Chapters 3 and 4, and corresponding results for the Mid-1 and Mid-2 Scenarios are presented in Appendix B.

2.5.1 Direct and Indirect Effects

2.5.1.1 Energy

President George W. Bush signed the EISA on December 17, 2007. In his signing statement, he reiterated his 2007 State of the Union goal to reduce car and light truck fuel consumption by 20 percent over 10 years. Consistent with the President's goals, EISA requires an industry-wide combined average fuel economy through vehicle and fuel standards of at least 35 miles per gallon by 2020, saving billions of gallons of fuel and also fulfilling a U.S. promise to reduce national greenhouse gas emissions.

Under NEPA, direct effects "are caused by the action and occur at the same time and place" (40 CFR 1508.8). CEQ regulations define indirect effects as those that "are caused by the action and are later in time or father removed in distance but are still reasonably foreseeable. Indirect effects may include …

effects on air and water and other natural systems, including ecosystems" (40 CFR 1508.8). Below is a description of the direct and indirect effects of the CAFE alternatives on energy, air quality, and climate.

2.5.1.1.1 Reference Case

Table 2.5-1 shows the impact on fuel consumption for passenger cars and light trucks from 2020 through 2060, a period in which an increasing volume of the fleet will be MY 2011-2015 passenger cars. The table shows total fuel consumption (both gasoline and diesel) under the No Action Alternative and the six other alternatives. Fuel consumption under the No Action Alternative is 264.9 billion gallons in 2060. Consumption falls to 256.3 billion gallons under the Optimized Alternative (Alternative 3) and falls to 214.3 billion gallons under the Technology Exhaustion Alternative (Alternative 7).

Table 2.5-1

Reference Case Passenger Car and Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Passenger Cars and Light Trucks Annual Fuel Consumption (billion gallons)							
2020	151.8	149.4	149.2	148.7	148.4	147.8	134.9
2030	172.4	167.7	167.2	166.5	165.8	164.9	141.8
2040	198.5	192.8	192.1	191.3	190.4	189.3	161.1
2050	229.7	222.9	222.2	221.2	220.1	218.7	185.9
2060	264.9	257.1	256.3	255.1	253.8	252.3	214.3
Passenger Cars and Light Trucks Annual Fuel Savings from No Action (billion gallons)							
2020	--	2.4	2.6	3.1	3.4	3.9	16.9
2030	--	4.7	5.2	5.8	6.6	7.5	30.5
2040	--	5.8	6.4	7.2	8.2	9.2	37.4
2050	--	6.8	7.4	8.5	9.5	10.8	43.8
2060	--	7.8	8.6	9.7	11.0	12.5	50.5

2.5.1.1.2 High Scenario

Table 2.5-2 lists the impact on fuel consumption under the High Scenario in the Volpe model for passenger cars and light trucks from 2020 through 2060. The High Scenario uses the economic inputs presented in Table 2.2-1. The table lists total fuel consumption for passenger cars and light trucks, both gasoline and diesel, under the No Action Alternative and the six alternative CAFE standards. The No Action Alternative in the High Scenario reflects a higher fuel price input than in the Reference Case, resulting in lower fuel consumption with no regulatory action by 2060, when the entire fleet is likely to be composed of MY 2011 or later cars, fuel consumption reaches 230.8 billion gallons. With the assumption of higher fuel prices, lower consumption is also expected across the alternatives. Consumption totals 210.2 billion gallons under the Optimized Alternative in 2060, as opposed to 256.3 billion gallons under the Optimized Alternative in the Reference Case.

Table 2.5-2

High Scenario Passenger Car and Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2015						
	Alt. 1	**Alt. 2**	**Alt. 3**	**Alt. 4**	**Alt. 5**	**Alt. 6**	**Alt. 7**
Calendar Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Cost Equal Total Benefit**	**Technology Exhaustion**
Passenger Cars and Light Trucks Annual Fuel Consumption (billion gallons)							
2020	139.1	133.4	132.4	131.4	130.5	129.6	123.7
2030	155.4	144.4	142.6	140.8	139.5	138.2	127.8
2040	177.2	163.7	161.6	159.5	157.7	156.3	143.8
2050	202.6	187.0	184.6	182.1	180.1	178.5	164.0
2060	230.8	213.0	210.2	207.4	205.1	203.1	186.7
Passenger Cars and Light Trucks Annual Fuel Savings from No Action (billion gallons)							
2020	--	5.6	6.7	7.8	8.6	9.4	15.5
2030	--	11.0	12.8	14.6	15.9	17.2	27.5
2040	--	13.5	15.6	17.8	19.4	20.9	33.4
2050	--	15.5	18.0	20.6	22.5	24.2	38.6
2060	--	17.8	20.6	23.4	25.6	27.6	44.1

2.5.1.2 Air Quality

2.5.1.2.1 Reference Case

Table 2.5-3 summarizes the total national criteria and air toxic pollutant emissions in 2035[15] for the seven alternatives under the Reference Case, left to right in order of increasing fuel economy requirements. Under the Reference Case, the No Action Alternative has the highest emissions of all the alternatives for NO_x, $PM_{2.5}$, SO_x, VOCs, acetaldehyde, 1,3-butadiene, and diesel particulate matter. Alternative 3 has the highest emissions of all the alternatives for CO_2 and benzene. Alternative 7 has the highest emissions of all the alternatives for acrolein and formaldehyde.

Localized increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the CAFE standards under the action alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act standards. All of the action alternatives would reduce adverse health outcomes and health costs related to motor vehicle air pollution, and thus would have beneficial health effects that would not need mitigation.

2.5.1.2.2 High Scenario

Table 2.5-4 summarizes the national criteria and air toxic pollutant emissions in 2035 for the seven alternatives for the High Scenario. For the High Scenario, emissions with the action alternatives are generally lower than under the Reference Case.

[15] NHTSA uses 2035 as the latest projection year because by 2035 almost all passenger cars and light trucks in operation would meet at least the MY 2011-2015 standards and the impact of the standards would start to come only from VMT growth rather than further tightening of the standards. NHTSA believes the year 2035 is a practical maximum for impacts of criteria and toxic air pollutants to be considered reasonably foreseeable rather than speculative.

Table 2.5-3

Reference Case Alternative CAFE Standards Nationwide Criteria Pollutant Emissions and Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) (Calendar Year 2035)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Criteria Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)							
Carbon monoxide (CO)	19,745,847	19,809,449	19,866,650	19,460,737	19,411,428	19,219,623	11,050,380
Nitrogen oxides (NO_x)	1,369,135	1,360,018	1,360,519	1,347,773	1,344,759	1,336,616	1,057,996
Particulate matter ($PM_{2.5}$)	99,707	98,692	98,625	98,064	97,853	97,861	91,101
Sulfur oxides (SO_x)	265,792	259,517	258,951	257,164	255,984	254,228	203,047
Volatile organic compounds (VOCs)	1,906,119	1,894,399	1,896,272	1,869,506	1,863,351	1,844,280	1,205,722
Toxic Air Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)							
Acetaldehyde	8,209	8,206	8,208	8,198	8,197	8,165	7,733
Acrolein	351	354	353	367	369	378	720
Benzene	47,515	47,428	47,517	46,703	46,570	46,154	29,324
1,3-butadiene	3,885	3,834	3,834	3,818	3,815	3,781	3,231
Diesel particulate matter (DPM)	119,499	116,161	115,786	115,400	114,858	114,592	104,644
Formaldehyde	13,035	12,949	12,915	13,122	13,142	13,169	16,745

Table 2.5-4

High Scenario Alternative CAFE Standards Nationwide Criteria Pollutant Emissions and Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) (Calendar Year 2035)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Criteria Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)							
Carbon monoxide (CO)	17,713,991	16,946,492	17,052,955	16,475,978	16,127,830	15,629,753	9,913,291
Nitrogen oxides (NO_x)	1,228,251	1,181,455	1,180,414	1,159,073	1,146,599	1,129,532	949,127
Particulate matter ($PM_{2.5}$)	89,447	86,654	86,251	86,389	85,756	85,318	81,727
Sulfur oxides (SO_x)	238,442	221,475	219,361	215,533	212,881	209,978	182,153
Volatile organic compounds (VOCs)	1,709,979	1,620,442	1,621,526	1,572,211	1,546,659	1,507,558	1,081,653

Table 2.5-4 (cont'd)

High Scenario Alternative CAFE Standards Nationwide Criteria Pollutant Emissions and Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) (Calendar Year 2035)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Toxic Air Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)							
Acetaldehyde	7,364	7,318	7,326	7,244	7,239	7,211	6,938
Acrolein	315	356	353	379	393	412	646
Benzene	42,626	40,639	40,753	39,588	38,860	37,822	26,306
1,3-butadiene	3,885	3,815	3,821	3,790	3,754	3,709	3,231
Diesel particulate matter (DPM)	107,203	99,856	98,495	98,385	97,499	96,932	93,876
Formaldehyde	11,694	11,933	11,878	12,000	12,178	12,394	15,022

Localized increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the CAFE standards under the action alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act standards. All of the action alternatives would reduce adverse health outcomes and health costs related to motor vehicle air pollution, and thus would have beneficial health effects that would not need mitigation.

2.5.1.3 Climate

2.5.1.3.1 Reference Case

GHG Emissions

Table 2.5-5 shows total emissions and emissions reductions from new passenger cars and light trucks from 2010-2100 for each of the seven alternatives for the Reference Case. Compared to the No Action Alternative, projections of emissions reductions over the 2010 to 2100 timeframe due to other MY 2011-2015 CAFE standard alternatives ranged from 5,922 to 28,047 million metric tons of carbon dioxide ($MMTCO_2$).[16] Over this period, this range of alternatives would reduce global CO_2 emissions by about 0.1 to 0.6 percent (based on global emissions of 4,850,000 $MMTCO_2$).

Climate: CO_2 Concentration and Global Mean Surface Temperature

Table 2.5-6 shows estimated CO_2 concentrations, increase in global mean surface temperature, and sea-level rise in 2030, 2060, and 2100 for the No Action Alternative and the six action alternative CAFE levels for the Reference Case. There is a fairly narrow band of estimated CO_2 concentrations as of 2100, from 714.6 ppm for Technology Exhaustion to 717.2 ppm for the No Action Alternative. As CO_2 concentrations are the key driver of all the other climate effects, this narrow range implies that the differences among alternatives are difficult to distinguish.

[16] The values here are summed from 2010 through 2100, and are thus considerably higher than the value of 520 $MMTCO_2$ that is cited in the NPRM for the "Optimized" alternative. The latter value is the reduction in CO_2 emissions by only MY 2011-15 cars and light trucks over their lifetimes resulting from the optimized CAFE standards, measured as a reduction from the NPRM baseline of extending the CAFE standards for MY 2010 to apply to 2011-15.

Table 2.5-5

Reference Case Emissions and Emissions Reductions Due to the MY 2011-2015 CAFE Standards from 2010-2100 ($MMTCO_2$)

Alternative	Emissions ($MMTCO_2$)	Emissions Reductions Compared to No Action Alternative ($MMTCO_2$)
1 No Action	221,258	0
2 25 Percent Below Optimized	215,337	5,922
3 Optimized	214,643	6,616
4 25 Percent Above Optimized	214,144	7,114
5 50 Percent Above Optimized	213,254	8,004
6 Total Costs Equal Total Benefits	212,345	8,913
7 Technology Exhaustion	193,212	28,047

Table 2.5-6

Reference Case MY 2011-2015 Alternative CAFE Standards Impact on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using the MAGICC Model (A1B a/)

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
	2030	2060	2100	2030	2060	2100	2030	2060	2100
1 No Action	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.5	573.4	716.7	0.873	1.943	2.957	7.99	19.29	37.08
3 Optimized	455.5	573.4	716.6	0.873	1.943	2.956	7.99	19.29	37.08
4 25 Percent Above Optimized	455.5	573.4	716.6	0.873	1.943	2.956	7.99	19.29	37.08
5 50 Percent Above Optimized	455.5	573.4	716.5	0.873	1.943	2.956	7.99	19.29	37.08
6 Total Costs Equal Total Benefits	455.4	573.3	716.4	0.873	1.943	2.956	7.99	19.28	37.07
7 Technology Exhaustion	455.3	572.5	714.6	0.872	1.938	2.946	7.99	19.25	36.99
Reduction from CAFE Alternatives									
2 25 Percent Below Optimized	0.0	0.3	0.5	0.000	0.001	0.002	0.00	0.01	0.02
3 Optimized	0.0	0.3	0.6	0.000	0.001	0.002	0.00	0.01	0.02
4 25 Percent Above Optimized	0.0	0.3	0.6	0.000	0.001	0.003	0.00	0.01	0.02
5 50 Percent Above Optimized	0.0	0.3	0.7	0.000	0.001	0.003	0.00	0.01	0.02
6 Total Costs Equal Total Benefits	0.1	0.4	0.8	0.000	0.002	0.003	0.00	0.02	0.03
7 Technology Exhaustion	0.2	1.2	2.6	0.002	0.007	0.013	0.00	0.05	0.11

a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Climate: Global Mean Rainfall and Global Mean Surface Temperature

The CAFE alternatives reduce temperature increases slightly with respect to the No Action Alternative, and thus reduce increases in precipitation slightly, as shown in Table 2.5-7. As shown in the table and figures, there is a fairly narrow band of estimated precipitation increase reductions as of 2090, from 4.50 percent to 4.51 percent, and there is very little difference among the alternatives for the Reference Case.

Table 2.5-7

Reference Case MY 2011-2015 CAFE Alternatives: Impact on Reductions in Global Mean Precipitation based on A1B a/ SRES Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC for 2020, 2055, and 2090 b/

Scenario	2020	2055	2090
Global mean rainfall change	1.45	1.51	1.63
Global Temperature Above Average 1980-1999 Levels (°C) for the A1B Scenario by 2100, Mid-level Results			
1 No Action	0.560	1.764	2.765
2 25 Percent Below Optimized	0.560	1.763	2.763
3 Optimized	0.560	1.763	2.763
4 25 Percent Above Optimized	0.560	1.763	2.762
5 50 Percent Above Optimized	0.560	1.763	2.762
6 Total Costs Equal Total Benefits	0.560	1.763	2.762
7 Technology Exhaustion	0.560	1.758	2.753
Reduction in Global Temperature (°C) for the A1B Scenario, Mid-level Results			
2 25 Percent Below Optimized	0.000	0.001	0.002
3 Optimized	0.000	0.001	0.002
4 25 Percent Above Optimized	0.000	0.001	0.002
5 50 Percent Above Optimized	0.000	0.001	0.003
6 Total Costs Equal Total Benefits	0.000	0.001	0.003
7 Technology Exhaustion	0.000	0.006	0.011
Mid level Global Mean Precipitation Change (%)			
1 No Action	0.81	2.66	4.51
2 Percent Below Optimized	0.81	2.66	4.50
3 Optimized	0.81	2.66	4.50
4 25 Percent Above Optimized	0.81	2.66	4.50
5 50 Percent Above Optimized	0.81	2.66	4.50
6 Total Costs Equal Total Benefits	0.81	2.66	4.50
7 Technology Exhaustion	0.81	2.65	4.49
Reduction in Global Mean Precipitation (%)			
2 25 Percent Below Optimized	0.00	0.00	0.00
3 Optimized	0.00	0.00	0.00
4 25 Percent Above Optimized	0.00	0.00	0.00
5 50 Percent Above Optimized	0.00	0.00	0.00
6 Total Costs Equal Total Benefits	0.00	0.00	0.00
7 Technology Exhaustion	0.00	0.01	0.02

a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

b/ The difference in the years displayed for the temperature and precipitation table is due to choosing a midpoint from ranges developed by the IPCC. *See* Table 3.4-6.

Climate: Impact on Sea-level Rise

Table 2.5-6 lists the impact on sea-level rise under the alternatives and shows sea-level rise in 2100 ranging from 37.1 centimeters (cm) under the No Action Alternative to 36.99 centimeters under the Technology Exhaustion Alternative, for a maximum reduction of 0.11 centimeter by 2100 from the CAFE alternatives for the Reference Case.

2.5.1.3.2 High Scenario

Comparing High Scenario Table 2.5-8 with Reference Case Table 2.5-5 shows that total emissions under the High Scenario were lower for all alternatives. Correspondingly, emissions reductions compared to the No Action Alternative were higher for all alternatives under the High Scenario. The primary reason for this difference is the higher mpg and lower VMT forecasted under the High Scenario.

Table 2.5-8

High Scenario Emissions and Emissions Reductions Due to the MY 2011-2015 CAFE Standards from 2010-2100 ($MMTCO_2$)

	Alternative	Emissions ($MMTCO_2$)	Emissions Reductions Compared to No Action Alternative ($MMTCO_2$)
1	No Action	195,501	0
2	25 Percent Below Optimized	182,890	12,611
3	Optimized	180,591	14,910
4	25 Percent Above Optimized	179,079	16,422
5	50 Percent Above Optimized	177,669	17,832
6	Total Costs Equal Total Benefits	176,736	18,765
7	Technology Exhaustion	170,829	24,672

Table 2.5-9 shows the resulting effects on CO_2 concentration, global mean surface temperature, and sea-level rise. Under the High Scenario, the resulting CO_2 concentration, global mean surface temperature, and sea-level rise were lower for all alternatives except the Technology Exhaustion Alternative (which were the same for both scenarios). Thus, the differences for the action alternatives compared to the No Action Alternative are greater for the High Scenario than the Reference Case.

2.5.2 Cumulative Effects

The CEQ identifies the impacts that must be addressed and considered by federal agencies in satisfying the requirements of NEPA. This includes permanent, temporary, indirect and cumulative impacts. CEQ regulations implementing the procedural provisions of NEPA define cumulative impacts as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions” (40 CFR 1508.7). The following sections describe the cumulative effects of the CAFE alternatives on energy, air quality, and climate.

2.5.2.1 Energy

2.5.2.1.1 Reference Case

Table 2.5-10 shows the cumulative fuel consumption of the fleet of passenger cars and light trucks under Alternative 1 (No Action) and the six alternative CAFE standards for the Reference Case. By 2060, when the entire fleet is likely to comprise MY 2011 or later cars, cumulative fuel consumption (from 2010) reaches 9.7 trillion gallons under the No Action Alternative. Cumulative consumption declines across the alternatives, from 8.8 trillion gallons under the Optimized Alternative (Alternative 3) to 7.4 trillion gallons under the Technology Exhaustion Alternative (Alternative 7), which represent cumulative savings of 2.3 trillion gallons relative to the Reference Case No Action Alternative.

Table 2.5-9

High Scenario 2011-2015 CAFE Alternatives Impact on CO_2 Concentration, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using the MAGICC Model (A1B a/)

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
	2030	2060	2100	2030	2060	2100	2030	2060	2100
1 No Action	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.4	573.2	716.1	0.873	1.942	2.954	7.99	19.28	37.06
3 Optimized	455.4	573.1	715.8	0.873	1.942	2.953	7.99	19.28	37.05
4 25 Percent Above Optimized	455.4	573.0	715.7	0.873	1.941	2.953	7.99	19.28	37.04
5 50 Percent Above Optimized	455.4	572.9	715.6	0.873	1.941	2.952	7.99	19.27	37.04
6 Total Costs Equal Total Benefits	455.3	572.9	715.5	0.873	1.940	2.951	7.99	19.27	37.03
7 Technology Exhaustion	455.3	572.6	714.9	0.872	1.938	2.948	7.99	19.26	37.00
Reduction from CAFE Alternatives									
2 25 Percent Below Optimized	0.1	0.5	1.1	0.001	0.002	0.005	0.00	0.02	0.04
3 Optimized	0.1	0.6	1.4	0.001	0.003	0.006	0.00	0.02	0.05
4 25 Percent Above Optimized	0.1	0.7	1.5	0.001	0.003	0.006	0.00	0.02	0.06
5 50 Percent Above Optimized	0.1	0.8	1.6	0.001	0.004	0.007	0.00	0.03	0.06
6 Total Costs Equal Total Benefits	0.2	0.8	1.7	0.001	0.004	0.008	0.00	0.03	0.07
7 Technology Exhaustion	0.2	1.1	2.3	0.002	0.006	0.011	0.00	0.04	0.10

a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Table 2.5-10

Reference Case Passenger Car and Light Trucks Cumulative Fuel Consumption and Cumulative Fuel Savings (billion gallons)

Calendar Year Range	Alternative CAFE Standards for Model Years 2011-2020						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized (Preferred)	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Passenger Cars and Light Trucks Cumulative Fuel Consumption							
2010-2020	1,601.3	1,583.2	1,581.8	1,579.5	1,577.7	1,574.5	1,510.9
2010-2030	3,229.6	3,083.6	3,076.0	3,063.1	3,051.9	3,038.5	2,786.4
2010-2040	5,092.6	4,731.3	4,714.0	4,684.5	4,658.6	4,630.4	4,125.8
2010-2050	7,245.2	6,620.1	6,591.1	6,541.1	6,497.2	6,451.1	5,647.9
2010-2060	9,733.2	8,800.2	8,757.5	8,683.5	8,618.6	8,551.6	7,401.6
Passenger Cars and Light Trucks Cumulative Fuel Savings							
2010-2020	--	18.1	19.5	21.8	23.6	26.7	90.3
2010-2030	--	146.0	153.7	166.5	177.7	191.1	443.2
2010-2040	--	361.3	378.6	408.1	434.0	462.2	966.8
2010-2050	--	625.1	654.1	704.1	748.0	794.1	1,597.2
2010-2060	--	933.1	975.7	1,049.8	1,114.6	1,181.6	2,331.7

2.5.2.1.2 High Scenario

In response to public comments, and to test how different economic assumptions could affect estimates of fuel consumption, NHTSA ran a series of scenarios (called the High, Mid-1 and Mid-2 Scenarios) using various economic input assumptions and compared the results to the Reference Case. Results from the High Scenario are presented in Table 2.5-11. The High Scenario assumes higher fuel prices than are assumed in the Reference Case, which results in lower fuel consumption across all of the CAFE alternatives examined. This is true even for the No Action Alternative (Alternative 1), because higher fuel prices in the High Scenario would reduce fuel consumption (relative to the Reference Case) even in the absence of any change in CAFE standards.

Table 2.5-11

High Scenario Passenger Car and Light Trucks Cumulative Fuel Consumption and Cumulative Fuel Savings (billion gallons)

Calendar Year Range	Alternative CAFE Standards for Model Years 2011-2020						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized (Preferred)	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Passenger Cars and Light Trucks Cumulative Fuel Consumption							
2010-2020	1,498.6	1,464.8	1,458.8	1,452.6	1,447.8	1,443.0	1,415.4
2010-2030	2,971.5	2,738.3	2,709.5	2,683.5	2,660.0	2,643.7	2,569.1
2010-2040	4,641.6	4,086.9	4,024.5	3,970.4	3,919.4	3,888.5	3,769.9
2010-2050	6,550.8	5,608.3	5,506.0	5,418.6	5,334.6	5,287.1	5,119.9
2010-2060	8,731.1	7,341.4	7,193.3	7,067.6	6,945.6	6,879.3	6,656.6
Passenger Cars and Light Trucks Cumulative Fuel Savings							
2010-2020	--	33.9	39.9	46.0	50.9	55.6	83.3
2010-2030	--	233.2	262.0	288.0	311.4	327.8	402.4
2010-2040	--	554.7	617.1	671.2	722.2	753.2	871.8
2010-2050	--	942.6	1,044.9	1,132.3	1,216.2	1,263.8	1,430.9
2010-2060	--	1,389.6	1,537.8	1,663.5	1,785.5	1,851.8	2,074.5

Table 2.5-11 shows the cumulative fuel consumption of the fleet of passenger cars and light trucks under the No Action Alternative and the six alternative CAFE standards in the High Scenario. By 2060, when the entire fleet is likely to comprise MY 2011 or later cars, cumulative fuel consumption (from 2010) reaches 8.7 trillion gallons under the No Action Alternative. Cumulative consumption declines across the alternatives from 7.2 trillion gallons under the Optimized Alternative (Alternative 3) to 6.7 trillion gallons under the Technology Exhaustion Alternative (Alternative 7), which represents cumulative savings of 2.1 trillion gallons relative to the High Scenario No Action Alternative.

2.5.2.2 Air Quality

2.5.2.2.1 Reference Case

Table 2.5-12 summarizes the cumulative national emissions of toxic and criteria pollutants in 2035, showing that the Reference Case No Action Alternative has the highest cumulative emissions of all the alternatives for all pollutants except CO, acetaldehyde, acrolein, and formaldehyde. Alternative 3 has the highest cumulative emissions of CO and acetaldehyde. Alternative 7 has the highest cumulative emissions of all the alternatives for acrolein and formaldehyde.

Table 2.5-12

Reference Case Alternative CAFE Standards Nationwide Criteria Pollutant Emissions and Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Criteria Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks							
Carbon monoxide (CO)	19,745,847	20,068,580	20,145,455	19,664,457	19,615,715	19,406,046	11,524,825
Nitrogen oxides (NO_x)	1,369,135	1,335,125	1,335,545	1,318,678	1,314,728	1,305,570	1,048,518
Particulate matter ($PM_{2.5}$)	99,707	95,588	95,468	94,650	94,333	94,305	89,788
Sulfur oxides (SO_x)	265,792	240,446	239,437	236,567	234,662	232,370	183,541
Volatile organic compounds (VOCs)	1,906,119	1,861,129	1,862,621	1,832,904	1,825,138	1,803,935	1,196,950
Toxic Air Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks							
Acetaldehyde	8,209	8,224	8,229	8,211	8,214	8,183	7,974
Acrolein	351	362	361	377	381	392	758
Benzene	47,515	47,256	47,364	46,405	46,251	45,791	29,613
1,3-butadiene	3,885	3,852	3,854	3,839	3,839	3,803	3,331
Diesel particulate matter (DPM)	119,499	105,773	105,131	104,372	103,457	102,999	94,643
Formaldehyde	13,035	12,717	12,677	12,899	12,924	12,961	17,034

Localized increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the CAFE standards alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of CAA standards. All of the action alternatives would reduce adverse health outcomes and health costs related to motor vehicle air pollution, and thus would have beneficial health effects that would not need mitigation.

2.5.2.2.2 High Scenario

Table 2.5-13 summarizes the national criteria and air toxic pollutant emissions in 2035 for the seven alternatives for the High Scenario. For the High Scenario, emissions with the action alternatives are generally lower than for the Reference Case. Localized increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the CAFE standards alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of CAA standards. All of the action alternatives would reduce adverse health outcomes and health costs related to motor vehicle air pollution, and thus would have beneficial health effects that would not need mitigation.

Table 2.5-13

High Scenario Alternative CAFE Standards Nationwide Criteria Pollutant Emissions and Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Criteria Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks							
Carbon monoxide (CO)	17,713,991	17,102,067	17,249,166	16,551,203	16,107,699	15,482,276	10,338,916
Nitrogen oxides (NO_x)	1,228,251	1,147,887	1,145,748	1,120,053	1,102,988	1,082,932	940,625
Particulate matter ($PM_{2.5}$)	89,447	83,017	82,423	82,542	81,642	81,247	80,549
Sulfur oxides (SO_x)	238,442	198,158	194,471	189,553	185,397	182,149	164,654
Volatile organic compounds (VOCs)	1,709,979	1,575,147	1,574,616	1,518,089	1,486,823	1,440,609	1,073,784
Toxic Air Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks							
Acetaldehyde	7,364	7,351	7,372	7,282	7,278	7,255	7,153
Acrolein	315	374	374	406	424	450	680
Benzene	42,626	40,169	40,301	38,917	37,990	36,721	26,566
1,3-butadiene	3,885	3,833	3,846	3,810	3,766	3,713	3,331
Diesel particulate matter (DPM)	107,203	87,624	85,380	85,166	83,729	83,295	84,904
Formaldehyde	11,694	11,783	11,730	11,897	12,127	12,433	15,281

2.5.2.3 Climate

2.5.2.3.1 Reference Case

GHG Emissions

Total emissions reductions from 2010-2100 new passenger cars and light trucks for each of the seven alternatives for the Reference Case are shown in Table 2.5-14. Projections of emissions reductions over the 2010 to 2100 timeframe due to the MY 2011-2020 CAFE standards ranged from 24,321 to 49,157 $MMTCO_2$. Compared against global emissions of 4,850,000 $MMTCO_2$ over this period (projected by the IPCC A1B-medium scenario), the incremental impact of this rulemaking is expected to reduce global CO_2 emissions by about 0.5 to 1.0 percent.

Climate: CO_2 Concentration and Global Mean Surface Temperature

The mid-range results of MAGICC model simulations for the No Action Alternative and the six alternative CAFE levels, in terms of CO_2 concentrations and increase in global mean surface temperature in 2030, 2060, and 2100 are presented in Table 2.5-15 and Figures 2.5-1 to 2.5-4. As Figures 2.5-1 and 2.5-2 show, the impact on the growth in CO_2 concentrations and temperature is just a fraction of the total growth in CO_2 concentrations and global mean surface temperature. However, the relative impact of the CAFE alternatives is illustrated by the reduction in growth of both CO_2 concentrations and temperature in the Technology Exhaustion Alternative, which is nearly double that of the 25 Percent Below Optimized Alternative, as shown in Figures 2.5-3 to 2.5-4.

Table 2.5-14

Reference Case Cumulative Emissions and Emissions Reductions Due to the MY 2011-2015 Standards and Potential MY 2016-2020 CAFE Standards Projected for 2010-2100 ($MMTCO_2$)

Alternative	Emissions ($MMTCO_2$)	Emissions Reductions Compared to No Action Alternative ($MMTCO_2$)
1 No Action	221,258	0
2 25 Percent Below Optimized	196,937	24,321
3 Optimized	195,816	25,442
4 25 Percent Above Optimized	194,057	27,201
5 50 Percent Above Optimized	192,478	28,780
6 Total Costs Equal Total Benefits	191,073	30,185
7 Technology Exhaustion	172,101	49,157

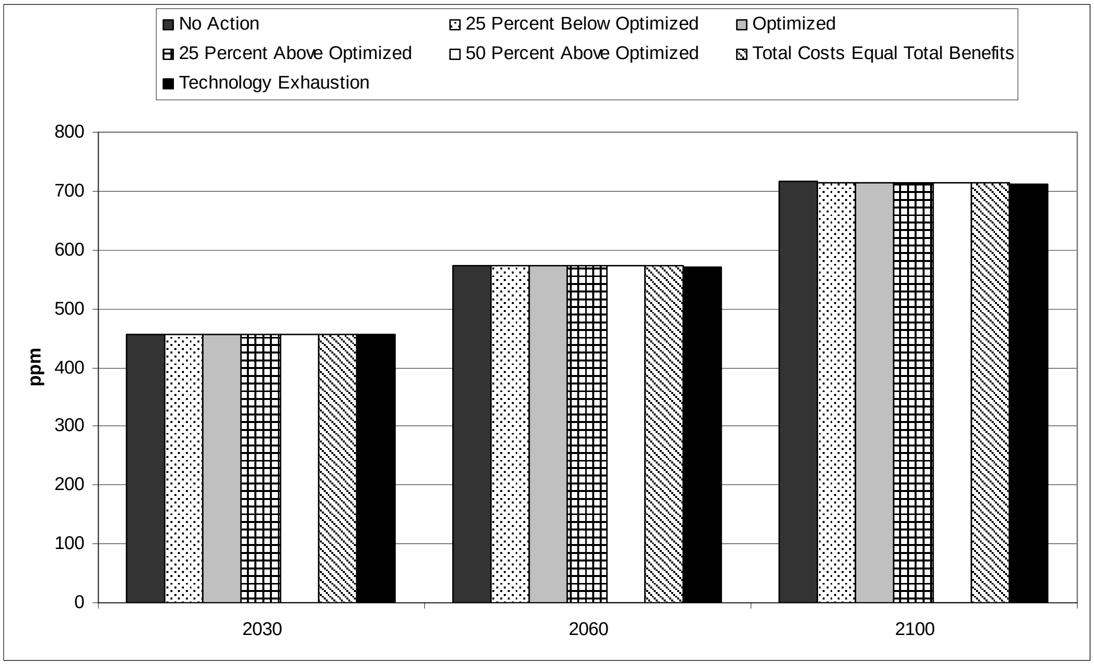
Table 2.5-15

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 CAFE Standards Cumulative Impact on CO_2 Concentration, Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC (A1B a/)

	CO_2 Concentration (ppm)			Surface Temperature Increase (°C)			Sea-level Rise (cm)		
	2030	2060	2100	2030	2060	2100	2030	2060	2100
Totals by Alternative									
1 No Action	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.4	572.7	714.9	0.873	1.940	2.950	7.99	19.27	37.02
3 Optimized	455.4	572.7	714.8	0.873	1.940	2.950	7.99	19.27	37.02
4 25 Percent Above Optimized	455.3	572.6	714.7	0.873	1.940	2.949	7.99	19.27	37.01
5 50 Percent Above Optimized	455.3	572.5	714.5	0.873	1.940	2.948	7.99	19.27	37.01
6 Total Costs Equal Total Benefits	455.3	572.5	714.4	0.873	1.939	2.948	7.99	19.26	37.00
7 Technology Exhaustion	455.1	571.7	712.6	0.871	1.934	2.938	7.99	19.23	36.92
Reduction from CAFE Alternatives									
2 25 Percent Below Optimized	0.1	1.0	2.3	0.001	0.004	0.009	0.00	0.03	0.08
3 Optimized	0.1	1.0	2.4	0.001	0.004	0.009	0.00	0.03	0.08
4 25 Percent Above Optimized	0.2	1.1	2.5	0.001	0.005	0.010	0.00	0.03	0.09
5 50 Percent Above Optimized	0.2	1.2	2.7	0.001	0.005	0.011	0.00	0.03	0.09
6 Total Costs Equal Total Benefits	0.2	1.2	2.8	0.001	0.005	0.011	0.00	0.04	0.10
7 Technology Exhaustion	0.4	2.0	4.6	0.002	0.010	0.020	0.00	0.07	0.18

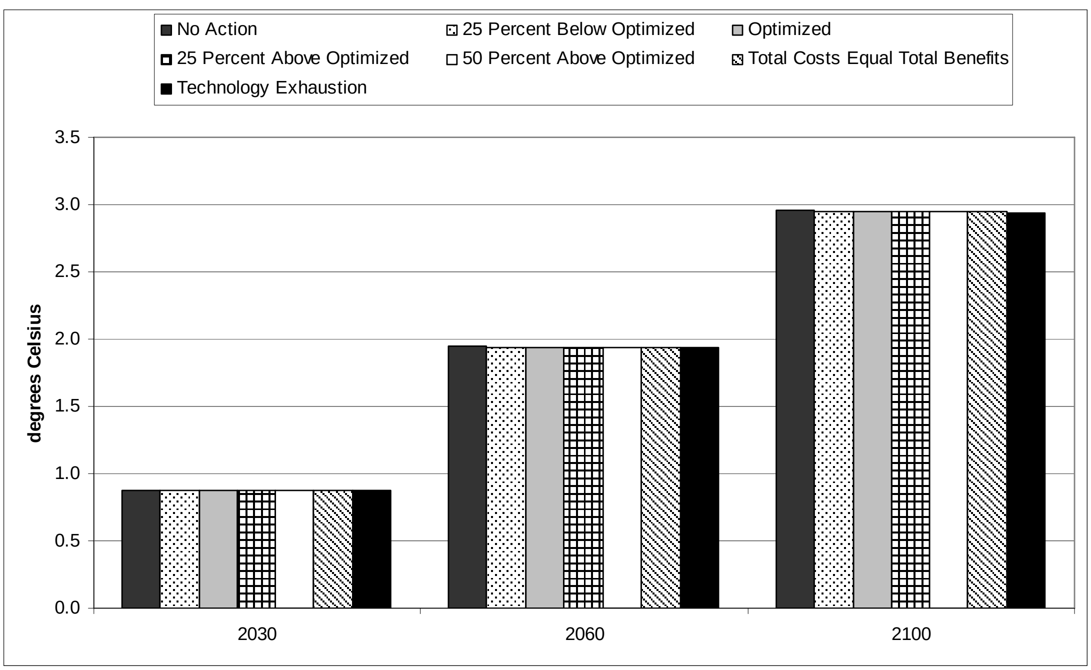
a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 2.5-1. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on CO_2 Concentrations Using the MAGICC Model (A1B a/)



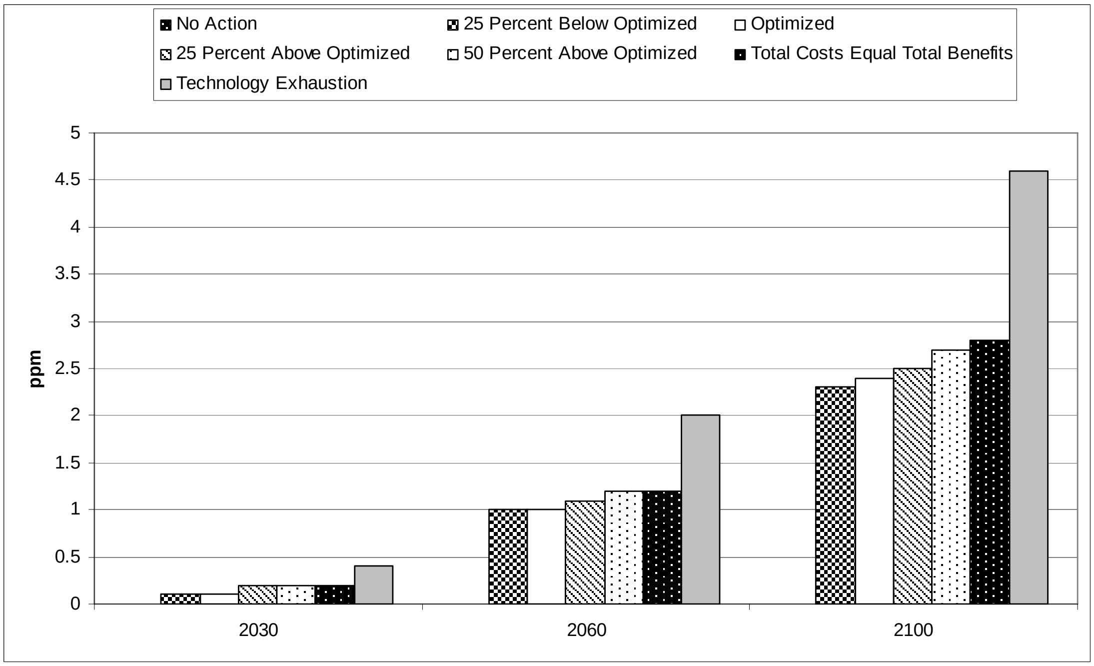
a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 2.5-2. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on the Increase in Global Mean Surface Temperature Using MAGICC (A1B a/)



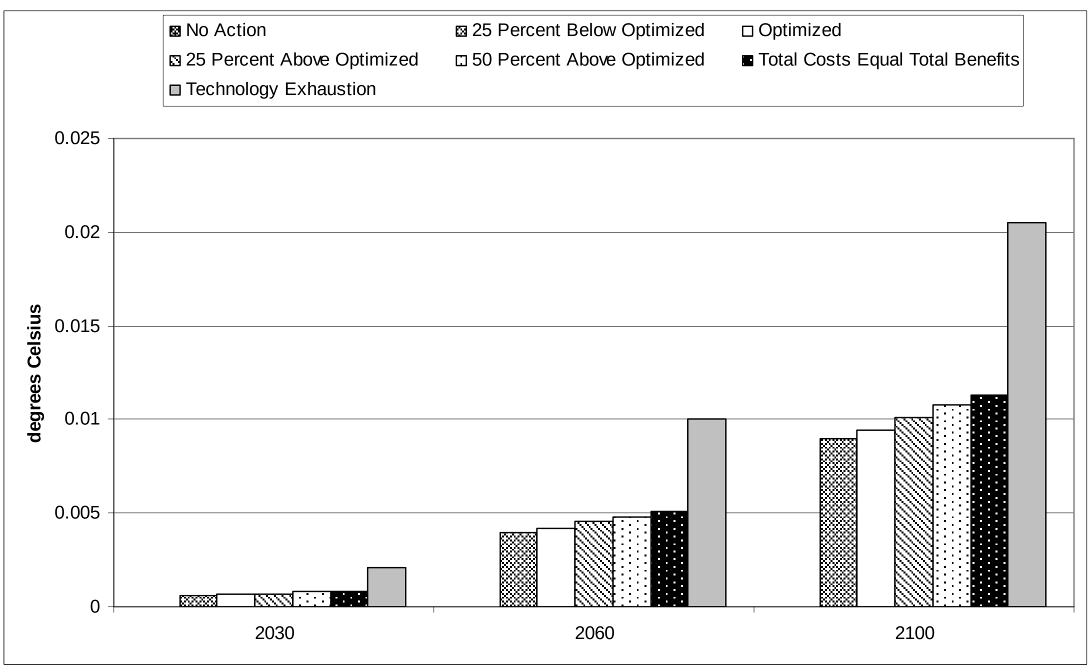
a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 2.5-3. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on the Reduction in the Growth of CO_2 Concentrations Using MAGICC (A1B a/)



a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 2.5-4. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on the Reduction in the Growth of Global Mean Temperature Using MAGICC (A1B a/)



a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

As shown in Table 2.5-15 and Figures 2.5-1 through 2.5-4, there is a fairly narrow band of estimated CO_2 concentrations as of 2100, from 712.6 ppm for the Technology Exhaustion Alternative to 717.2 ppm for the No Action Alternative. As CO_2 concentrations are the key driver of all the other climate effects, this narrow range implies that the differences among alternatives are difficult to distinguish. The MAGICC simulations of mean global surface air temperature increases are also shown below in Table 2.5-15. For all alternatives, the temperature increase is about 0.9 °C as of 2030, 1.9 °C as of 2060, and 2.9 °C as of 2100. The differences among alternatives are small. As of 2100, the reduction in temperature increase, with respect to the No Action Alternative, ranges from 0.009 °C to 0.02 °C. These estimates include considerable uncertainty due to a number of factors of which the climate sensitivity is the most important. The IPCC Fourth Assessment Report estimates a range of the climate sensitivity from 2.5 to 4.0 °C with a mid-point of 3.0 °C which directly relates to the uncertainty in the estimated global mean surface temperature.

Climate: Global Mean Rainfall and Global Mean Surface Temperature

The CAFE action alternatives for the Reference Case reduce temperature increases slightly with respect to the No Action Alternative. Thus, they also reduce predicted increases in precipitation slightly, as shown in Table 2.5-16. As shown in the Table 2.5-16 and Figures 2.5-1 through 2.5-4, there is a fairly narrow band of estimated precipitation increase reductions as of 2100, from 4.48 percent to 4.51 percent, and there is very little difference between the alternatives.

Table 2.5-16

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 CAFE Standards: Cumulative Impact on Reductions in Global Mean Precipitation Based on A1B a/ SRES Scenario, Using Increases in Global Mean Surface Temperature Simulated by MAGICC

Scenario	2020	2055	2090 b/
Global Mean Precipitation Change	1.45	1.51	1.63
Global Temperature above average 1980-1999 levels (°C) for the A1B scenario and CAFE Alternatives, mid-level results			
1 No Action	0.560	1.764	2.765
2 25 Percent Below Optimized	0.560	1.759	2.753
3 Optimized	0.560	1.758	2.752
4 25 Percent Above Optimized	0.560	1.758	2.751
5 50 Percent Above Optimized	0.560	1.757	2.750
6 Total Costs Equal Total Benefits	0.560	1.757	2.750
7 Technology Exhaustion	0.559	1.756	2.749
Reduction in Global Temperature (°C) for CAFE Alternatives, mid-level results (compared to No Action Alternative)			
2 25 Percent Below Optimized	0.000	0.005	0.011
3 Optimized	0.000	0.006	0.013
4 25 Percent Above Optimized	0.000	0.006	0.014
5 50 Percent Above Optimized	0.000	0.007	0.015
6 Total Costs Equal Total Benefits	0.000	0.007	0.015
7 Technology Exhaustion	0.000	0.008	0.016

Table 2.5-16 (cont'd)

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 CAFE Standards: Cumulative Impact on Reductions in Global Mean Precipitation Based on A1B a/ SRES Scenario, Using Increases in Global Mean Surface Temperature Simulated by MAGICC

Scenario	2020	2055	2090 b/
Mid Level Global Mean Precipitation Change (%)			
1 No Action	0.81	2.66	4.51
2 25 Percent Below Optimized	0.81	2.66	4.49
3 Optimized	0.81	2.65	4.49
4 25 Percent Above Optimized	0.81	2.65	4.48
5 50 Percent Above Optimized	0.81	2.65	4.48
6 Total Costs Equal Total Benefits	0.81	2.65	4.48
7 Technology Exhaustion	0.81	2.65	4.48
Reduction in Global Mean Precipitation Change for CAFE Alternatives (% compared to No Alternative Action)			
2 25 Percent Below Optimized	0.00	0.01	0.02
3 Optimized	0.00	0.01	0.02
4 25 Percent Above Optimized	0.00	0.01	0.02
5 50 Percent Above Optimized	0.00	0.01	0.02
6 Total Costs Equal Total Benefits	0.00	0.01	0.02
7 Technology Exhaustion	0.00	0.01	0.03

a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.
b/ The difference in the years displayed for precipitation is due to choosing a mid-point from ranges developed by the IPCC

Climate: Impact on Sea-level Rise

The impact on sea-level rise from the CAFE Standards alternatives is presented in Table 2.5-18, showing sea-level rise in 2100 ranging from 37.10 cm in Alternative 1 (No Action) to 36.94 cm in the Technology Exhaustion Alternative, for a maximum reduction of 0.16 cm by 2100 from the CAFE alternatives for the Reference Case.

2.5.2.3.2 High Scenario

The results for the High Scenario are presented in Tables 2.5-17 and 2.5-18. Comparing High Scenario Table 2.5-17 with Reference Case Table 2.5-14 shows that total emissions under the High Scenario were lower for all alternatives except the Technology Exhaustion Alternative (which was the same for both scenarios). Correspondingly, emissions reductions compared to the No Action Alternative were higher for all alternatives under the High Scenario except the Technology Exhaustion Alternative (which was the same for both scenarios). The primary reason for this difference is the higher mpg and lower VMT forecasted under the High Scenario.

Table 2.5-17

High Scenario Alternative CAFE Standards Cumulative Emissions and Emissions Reductions Due to the MY 2011-2015 Standards and Potential MY 2016-2020 Standards for 2010 through 2100 ($MMTCO_2$)

Alternative	Emissions ($MMTCO_2$)	Emissions Reductions Compared to No Action Alternative ($MMTCO_2$)
1 No Action	195,501	0
2 25 Percent Below Optimized	160,903	34,598
3 Optimized	157,088	38,413
4 25 Percent Above Optimized	154,618	40,884
5 50 Percent Above Optimized	151,781	43,721
6 Total Costs Equal Total Benefits	150,919	44,583
7 Technology Exhaustion	152,290	43,211

Table 2.5-18

High Scenario Alternative CAFE Standards MY 2011-2015 and Potential MY 2016-2020 Standards Cumulative Impact on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using the MAGICC Model (A1B a/)

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
	2030	2060	2100	2030	2060	2100	2030	2060	2100
1 No Action	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.3	572.3	714.0	0.873	1.938	2.946	7.99	19.26	36.99
3 Optimized	455.2	572.1	713.6	0.872	1.937	2.944	7.99	19.25	36.97
4 25 Percent Above Optimized	455.2	572.0	713.4	0.872	1.937	2.943	7.99	19.25	36.96
5 50 Percent Above Optimized	455.2	571.9	713.1	0.872	1.936	2.942	7.99	19.25	36.95
6 Total Costs Equal Total Benefits	455.2	571.9	713.0	0.872	1.936	2.942	7.99	19.24	36.95
7 Technology Exhaustion	455.2	571.9	713.1	0.872	1.935	2.941	7.99	19.24	36.94
Reduction from CAFE Alternatives									
2 25 Percent Below Optimized	0.2	1.4	3.2	0.001	0.006	0.013	0.00	0.04	0.11
3 Optimized	0.3	1.6	3.6	0.001	0.007	0.015	0.00	0.05	0.13
4 25 Percent Above Optimized	0.3	1.7	3.8	0.001	0.007	0.016	0.00	0.05	0.14
5 50 Percent Above Optimized	0.3	1.8	4.1	0.001	0.008	0.017	0.00	0.05	0.15
6 Total Costs Equal Total Benefits	0.3	1.8	4.2	0.002	0.008	0.017	0.00	0.06	0.15
7 Technology Exhaustion	0.3	1.8	4.1	0.002	0.009	0.018	0.00	0.06	0.16

a/ The IPCC A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Table 2.5-18 shows the resulting effects on CO_2 concentration, global mean surface temperature, and sea-level rise. Under the High Scenario, the resulting CO_2 concentration, global mean surface temperature, and sea-level rise were lower for all alternatives except the Technology Exhaustion Alternative (which were the same for both scenarios). Thus, the differences for the action alternatives compared to the No Action Alternative are greater for the High Scenario than the Reference Case.

2.5.3 Scenario Comparison

The data shown in Table 2.3-5, and graphed in Figure 2.5-5, show the required combined mpg standards for cars and light trucks associated with the seven alternatives across the Reference Case the three Input Scenarios. As noted above, the information provided in this FEIS, across alternatives for the Reference Case and the three Input Scenarios, is designed to allow the public and decisionmakers to evaluate environmental impacts for the entire range of feasible alternatives. Table 2.5-19 demonstrates the continuum of fuel savings and greenhouse gas reductions associated with the Optimized Alternatives of each Input Scenario. Table 2.5-20 compares energy and climate effect results for the alternatives of each Input Scenario.

Figure 2.5-5. MY 2015 Required MPG for Passenger Cars and Light Trucks by Alternative and Input Scenario

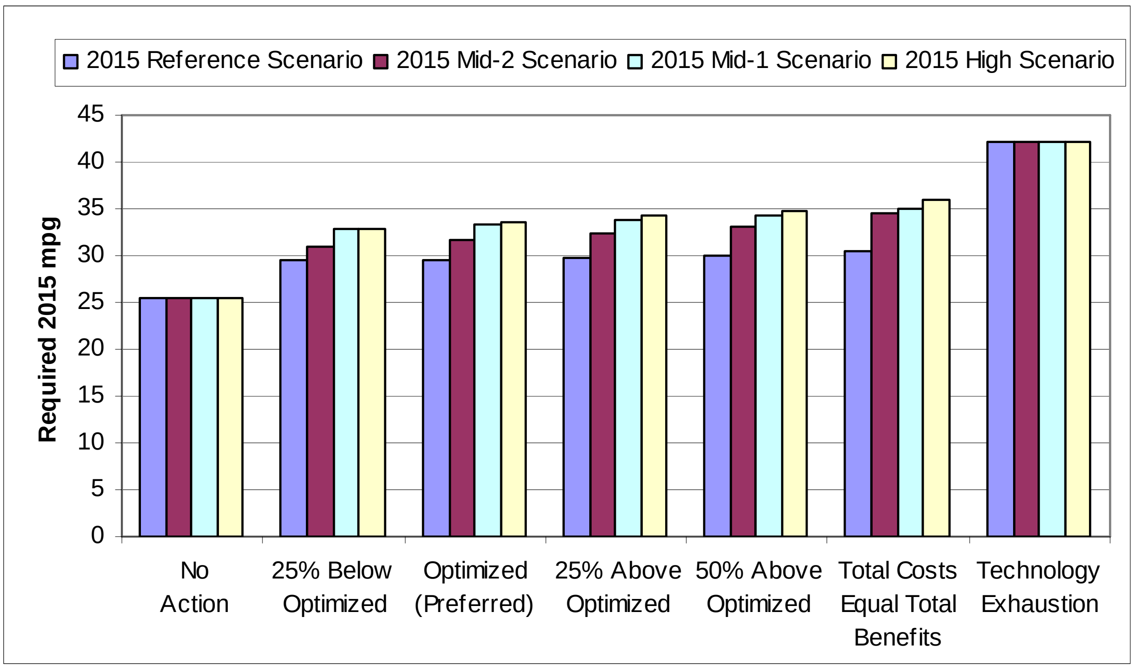


Table 2.5-19
Volpe Model Scenario Inputs and Outputs for Optimized Alternative

Input Scenario	Fuel Price	SCC	Oil Import Externalities (2007$/gallon)	Discount Rate	Cars (Baseline 27.5) 2015 (mpg)	Trucks (Baseline 23.5) 2015 (mpg)	Combined (Baseline 25.3) 2015 (mpg)	Fuel Savings 2010-2060 (billion gallons)	CO_2 Emission Reduction 2010-2100 (MMT) b/
1: Reference	$2.41	$2	$0.326	3% CO_2 – 7% Other	33.4	26.0	29.6	975.7	6,616
2: Mid-2	$3.33	$2	$0.382	3% CO_2 – 7% Other	37.1	27.1	31.8	1302.4	11,463
5: Mid-1	$3.33	$33	$0.116	3% CO_2 – 7% Other	37.2	29.6	33.3	1490.9	13,992
9: High	$3.33	$33	$0.116	3% CO_2 – 3% Other	37.7	29.6	33.6	1537.8	14,910

Table 2.5-20

Volpe Model Scenario Inputs and Outputs for Optimized Alternative

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Combined 2015 (mpg)							
Reference Case	25.5	29.4	29.6	29.8	30.0	30.4	42.0
Mid-2 Scenario	25.5	31.1	31.8	32.5	33.2	34.6	42.0
Mid-1 Scenario	25.5	32.9	33.3	33.8	34.2	35.0	42.0
High Scenario	25.5	32.9	33.6	34.2	34.8	36.0	42.0
Fuel Use (billion gallons)							
Reference Case	151.8	149.4	149.2	148.7	148.4	147.8	134.9
Mid-2 Scenario	139.1	134.5	133.8	132.9	132.2	130.8	123.7
Mid-1 Scenario	139.1	133.6	133.0	132.3	131.7	130.4	123.7
High Scenario	139.1	133.4	132.4	131.4	130.5	129.6	123.7
CO_2 Emissions (MMT)							
Reference Case	221,258	215,337	214,643	214,144	213,254	212,345	193,212
Mid-2 Scenario	195,501	185,761	184,038	182,281	180,886	178,093	170,829
Mid-1 Scenario	195,501	182,893	181,509	180,401	179,464	177,743	170,829
High Scenario	195,501	182,890	180,591	179,079	177,669	176,736	170,829
Sea-level Rise (cm)							
Reference Case	37.10	37.08	37.08	37.08	37.08	37.07	36.99
Mid-2 Scenario	37.10	37.07	37.06	37.06	37.05	37.04	37.00
Mid-1 Scenario	37.10	37.06	37.05	37.05	37.05	37.04	37.00
High Scenario	37.10	37.06	37.05	37.04	37.04	37.03	37.00
Mean Global Temperature Increase (Degrees C)							
Reference Case	2.959	2.957	2.956	2.956	2.956	2.956	2.946
Mid-2 Scenario	2.959	2.955	2.955	2.954	2.953	2.952	2.948
Mid-1 Scenario	2.959	2.954	2.954	2.953	2.953	2.952	2.948
High Scenario	2.959	2.954	2.953	2.953	2.952	2.951	2.948

Chapter 3 Affected Environment and Environmental Consequences

3.1 INTRODUCTION

Council on Environmental Quality (CEQ) regulations for implementing the procedural provisions of the National Environmental Policy Act (NEPA) suggest a standard format for an environmental impact statement (EIS) that includes a section on affected environment and a section on environmental consequences. In this Final EIS (FEIS), the National Highway Traffic Safety Administration (NHTSA) addresses affected environment and potential environmental consequences of the proposed action and alternatives in sections under the heading for each resource area – energy (Section 3.2), air quality (Section 3.3), climate (Section 3.4), and various other potentially affected resource areas (Section 3.5). This structure enables the reader to readily learn about existing environmental conditions and potential environmental consequences related to each resource area.

The table below lists topics in a typical NEPA analysis and the section(s) in this chapter that address each topic.

Typical NEPA Topics	FEIS Sections
Water	3.4 Climate; 3.5.1 Water Resources
Ecosystems	3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources
Threatened and endangered species	3.5.2.1.4 Endangered Species
Publicly owned parklands, recreational areas, wildlife and waterfowl refuges, historic sites, Section 4(f)-related issues	3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development; 3.5.6 Land Uses Protected under Section 4(f); 3.5.7 Historic and Cultural Resources
Properties and sites of historic and cultural significance	3.4 Climate; 3.5.3 Land Use and Development; 3.5.6 Land Uses Protected under Section 4(f); 3.5.7 Historic and Cultural Resources
Considerations relating to pedestrians and bicyclists	3.4 Climate; 3.5.3 Land Use and Development
Social impacts	3.2 Energy; 3.4 Climate; 3.5.3 Land Use and Development; 3.5.9 Environmental Justice
Noise	3.4 Climate; 3.5.3 Land Use and Development; 3.5.8 Noise
Air	3.2 Energy; 3.3 Air Quality; 3.4 Climate
Energy supply and natural resource development	3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development
Floodplain management evaluation	3.4 Climate; 3.5.1 Water Resources
Wetlands and coastal zones	3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources
Construction impacts	3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development
Land use and urban growth	3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development
Human environment involving community disruption and relocation	3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.3 Land Use and Development; 3.5.4 Safety and Other Human Health Impacts; 3.5.5 Hazardous Materials and Regulated Wastes; 3.5.9 Environmental Justice

3.1.1 Direct and Indirect Impacts

CEQ regulations state that an EIS "shall succinctly describe" the environment to be affected by the alternatives under consideration and to provide data and analyses "commensurate with the importance of the impact[s]." 40 Code of Federal Regulations (CFR) §§ 1502.15, 1502.16. This chapter provides the analysis to determine and compare the significance of the direct and indirect effects of the proposed action and alternatives. Under NEPA, direct effects "are caused by the action and occur at the same time and place." 40 CFR §1508.8. CEQ regulations define indirect effects as those that "are caused by the action and are later in time or farther removed in distance but are still reasonably foreseeable. Indirect effects may include … effects on air and water and other natural systems, including ecosystems." 40 CFR §1508.8. Sections 3.2, 3.3, and 3.4 provide a quantitative analysis of the direct and indirect effects of the proposed action on energy, air, and climate, respectively. Impacts to other resource areas typically addressed in an EIS and the areas required by U.S. Department of Transportation (DOT) Order 5610, such as biological resources, water resources, noise, land use, and environmental justice, are described qualitatively in Section 3.5, because there were not enough data available in the literature for a quantitative analysis and because many of these effects are not localized. In this FEIS, such qualitative analysis is sufficient for NEPA purposes (DOT 1979).

3.1.2 Areas Not Affected

DOT's NEPA procedures[1] describe various areas that should be considered in an EIS. Many of these areas are covered in the sections below. NHTSA has considered the impact of the proposed action alternatives to all areas outlined by the procedures and has determined the following would not be directly or indirectly affected by the proposed action: human environment, including disruption and relocation, and considerations relating to pedestrians and bicyclists; floodplain management; and construction impacts. However, some of these areas could be affected by the cumulative impacts of the proposed action in combination with other foreseeable actions (*see* Chapter 4).

3.1.3 Approach to Scientific Uncertainty and Incomplete Information

3.1.3.1 CEQ Regulations

CEQ regulations recognize that many federal agencies encounter limited information and substantial uncertainties when analyzing the potential environmental impacts of their actions under NEPA. Accordingly, the regulations provide agencies with a means of formally acknowledging incomplete or unavailable information in NEPA documents. Where "information relevant to reasonably foreseeable significant adverse impacts cannot be obtained because the overall costs of obtaining it are exorbitant or the means to obtain it are not known," the regulations (40 CFR § 1502.22(b)) require an agency to include in its NEPA document:

1. A statement that such information is incomplete or unavailable

2. A statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment

[1] *See* 42 United States Code (U.S.C.) § 4332 (requiring federal agencies to "identify and develop methods and procedures … which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ 1984 (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

3. A summary of existing credible scientific evidence relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment

4. The agency's evaluation of such impacts based on theoretical approaches or research methods generally accepted in the scientific community

Relying on these provisions is appropriate when an agency is performing a NEPA analysis that involves potential environmental impacts due to carbon dioxide (CO_2) emissions. *See*, for example, *Mayo Found. v. Surface Transp. Bd.*, 472 F.3d 545, 555 (8th Cir. 2006). CEQ regulations also authorize agencies to incorporate material into a NEPA document by reference to "cut down on bulk without impeding agency and public review of the action" (40 CFR § 1502.21).

Throughout this FEIS, NHTSA uses these two mechanisms – acknowledging incomplete or unavailable information and incorporation by reference – to address areas for which NHTSA cannot develop a credible estimate of the potential environmental impacts of the proposed action or alternatives. In particular, NHTSA recognizes that information about the potential environmental impacts of changes in emissions of CO_2 and other greenhouse gases (GHGs) and associated changes in temperature, including those expected to result from the proposed rule, is incomplete. NHTSA often relies on the Intergovernmental Panel on Climate Change (IPCC) 2007 Fourth Assessment Report as a recent "summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment" (40 CFR § 1502.22(b)(3)).

3.1.3.2 Uncertainty with the IPCC Framework

The IPCC reports communicate uncertainty and confidence bounds using descriptive words in italics, such as *likely* and *very likely*, to represent levels of confidence in conclusions. This convention is briefly explained in the IPCC Fourth Assessment Synthesis Report and the IPCC Fourth Assessment Report Summary for Policymakers (IPCC 2007d, IPCC 2007c). A more detailed discussion of the IPCC treatment of uncertainty can be found in the IPCC Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties (IPCC 2005).

This FEIS uses the IPCC uncertainty language (always noted in italics) throughout Chapters 3 and 4 when discussing qualitative environmental impacts to certain resources. The reader should refer to the referenced IPCC documents above to gain a full understanding of the meaning of those uncertainty terms, because they might be used differently than similar language describing uncertainty in the FEIS, as required by the CEQ regulations described in Section 3.1.3.1.

3.1.4 Common Methodologies

The Corporate Average Fuel Economy (CAFE) Compliance and Effects Modeling System (referred to herein as the Volpe model) is a peer-reviewed modeling system developed by the DOT Volpe National Transportation Systems Center (Volpe Center). The Volpe model serves two fundamental purposes: (1) to identify technologies each manufacturer could apply to comply with a specified set of CAFE standards and (2) to calculate the costs and effects of manufacturers' application of technologies – including changes in fuel use and, therefore, CO_2 emissions. The Volpe model provides data that were used to analyze energy, air, and climate impacts.

The Volpe model begins with an initial state of the domestic vehicle market, which in this case is the market for passenger cars and light trucks to be sold during the period covered by the proposed rule. The vehicle market is defined on a model-by-model, engine-by-engine, and transmission-by-transmission basis, such that each defined vehicle model refers to a separately defined engine and a separately defined transmission.

For the model years covered by the current proposal, the light vehicle (passenger car and light truck) market forecast includes more than 3,000 vehicle models, more than 400 specific engines, and nearly 400 specific transmissions. This level of detail in the representation of the vehicle market is vital to an accurate analysis of manufacturer-specific costs and the analysis of reformed CAFE standards, and is much greater than the level of detail used by many other models and analyses relevant to light vehicle fuel economy.[2]

The Volpe model also uses several additional categories of data and estimates provided in various external input files for all vehicle categories (small, mid-size, and large sport utility vehicles [SUVs]; small and large pickups; minivans; sub-compact, compact, midsize, and large cars) including:

- Fuel-saving technology characteristics
  - Commercialization year
  - Effectiveness and cost
  - "Learning effect" cost coefficients
  - "Technology path" inclusion/exclusion
  - "Phase-in caps" on penetration rates
  - "Synergy" options
- Vehicular emissions rates, carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NO_x), particulate matter (PM), and sulfur dioxide (SO_2) for vehicular travel (that is, vehicle miles traveled [VMT])
- Economic and other data and estimates
  - Vehicle survival (percent of vehicles of a given vintage that remain in service)
  - Mileage accumulation (annual travel by vehicles of a given vintage)
  - Price/fuel taxation rates for seven fuels (such as gasoline and diesel)
  - Pump prices (including taxes) for vehicle fuel savings/retail price
  - Rebound effect coefficient (the elasticity of VMT in relation to per-mile cost of fuel)
  - Discount rate; "payback period" (the number of years purchasers consider when taking into account fuel savings)
  - Fuel economy "gap" (for example, laboratory versus actual)
  - Per-vehicle value of travel time (in dollars per hour)
  - The economic costs (in dollars per gallon) of petroleum consumption
  - Various external costs (all in dollars per mile) associated with changes in vehicle use

[2] Because CAFE standards apply to the average performance of each manufacturer's fleet of cars and light trucks, the impact of potential standards on individual manufacturers cannot be credibly estimated without analysis of manufacturers' planned fleets. Furthermore, because required CAFE levels under an attribute-based CAFE standard depend on manufacturers' fleet composition, the stringency of an attribute-based standard cannot be predicted without performing analysis at this level of detail.

- Damage costs (all on a dollar-per-ton basis) for each of the above-mentioned criteria pollutants
- The civil-penalties rate for noncompliance

- Properties of different fuels
  - Upstream CO_2 and criteria pollutant emissions rates (that is, U.S. emissions resulting from the production and distribution of each fuel)
  - Density (pounds per gallon); energy density (British thermal unit [BTU] per gallon)
  - Carbon content
  - Shares of fuel savings leading to reduced domestic refining
  - Relative shares of different gasoline blends

- Sensitivity analysis coefficients; high and low fuel price forecasts

- CAFE scenarios
  - Baseline (no action or business-as-usual)
  - Alternative scenarios defining coverage, structure, and stringency of CAFE standards

With all of the above input data and estimates, the modeling system develops an estimate of a set of technologies each manufacturer could apply in response to each specified CAFE scenario alternative.

The modeling system begins with the "initial state" (baseline) of each manufacturer's future vehicles and accumulates the estimated costs of progressive additions of fuel-saving technologies. Within a set of specified constraints, the system adds technologies following a cost-minimizing approach. At each step, the system evaluates the effective cost of applying available technologies to individual vehicle models, engines, or transmissions, and selects the application of technology that produces the lowest effective cost. The effective cost estimated to be considered by the manufacturer is calculated by adding the total incurred technology costs (in retail price equivalent [RPE]), subtracting the reduction in civil penalties owed for noncompliance with the CAFE standard, subtracting the estimated value of the reduction in fuel costs, and dividing the result by the number of affected vehicles.

In representing manufacturer decisions in response to a given CAFE standard, the modeling system accounts for the fact that, historically, some manufacturers have not been willing to pay penalties and some have. Thus, the system applies technologies until any of the following conditions are met: the manufacturer no longer owes civil penalties for failing to meet the applicable standard, the manufacturer has exhausted technologies expected to be available in that model year, or the manufacturer is estimated to be willing to pay civil penalties, and doing so is estimated to be less expensive than continuing to add technologies.

The system then progresses to the next model year (if included in the vehicle market and scenario input files), "carrying over" technologies where vehicle models are projected to be succeeded by other vehicle models. The Volpe model does not attempt to account for CAFE credits or intentional over-compliance (that is, achieving an average fuel economy higher than that required by law), or the "pull ahead" application of technologies.[3]

[3] Manufacturers might "pull ahead" the implementation of some technologies in response to CAFE standards that they know will be steadily increasing over time. For example, if a manufacturer plans to redesign many vehicles in

The Volpe model completes this compliance simulation for all manufacturers and all model years and produces various outputs from the effects of changes in fuel economy. The outputs include:

- Total cost (TC) of all applied technologies
- Year-by-year mileage accumulation – including the rebound effect
- Year-by-year fuel consumption
- CO_2 and criteria pollutants – domestic full fuel-cycle emissions,[4] monetary damages
- Total discounted/undiscounted national societal costs of year-to-year fuel consumption
- Additional travel – consumer surplus[5]
- Economic externalities – congestion, accidents, noise
- Value of time saved
- Total discounted/undiscounted societal benefits – including net social benefits and benefit-cost ratio (EIA 2008a)

The specific outputs associated with each alternative examined in this FEIS reflect the estimated values for key inputs into the Volpe model. The outputs of the Volpe model provide data used to analyze energy, air, and climate impacts, so these environmental impacts also reflect the inputs into the Volpe model. NHTSA acknowledges that appropriate model input values are subject to uncertainty and debate. In this FEIS, NHTSA addresses uncertainty by explicitly presenting analytical results for Reference Case model inputs, high case (High Scenario) model inputs, and several other scenarios with model inputs (such as fuel prices) and outputs (such as required miles per gallon) that fall between those in the Reference Case and High Scenarios. Table 2.5-19 in this FEIS shows how variations in key Volpe model input values affect Volpe model outputs (vehicle miles, miles per gallon [mpg], fuel consumption, and carbon emissions) across the range of input scenarios for the Optimized Alternative. For discussions of model inputs chosen for the various scenarios, refer to Chapter 10 of this FEIS.

Sections 3.3.3.2 through 3.3.4.9 describe the analysis of alternatives for the Reference Case model inputs (Sections 3.3.3.2 through 3.3.3.8) and then describe the impacts for the same alternatives under the High Scenario and two other scenarios – Mid-1 and Mid-2 – that have Volpe model inputs and outputs that fall between those of the Reference Case and High Scenario (Sections 3.3.4.2 through 3.3.4.9). This analytical structure is designed to fully inform the public and decisionmakers about the potential environmental impacts of any combination of economic inputs into the Volpe model, across the range of feasible alternatives.

model year (MY) 2011 and not in MY 2013, but the standard for MY 2013 is considerably higher than that for MY 2011, the manufacturer might find it less expensive during MY 2011 through MY 2013 (taken together) to apply more technology in MY 2011 than is necessary for compliance with the MY 2011 standard.

[4] Domestic full fuel-cycle emissions include the emissions associated with production, transportation, and refining operations, and the CO_2 emissions from fuel combustion.

[5] Consumer surplus measures the net benefits that drivers receive from additional travel and refers to the amount by which the benefits from additional travel exceed its costs (for fuel and other operating expenses).

3.2 ENERGY

Over the past decade and a half, energy intensity in the United States (energy use per dollar of gross domestic product [GDP]) has declined at about 2 percent per year (EIA 2008a). Despite the growth in population and the economy, energy intensity has fallen due to a combination of increased efficiency and a structural shift in the economy to less energy-intensive industries. Nevertheless, transportation fuel consumption has grown steadily and is the major component of the use of petroleum.

3.2.1 Affected Environment

Table 3.2-1 shows U.S. and global energy consumption by sector from the Energy Information Administration (EIA), which collects and provides the official energy statistics for the United States and whose data are the primary source for analysis and modeling of energy systems by government and private entities. Actual-consumption data show a steady increase in the United States in most of the sectors, particularly the transportation sector. By 2004, transportation was the second highest consumer of energy after industrial and comprised 27.8 and 17.3 percent of the U.S. and global (less U.S.) energy use, respectively.

Table 3.2-1

Energy Consumption By Sector

Sector (Quadrillion Btu)	Actual a/				Forecast b/				
	1990	1995	2000	2004	2010	2015	2020	2025	2030
United States									
Residential	17.0	18.6	20.5	21.2	22.2	22.6	23.4	24.2	25.0
Commercial	13.3	14.7	17.2	17.7	18.7	20.3	22.0	23.5	25.0
Industrial	31.9	34.0	34.8	33.6	33.3	33.9	34.3	34.9	35.0
Transportation	22.4	23.8	26.6	27.9	29.0	30.4	31.2	31.9	33.0
Total	84.7	91.2	99.0	100.4	103.3	107.3	110.8	114.5	118.0
Transportation (%)	26.5	26.2	26.8	27.8	28.1	28.4	28.2	27.9	28.0
World									
Residential	- -	- -	- -	47.7	53.9	59.0	62.7	65.8	69.0
Commercial	- -	- -	- -	24.5	28.3	31.7	34.6	37.5	40.7
Industrial	- -	- -	- -	163.6	183.1	201.4	220.5	238.1	257.1
Transportation	- -	- -	- -	87.7	97.5	106.3	115.4	125.3	136.5
Total	347.4	365.0	398.1	446.7	511.1	559.4	607.0	653.7	701.6
Transportation (%)	- -	- -	- -	19.6	19.1	19.0	19.0	19.2	19.5
International (World less United States)									
Residential	- -	- -	- -	26.5	31.7	36.4	39.3	41.6	44.0
Commercial	- -	- -	- -	6.8	9.6	11.4	12.6	14.0	15.7
Industrial	- -	- -	- -	130.0	149.8	167.5	186.2	203.2	222.1
Transportation	- -	- -	- -	59.8	68.5	75.9	84.2	93.4	103.5
Total	262.8	273.9	299.2	346.3	407.8	452.1	496.2	539.2	583.6
Transportation (%)	- -	- -	- -	17.3	16.8	16.8	17.0	17.3	17.7

a/ **Actual United States data**: Annual Energy Review (AER) 2006, http://www.eia.doe.gov/aer/pdf/pages/sec2_4.pdf
Actual World data: International Energy Review (IER) 2005, http://www.eia.doe.gov/pub/international/iealf/tablee1.xls

b/ **Forecasted United States data**: Annual Energy Outlook (AEO) 2008, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_2.xls
Forecasted World data: International Energy Outlook (IEO) 2007, http://www.eia.doe.gov/oiaf/ieo/excel/ieonuctab_1.xls

EIA projections show a steady increase in both U.S. and global transportation energy consumption (EIA 2008a). Despite efforts to increase the use of non-fossil fuels in transportation, fuel use remains largely petroleum based. In 2007, finished motor gasoline and on-road diesel constituted 66 percent of all finished petroleum products consumed in the United States. If other transportation fuels (aviation fuels, marine and locomotive diesel, and bunkers) are included, transportation fuels constitute approximately 79 percent of the finished petroleum products used.

Most U.S. gasoline and diesel is produced domestically (EIA 2008b). In 2007, 4 percent of finished motor gasoline and 6 percent of on-road diesel were imported. However, increasing volumes of crude oil are imported for processing in U.S. refineries because indigenous production is declining steadily. By 2006, petroleum imports equaled 60 percent of total liquids supplied, and by 2007 crude oil imports had surpassed 10 million barrels per day (EIA 2008b), a high proportion of it coming from volatile and unstable regions.

A fall in the demand for transportation fuels likely would affect the import of crude oil more than motor gasoline. Over the last decade there has been a shift in product imports, with volumes of finished gasoline stabilizing and declining slightly. However, volumes of motor gasoline blending components have been rapidly increasing, so that by 2007, the imports of blending components were twice that of finished gasoline.

According to the EIA, net imports, in part due to the changes in CAFE standards and in part due to biofuels, will fall to 51 percent in 2022 and then rise again to 54 percent in 2030. The impact on the industry and the environment in which it works will be felt largely by overseas producers. The actual impact on overseas producers and whether there is a decline in production, and a concomitant decline in emissions, would depend on the demand patterns in the developing nations.

The projections used in this FEIS do not include any large-scale, national efforts to reduce energy consumption or dramatically reduce fossil-fuel use as a result of national security or climate change-issues. NHTSA notes this only to remind readers that the FEIS projections are based on past trends and, in light of the current national focus on energy and climate-change concerns, do not project future regulations or initiatives that could arise but are not, at present, foreseeable. Any large-scale initiative such as this would obviously change the assumptions used in this analysis.

3.2.2 Methodology

The Volpe model, as described in Section 3.1.4, begins with an initial state of the domestic vehicle market, which in this case is the market for passenger cars and light trucks to be sold during the period covered by the proposed rule. It uses several categories of data and estimates for all vehicle categories to develop an estimate of a set of technologies each manufacturer could apply in response to the standard. The Volpe model produces various outputs, one of which is year-by-year fuel consumption, which NHTSA used in the analysis below. NHTSA estimated fuel consumption to 2060, at which point nearly all of the operating fleet of passenger cars and light trucks would be MY 2011-2015 or newer, thus achieving the maximum fuel savings under this rule.

3.2.3 Environmental Consequences

Table 3.2-2 lists the impact on fuel consumption for passenger cars from 2020 through 2060 (a period in which an increasing proportion of the fleet would be MY 2011-2015 cars), which shows the increasing impact of the CAFE alternatives over time. The table lists the total fuel consumption for passenger cars, both gasoline and diesel, under the No Action Alternative (Alternative 1) and the six action alternatives with the Reference Case inputs, as described in Table 2.2-1. By 2060, when the entire

Table 3.2-2

Reference Case Passenger Car Annual Fuel Consumption and Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Fuel Consumption							
2020	67.8	66.4	66.4	66.3	66.2	66.1	59.4
2030	78.9	76.3	76.2	76.1	75.9	75.7	64.3
2040	91.2	88.2	88.0	87.9	87.7	87.4	74.0
2050	105.7	102.1	102.0	101.8	101.6	101.2	85.7
2060	121.9	117.8	117.6	117.4	117.1	116.7	98.8
Fuel Savings Compared to No Action							
2020	--	1.4	1.4	1.5	1.6	1.7	8.4
2030	--	2.6	2.7	2.8	3.0	3.2	14.5
2040	--	3.1	3.2	3.3	3.6	3.8	17.2
2050	--	3.6	3.7	3.9	4.1	4.4	20.0
2060	--	4.1	4.3	4.4	4.7	5.1	23.0

fleet is likely to be composed of MY 2011 or later cars, fuel consumption reaches 121.9 billion gallons under the No Action Alternative. Consumption falls under all the action alternatives, from 117.6 billion gallons under the Optimized Alternative (Alternative 3) to 98.8 billion gallons under the Technology Exhaustion Alternative (Alternative 7). As a point of comparison, in 2007 the United States consumed 9.3 million barrels of fuel per day. Consumption under the Technology Exhaustion Alternative amounts to 6.4 million barrels of fuel per day.

Table 3.2-3 lists results for light trucks/SUVs for the same period and for the same alternatives. As in the previous table, fuel consumption is the total for both diesel and gasoline. Fuel consumption

Table 3.2-3

Reference Case Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Fuel Consumption							
2020	84.0	83.0	82.8	82.4	82.2	81.7	75.5
2030	93.5	91.4	91.0	90.4	89.9	89.2	77.5
2040	107.3	104.6	104.1	103.4	102.7	101.9	87.1
2050	124.0	120.8	120.2	119.4	118.5	117.5	100.2
2060	143.0	139.3	138.7	137.7	136.7	135.6	115.5
Fuel Savings Compared to No Action							
2020	--	1.0	1.2	1.6	1.8	2.2	8.5
2030	--	2.1	2.5	3.0	3.6	4.3	16.0
2040	--	2.7	3.2	3.9	4.6	5.4	20.2
2050	--	3.2	3.7	4.6	5.4	6.4	23.8
2060	--	3.7	4.3	5.3	6.3	7.4	27.5

under the No Action Alternative is 143.0 billion gallons in 2060. Consumption falls under the action alternatives from 138.7 under the Optimized Alternative to 115.5 billion gallons under the Technology Exhaustion Alternative, which represent a savings of 27.5 billion gallons from the No Action Alternative.

3.2.4 Input Scenarios

In response to public comments, and to test how different economic assumptions could affect estimates of fuel consumption, NHTSA ran a scenario using the High Scenario assumptions and compared the results below to the Reference Case. Table 3.2-4 lists the impact on fuel consumption under the High Scenario in the Volpe model for passenger cars from 2020 through 2060. The High Scenario uses the economic inputs described in Table 2.2-1. Table 3.2-4 lists total fuel consumption for passenger cars, both gasoline and diesel, under the No Action Alternative and the six action alternatives. With the assumption of higher fuel prices, lower consumption is expected across the alternatives. By 2060, when the entire fleet is likely to be composed of MY 2011 or later cars, fuel consumption reaches 106.2 billion gallons under the No Action Alternative. Consumption totals 96.6 billion gallons under the Optimized Alternative, as opposed to 117.6 billion gallons under the Optimized Alternative in the Reference Case. Consumption under the Technology Exhaustion Alternative is 86.1 billion gallons, equivalent to 5.6 million barrels per day.

Table 3.2-4

High Scenario Passenger Car Annual Fuel Consumption and Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Fuel Consumption							
2020	62.1	59.3	58.8	58.3	57.9	57.3	54.5
2030	71.1	65.7	64.9	64.0	63.5	62.6	58.0
2040	81.4	75.0	74.1	73.1	72.4	71.4	66.0
2050	93.2	85.9	84.8	83.7	82.9	81.8	75.6
2060	106.2	97.8	96.6	95.3	94.4	93.1	86.1
Fuel Savings Compared to No Action							
2020	--	2.8	3.3	3.9	4.3	4.8	7.7
2030	--	5.4	6.2	7.1	7.6	8.5	13.1
2040	--	6.4	7.4	8.4	9.0	10.0	15.4
2050	--	7.3	8.4	9.6	10.3	11.5	17.6
2060	--	8.4	9.6	10.9	11.7	13.1	20.1

Table 3.2-5 shows the High Scenario results for light trucks/SUVs for the same period and the same alternatives. As in previous tables, fuel consumption is the total for diesel and gasoline. Fuel consumption under the No Action Alternative is 124.6 billion gallons in 2060. Consumption under the Optimized Alternative is 113.6 billion gallons, compared to 138.7 billion gallons under the Optimized Alternative in the Reference Case. Consumption under the Technology Exhaustion Alternative is 100.6 billion gallons.

To further assess how different economic assumptions could affect estimates of fuel consumption, NHTSA ran two additional scenarios in the Volpe model: the Mid-1 Scenario and the Mid-2 Scenario. As the names of the scenarios suggest, results from the two additional scenarios fall between those of the Reference Case and the High Scenario. These scenarios use the economic inputs listed in Table 2.2-1. *See* Appendix B for a summary of Mid-1 and Mid-2 Scenario results.

Table 3.2-5

High Scenario Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Fuel Consumption							
2020	77.0	74.1	73.6	73.1	72.6	72.3	69.2
2030	84.3	78.7	77.7	76.8	76.0	75.6	69.8
2040	95.8	88.7	87.5	86.4	85.3	84.9	77.8
2050	109.4	101.1	99.8	98.4	97.2	96.7	88.4
2060	124.6	115.2	113.6	112.1	110.7	110.0	100.6
Fuel Savings Compared to No Action							
2020	--	2.8	3.4	3.9	4.3	4.6	7.8
2030	--	5.6	6.6	7.5	8.3	8.7	14.4
2040	--	7.1	8.2	9.4	10.4	10.9	18.0
2050	--	8.2	9.6	11.0	12.2	12.7	21.0
2060	--	9.4	11.0	12.5	13.9	14.5	24.0

3.3 AIR QUALITY

3.3.1 Affected Environment

3.3.1.1 Relevant Pollutants and Standards

The new CAFE standards would affect air pollution and air quality, which in turn, has potential effects on public health and welfare. The primary federal legislation that addresses air quality is the Clean Air Act (CAA). Under the authority of the CAA and its amendments, the U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS) for six criteria pollutants (relatively commonplace pollutants that can accumulate in the atmosphere as a result of normal levels of human activity). The air quality analysis assesses the impacts of the alternatives in relation to criteria pollutants and some hazardous air pollutants from mobile sources (also known as mobile source air toxics [MSATs]).

The criteria pollutants are CO, nitrogen dioxide (NO_2) (one of several oxides of nitrogen, ozone, SO_2, suspended PM of 10 microns diameter or less (PM_{10}) and 2.5 microns diameter or less ($PM_{2.5}$), and lead. Ozone is not emitted directly from vehicles, but is evaluated based on emissions of the ozone precursor pollutants NO_x and VOCs.

The U.S. transportation sector is a major source of emissions of certain criteria pollutants or their chemical precursors. Total emissions from on-road mobile sources (cars and trucks) have declined dramatically since 1970 as a result of pollution controls on vehicles and regulation of the chemical content of fuels, despite continuing increases in the amount of vehicle travel. From 1970 to 2006, the most recent year for which data are available, emissions from on-road mobile sources declined 67 percent for CO, 48 percent for NO_x, 62 percent for PM_{10}, 31 percent for SO_2, and 77 percent for VOCs. Emissions of $PM_{2.5}$ from onroad mobile sources declined 62 percent from 1990, the earliest year of available data, to 2006 (EPA 2006c).

On-road mobile sources are responsible for 54 percent of total U.S. emissions of CO, 5 percent of $PM_{2.5}$ emissions, and 1 percent of PM_{10} emissions (EPA 2006c). Almost all of the PM in vehicle exhaust is $PM_{2.5}$; therefore, this analysis focuses on $PM_{2.5}$ rather than PM_{10}. On-road mobile sources also contribute 22 percent of total nationwide emissions of VOCs and 36 percent of NO_x, which are chemical precursors of ozone. On-road mobile sources contribute only 1 percent of SO_2, but SO_2 and other oxides of sulfur (SO_x) are important because they contribute to the formation of $PM_{2.5}$ in the atmosphere. With the elimination of lead in gasoline, lead is no longer emitted in more than negligible quantities from motor vehicles, and is no longer a pollutant of significance for transportation projects. Lead is not assessed further in this analysis.

Table 3.3-1 lists the primary and secondary NAAQS for each criteria pollutant. Primary standards are set at levels intended to protect against adverse effects on human health; secondary standards are intended to protect against adverse effects on public welfare, such as damage to agricultural crops or vegetation, and damage to buildings or other property. Because each criteria pollutant has different potential effects on human health and public welfare, the NAAQS specify different permissible levels for each pollutant. NAAQS for some pollutants include standards for both short- and long-term average levels. Short-term standards, which typically specify higher levels of a pollutant, are intended to protect against acute health effects from short-term exposure to higher levels of a pollutant; long-term standards are established to protect against chronic health effects resulting from long-term exposure to lower levels of a pollutant.

Table 3.3-1

National Ambient Air Quality Standards

Pollutant	Primary Standards		Secondary Standards	
	Level a/	Averaging Time	Level a/	Averaging Time
Carbon monoxide	9 ppm ($10\ mg/m^3$)	8 hours b/	None	
	35 ppm ($40\ mg/m^3$)	1 hour b/		
Lead	$1.5\ \mu g/m^3$	Quarterly Average	Same as Primary	
Nitrogen dioxide	0.053 ppm ($100\ \mu g/m^3$)	Annual (Arithmetic Mean)	Same as Primary	
Particulate matter (PM_{10})	$150\ \mu g/m^3$	24 hours c/	Same as Primary	
Particulate matter ($PM_{2.5}$)	$15.0\ \mu g/m^3$	Annual d/ (Arithmetic Mean)	Same as Primary	
	$35\ \mu g/m^3$	24 hours e/	Same as Primary	
Ozone	0.075 ppm (2008 std.)	8 hours f/	Same as Primary	
	0.08 ppm (1997 std.)	8 hours g/ h/	Same as Primary	
	0.12 ppm	1 hour i/ j/ (Applies only in limited areas)	Same as Primary	
Sulfur dioxide	0.03 ppm	Annual (Arithmetic Mean)	0.5 ppm ($1300\ \mu g/m^3$)	3 hours b/
	0.14 ppm	24 hours b/		

a/ Units of measure for the standards are parts per million (ppm) by volume, milligrams per cubic meter of air (mg/m^3), and micrograms per cubic meter of air ($\mu g/m^3$).
b/ Not to be exceeded more than once per year.
c/ Not to be exceeded more than once per year on average over 3 years.
d/ To attain this standard, the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed $15.0\ \mu g/m^3$.
e/ To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed $35\ \mu g/m^3$ (effective December 17, 2006).
f/ To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm (effective May 27, 2008).
g/ To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.
h/ The 1997 standard—and the implementation rules for that standard—will remain in place for implementation purposes as EPA undertakes rulemaking to address the transition from the 1997 ozone standard to the 2008 ozone standard.
i/ The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is less than 1.
j/ As of June 15, 2005, EPA revoked the 1-hour ozone standard in all areas except the 8-hour ozone nonattainment Early Action Compact (EAC) Areas.

Source: 40 CFR 50, as presented in EPA 2008c.

Under the CAA, EPA is required to review NAAQS every 5 years and to change the levels of the standards if warranted by new scientific information. NAAQS formerly included an annual standard, but EPA revoked the annual PM_{10} standard in 2005 based on an absence of evidence of health effects associated with annual PM_{10} levels. In September 2006, EPA tightened the 24-hour $PM_{2.5}$ standard from

65 micrograms per cubic meter (μg/m^3) to 35 μg/m^3. In March 2008, EPA tightened the 8-hour ozone standard from 0.08 parts per million (ppm) to 0.075 ppm. EPA currently is considering further changes to the $PM_{2.5}$ standards.

The air quality of a geographic region is usually assessed by comparing the levels of criteria air pollutants found in the atmosphere to the levels established by NAAQS. Concentrations of criteria pollutants within the air mass of a region are measured in parts of a pollutant per million parts of air or in micrograms of a pollutant per cubic meter of air present in repeated air samples taken at designated monitoring locations. These ambient concentrations of each criteria pollutant are compared to the permissible levels specified by NAAQS to assess whether the region's air quality could be unhealthful.

When the measured concentrations of a criteria pollutant within a geographic region are below those permitted by NAAQS, EPA designates the region as an attainment area for that pollutant; regions where concentrations of criteria pollutants exceed federal standards are called nonattainment areas. Former nonattainment areas that have attained NAAQS are designated as maintenance areas. Each nonattainment area is required to develop and implement a State Implementation Plan (SIP), which documents how the region will reach attainment levels within periods specified in the CAA. In maintenance areas, the SIP documents how the state intends to maintain compliance with NAAQS. When EPA changes a NAAQS, states must revise their SIPs to address how they will attain the new standard.

Toxic air pollutants emitted from vehicles are known as mobile source air toxics (MSATs). The MSATs included in this analysis are acetaldehyde, acrolein, benzene, 1,3-butadiene, diesel particulate matter (DPM), and formaldehyde. EPA and the Federal Highway Administration (FHWA) have identified these air toxics as the MSATs of concern for impacts of highway vehicles (EPA 2007c, FHWA 2006). DPM is a component of exhaust from diesel-fueled vehicles and falls almost entirely within the $PM_{2.5}$ particle-size class.

Section 3.4 addresses the major GHGs – CO_2, methane (CH_4), and nitrous oxides (N_2O); these GHGs are not included in this air quality analysis, except that N_2O, as one of the oxides of nitrogen (NO_x), is included in the evaluation of NO_x.

3.3.1.2 Health Effects of Criteria Pollutants

The health effects of the six federal criteria pollutants are briefly summarized below. (This section is adapted from EPA 2008e.) Though we did not conduct a formal analysis of health impacts, the alternatives considered in this FEIS will contribute to reductions in criteria pollutants that will improve public health and welfare.

- Ozone is a photochemical oxidant and the major component of smog. Ozone is not emitted directly into the air but is formed through complex chemical reactions between precursor emissions of VOCs and NO_x in the presence of the ultraviolet component of sunlight. Ground-level ozone causes health problems because it irritates the mucous membranes, damages lung tissue, reduces lung function, and sensitizes the lungs to other irritants. Exposure to ozone for several hours at relatively low concentrations has been found to substantially reduce lung function and induce respiratory inflammation in normal, healthy people during exercise. There is also evidence that short-term ozone exposure directly or indirectly contributes to non-accidental and cardiopulmonary-related mortality.

- PM includes dust, dirt, soot, smoke, and liquid droplets directly emitted into the air, and particles formed in the atmosphere by condensation or the transformation of emitted gases such as SO_2 and VOCs. PM is emitted by both gasoline-fueled and diesel-fueled vehicles.

Particles composed of elemental carbon (carbon black or black carbon) are included in the definition of PM. Heavy-duty diesel vehicles (large trucks and buses) are a major source of PM emissions. In general, the smaller the PM, the deeper it can penetrate into the respiratory system, and the more damage it can cause. Depending on the size and composition, PM can damage lung tissue, aggravate existing respiratory and cardiovascular diseases, alter the body's defense systems against foreign materials, damage lung tissue, and cause cancer and premature death. As noted above, EPA regulates PM according to two particle size classifications: PM_{10} and $PM_{2.5}$.

- CO is a colorless, odorless, and poisonous gas produced by incomplete burning of carbon in fuels. Motor vehicles are the largest source of CO emissions nationally. When CO enters the bloodstream, it acts as an asphyxiant by reducing the delivery of oxygen to the body's organs and tissues. It can impair the brain's ability to function properly. Health threats are most serious for those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease.

- Lead is a toxic heavy metal used in industry, such as in battery manufacturing, and formerly in widespread use as an additive in paints. Lead exposure can occur through multiple pathways, including inhalation of air and ingestion of lead in food, water, soil, or dust. Excessive lead exposure can cause seizures, mental retardation, behavioral disorders, severe and permanent brain damage, and death. Even low doses of lead can lead to central nervous system damage. Because of the prohibition of lead as an additive in liquid fuels, transportation sources are no longer a major source of lead pollution.

- SO_2, one of various oxides of sulfur (SO), is a gas formed from combustion of fuels containing sulfur. Most SO_2 emissions are produced by stationary sources such as power plants. SO_2 is also formed when gasoline is extracted from crude oil in petroleum refineries, and in other industrial processes. High concentrations of SO_2 cause severe respiratory distress (difficulty breathing), irritate the upper respiratory tract, and can aggravate existing respiratory and cardiovascular disease. SO_2 also is a primary contributor to acid deposition, or acid rain, which causes acidification of lakes and streams and can damage trees, crops, historic buildings, and statues.

- NO_2 is a reddish-brown, highly reactive gas, one of the oxides of nitrogen formed by high-temperature combustion (as in vehicle engines) of nitrogen and oxygen. Most NO_x created in the combustion reaction consists of nitric oxide (NO), and the NO oxidizes to NO_2 in the atmosphere. NO_2 can irritate the lungs and mucous membranes, cause bronchitis and pneumonia, and lower resistance to respiratory infections. Nitrogen oxides are an important precursor both to ozone and acid rain, and can affect both terrestrial and aquatic ecosystems.

3.3.1.3 Health Effects of Mobile Source Air Toxics

The health effects of the MSATs of concern are briefly summarized below (adapted from EPA 2007c.)

- Acetaldehyde is a probable human carcinogen based on increased incidence of nasal tumors in rats and throat tumors in hamsters after inhalation exposure. Acetaldehyde is also a potent respiratory irritant.

- Acrolein, an aldehyde, is a respiratory irritant. Its potential carcinogenic effects are uncertain.

- Benzene, an aromatic hydrocarbon, is a known human carcinogen (causing leukemia) by all routes of exposure. Benzene also affects the immune system.

- 1,3-butadiene, a hydrocarbon, is characterized as carcinogenic to humans by inhalation. It also damages the reproductive system.

- Diesel particulate matter is a component, along with diesel exhaust organic gases, of diesel exhaust. EPA has not established a particle size classification for regulating DPM. The DPM particles are very fine, with most particles smaller than 1 micron, and their small size allows inhaled DPM to reach the lungs. Particles typically have a carbon core coated by condensed organic compounds, which include mutagens and carcinogens. DPM also includes elemental carbon (carbon black or black carbon) particles emitted from diesel engines. Diesel exhaust is likely to be carcinogenic to humans by inhalation from environmental exposure.

- Formaldehyde is a probable human carcinogen, based on evidence in humans and in rats, mice, hamsters, and monkeys. Formaldehyde also is a respiratory and eye irritant.

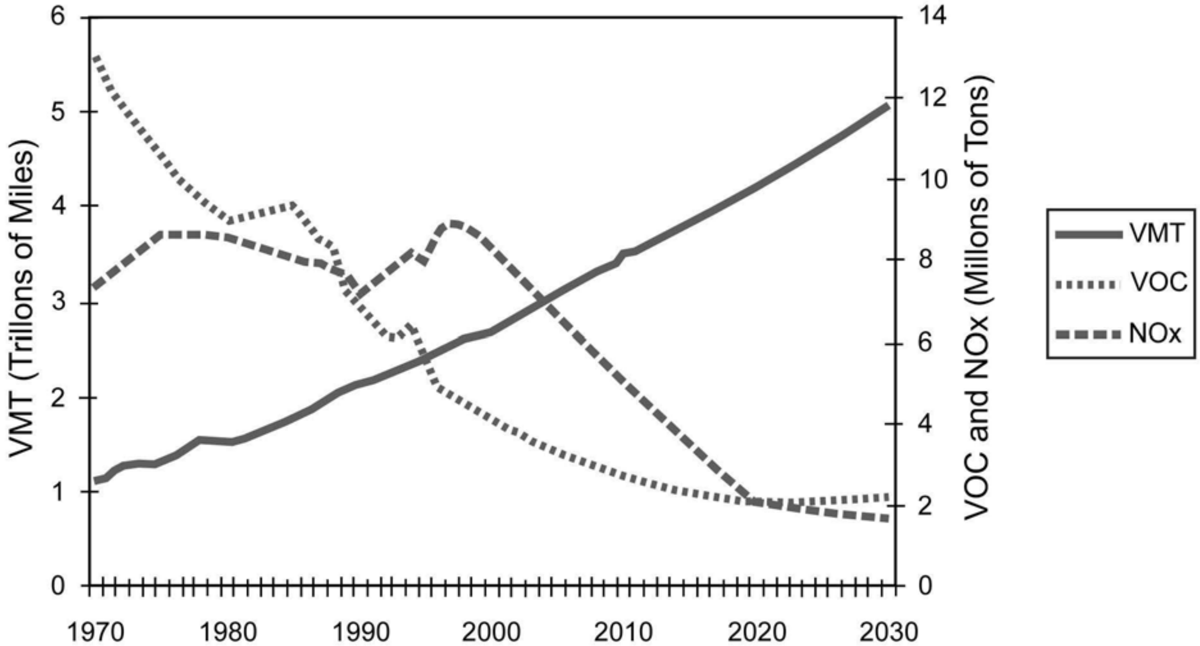
3.3.1.4 Clean Air Act and Conformity Regulations

3.3.1.4.1 Vehicle Emissions Standards

Under the CAA, EPA has established emissions standards for vehicles. EPA has tightened the emissions standards over time as more effective emission control technologies have become available. These reductions in the levels of the standards are responsible for the declines in total emissions from motor vehicles, as discussed above. The emissions standards that will apply to MY 2011-2015 passenger cars and light trucks were established by the EPA Tier 2 Vehicle & Gasoline Sulfur Program, which went into effect in 2004 (EPA 1999b). Under the Tier 2 standards, emissions from passenger cars and light trucks will continue to decline. In 2004, the Nation's refiners and importers of gasoline began to manufacture gasoline with sulfur levels capped at 300 ppm, approximately a 15-percent reduction from the previous industry average of 347 ppm. By 2006, refiners met a 30-ppm average sulfur level with a cap of 80 ppm. These fuels enable post-2006 model year vehicles to use emissions controls that reduce tailpipe emissions of NO_x by 77 percent for passenger cars and by as much as 95 percent for pickup trucks, vans, and SUVs compared to 2003 levels. Figure 3.3-1 shows that cleaner vehicles and fuels will result in continued reductions in emissions from passenger cars and light trucks, despite increases in travel. Figure 3.3-1 illustrates current trends in travel and emissions from passenger cars and light trucks under the current CAFE standards. Figure 3.3-1 does not show the effects of the alternatives, which are discussed in 3.3.3.

From 1970 to 1999, aggregate emissions traditionally associated with vehicles substantially decreased (with the exception of NO_x) even as vehicle miles traveled have increased by approximately 149 percent. NO_x emissions increased between 1970 and 1999 by 16 percent, due mainly to emissions from light-duty trucks and heavy-duty vehicles. However, as future trends show, vehicle travel is having a smaller and smaller impact on emissions as a result of stricter EPA standards for vehicle emissions and the chemical composition of fuels, even with additional growth in VMT (Smith 2002). This general trend will continue, to a greater or lesser degree, with implementation of any of the alternative CAFE standards.

Figure 3.3-1. Vehicle Miles Traveled (VMT) vs. Vehicle Emissions



EPA is addressing air toxics through its MSAT rules (EPA 2007c). These rules limit the benzene content of gasoline beginning in 2011. They also limit exhaust emissions of hydrocarbons (many VOCs and MSATs are hydrocarbons) from passenger cars and light trucks when they are operated at cold temperatures. The cold-temperature standard will be phased in from 2010 to 2015. The MSAT rules also adopt nationally the California evaporative emissions standards. EPA projects that these controls will substantially reduce emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde.

3.3.1.4.2 Conformity Regulations

Section 176(c) of the CAA prohibits federal agencies from taking actions in nonattainment or maintenance areas that do not “conform” to the SIP. The purpose of this conformity requirement is to ensure that general activities do not interfere with meeting the emissions targets in the SIPs, do not cause or contribute to new violations of NAAQS, and do not impede the ability to attain or maintain NAAQS. The EPA has issued two sets of regulations to implement CAA Section 176(c):

- The Transportation Conformity Rules (40 CFR 51, Subpart T), which apply to transportation plans, programs, and projects funded under title 23 U.S.C. or the Federal Transit Act. Highway and transit infrastructure projects funded by FHWA or the Federal Transit Administration (FTA) usually are subject to transportation conformity.
- The General Conformity Rules (40 CFR 51, Subpart W) apply to all other federal actions not covered under transportation conformity. The General Conformity Rules established emissions thresholds, or *de minimis* levels, for use in evaluating the conformity of a project. If the net emissions increases due to the project are less than these thresholds, then the project is presumed to conform and no further conformity evaluation is required. If the emissions increases exceed any of these thresholds, then a conformity determination is required. The conformity determination can entail air quality modeling studies, consultation with EPA and

state air quality agencies, and commitments to revise the SIP or to implement measures to mitigate air quality impacts.

The CAFE standards and associated program activities are not funded under title 23 U.S.C. or the Federal Transit Act. Further, CAFE standards are established by NHTSA and are not an action undertaken by FHWA or FTA. Accordingly, the CAFE standards and associated rulemakings are not subject to transportation conformity.

The General Conformity Rules contain several exemptions applicable to federal actions, which the conformity regulations define as: "any activity engaged in by a department, agency, or instrumentality of the Federal Government, or any activity that a department, agency or instrumentality of the Federal Government supports in any way, provides financial assistance for, licenses, permits, or approves, other than activities [subject to transportation conformity]." 40 CFR 51.852. "Rulemaking and policy development and issuance" are exempted at 40 CFR 51.853(c)(2)(iii). Because NHTSA's CAFE standards involve a rulemaking process, NHTSA's action is exempt from general conformity. Also, emissions for which a federal agency does not have a "continuing program responsibility" are not considered "indirect emissions" subject to general conformity under 40 CFR 51.852. "Emissions that a Federal agency has a continuing program responsibility for means emissions that are specifically caused by an agency carrying out its authorities, and does not include emissions that occur due to subsequent activities, unless such activities are required by the Federal agency" (40 CFR 51.852). Emissions that occur as a result of the CAFE standards are not caused by NHTSA carrying out its statutory authorities and clearly occur due to subsequent activities, including vehicle manufacturers' production of passenger-car and light-truck fleets and consumer purchases and driving behavior. Thus, changes in any emissions that result from NHTSA's new CAFE standards are not those for which the agency has a "continuing program responsibility" and therefore a general conformity determination is not required. Nonetheless, NHTSA is evaluating the potential impacts of air emissions for the purposes of NEPA.

3.3.2 Methodology

3.3.2.1 Overview

NHTSA analyzed air quality impacts by calculating the emissions from passenger cars and light trucks that would occur under each alternative, and assessing the changes in emissions in relation to the No Action Alternative (Alternative 1). Many of the factors that affect air quality at any given location, such as meteorology and atmospheric processes, cannot be accounted for when evaluating human health and environmental impacts; such analysis cannot be performed without a full-scale photochemical air quality modeling analysis. NHTSA did not perform full-scale photochemical air quality modeling for this analysis; therefore, the FEIS does not characterize the ambient air quality impacts associated with each alternative. Full-scale photochemical air quality modeling is necessary to accurately project levels of $PM_{2.5}$, ozone, and air toxics. A national-scale air quality modeling analysis would analyze the combined impacts of each alternative on $PM_{2.5}$, ozone, and MSATs. The atmospheric chemistry related to ambient concentrations of $PM_{2.5}$, ozone, and air toxics is very complex, and making predictions based solely on emissions changes is extremely difficult. The analysis of the alternatives is predicated on the common-sense proposition that assessing emissions is a valid approach to assessing air quality impacts because emissions, ambient concentrations, and health effects are connected. Lower emissions should result in lower ambient concentrations of pollutants on an overall average basis, which should lead to decreased health effects of those pollutants.

The No Action Alternative consists of the existing CAFE standards with no changes in the future. The basic method used to estimate emissions entails multiplying activity levels of passenger cars and light trucks expressed as VMT, by emissions factors in grams of pollutant emitted per VMT. National emissions estimates were provided by the Volpe model. The Volpe model entails the EPA's MOBILE6.2 emissions factor model (EPA 2004d). MOBILE6.2 is EPA's required model for calculating emissions factors for onroad vehicles. In calculating emissions factors, MOBILE6.2 accounts for EPA's emission control requirements for passenger cars and light trucks, including exhaust (tailpipe) emissions, evaporative emissions, and the Tier 2 Vehicle & Gasoline Sulfur Program.

Higher CAFE standards would create an incentive to drive more because they would decrease the vehicle's fuel cost per mile. The total amount of passenger car and light truck VMT would increase slightly due to this "rebound effect." Emissions from passenger cars and light trucks would increase proportionately to the rebound effect. Although higher CAFE standards would decrease the total amount of fuel consumed despite the rebound effect, the decrease in fuel usage cannot be linked directly to any decrease in emissions. The EPA emissions standards and the NHTSA CAFE standards are separate sets of requirements and do not depend on each other. Vehicle manufacturers must meet both the EPA emissions standards and the CAFE standards simultaneously, but neither EPA nor NHTSA dictates the design and technology choices that manufacturers must make to comply. For example, a manufacturer could use a technique that increases fuel economy but also increases emissions, as long as the manufacturer's production still meets both the EPA emissions standards and the CAFE standards. For this reason, the air quality methodology does not assume any emissions benefits solely due to fuel economy improvements.

The new standards also would lead to reductions in "upstream" emissions, which are emissions associated with extraction, refining, storage, and distribution of the fuel. Upstream emissions would decrease with the new CAFE standards because the total amount of fuel used by passenger cars and light trucks would decrease. At the national scale, the reduction in upstream emissions would offset the rebound effect, resulting in a slight net decrease in emissions from passenger cars and light trucks.

While the rebound effect is assumed to affect all areas equally as a percentage of regional VMT, upstream emissions vary by region because fuel refining and storage facilities are not uniformly distributed across the country. An individual region could experience either a net increase or a net decrease in emissions due to the new CAFE standards. To assess regional differences in the effects of the alternatives, net emissions changes were calculated for individual nonattainment areas. Nonattainment areas were used because these are the regions in which are quality problems have been greatest. All nonattainment areas assessed were in nonattainment for ozone or $PM_{2.5}$ because these are the pollutants for which emissions from passenger cars and light trucks are of greatest concern. NHTSA did not quantify PM_{10} emissions separately from $PM_{2.5}$. The road-dust component of PM_{10} emissions from passenger cars and light trucks would increase in proportion to the rebound effect, but because almost all PM from vehicle exhaust consists of $PM_{2.5}$, the alternatives would have almost no effect on exhaust PM_{10}. There are no longer any nonattainment areas for annual PM_{10} because EPA revoked the annual PM_{10} standard.

3.3.2.2 Time Frames for Analysis

Ground-level concentrations of criteria and toxic air pollutants generally respond quickly to changes in emissions rates. The longest averaging period for NAAQS is 1 year. (The ozone and $PM_{2.5}$ NAAQS use annual averages over a 3-year period to account for meteorological variations). The air quality analysis considers the emissions that would occur over annual periods, consistent with NAAQS. Calendar years were selected that are meaningful for the timing of likely effects of the alternatives.

Passenger cars and light trucks remain in use for many years, so the change in emissions due to any change in the CAFE standards would also continue for many years. The influence of vehicles of a particular model year declines with age as vehicles are driven less or scrapped. The Volpe model defines vehicle lifetime as the point at which 2 percent of the vehicles originally produced in a model year survive. Under this definition, cars can survive in the fleet to 26 years of age and light trucks can survive to 37. Any individual vehicle might not necessarily survive to these ages. The survival of vehicles and the amount they are driven can be forecast with reasonable accuracy for a decade or two, while the influences of fuel prices and general economic conditions are less certain. To evaluate air quality impacts, specific years must be selected for which emissions will be estimated and effects calculated. The air quality analysis was conducted in two ways that affect the choice of analysis years: for the NEPA environmental consequences analysis, we assumed that the CAFE standards for MY 2011-2015 would remain in force indefinitely at the 2015 level. Potential CAFE standards for MY 2016-2020 were not included because they are not within the scope of this rulemaking. However, under NEPA, the analysis of cumulative impacts must include potential future actions that are "reasonably foreseeable." In the cumulative impacts analysis (Chapter 4) we included potential CAFE standards for MY 2016-2020 because they are considered a reasonably foreseeable action. With the potential MY 2016-2020 standards, model years after 2020 would continue to meet the MY 2020 standards.

The analysis years used in this FEIS and the rationales for each are listed below.

- 2015 – Required attainment date for most $PM_{2.5}$ nonattainment areas; first year of complete implementation of the MY 2011-2015 CAFE standards; year of highest overall emissions from passenger cars and light trucks following complete implementation.

- 2020 – Latest required attainment date for 8-hour ozone nonattainment areas (2020 is latest full year, as last attainment date is June 2021 for South Coast Air Basin, California); by this point a large proportion of passenger car and light truck VMT would be in vehicles that meet the MY 2011-2015 standards; first year of complete implementation of potential MY 2016-2020 CAFE standards (Section 4.3).

- 2025 – By this point, a large proportion of passenger car and light truck VMT would be in vehicles that meet the potential MY 2016-2020 standards.

- 2035 – By 2035, almost all passenger cars and light trucks in operation would meet at least the MY 2011-2015 standards and the impact of the standards would start to come only from VMT growth rather than further tightening of the standards. The impacts of the CAFE and EPA standards on a year-by-year basis by 2035 will change little from model year turnover, and most changes in emissions from year to year will come from the rebound effect. Year 2035 represents a reasonable limit to the ability to forecast important variables such as survival rates and mileage accrual rates of vehicles in the fleet, future EPA emissions standards, emission control technologies, and the emissions rates from vehicles. NHTSA believes the year 2035 is a practical maximum for impacts of criteria and toxic air pollutants to be considered reasonably foreseeable rather than speculative.

- 2100 – Used for climate change effects but not criteria and toxic air pollutants; NHTSA believes that given the current state of the science, the year 2100 is a practical maximum for impacts of climate change to be considered reasonably foreseeable rather than speculative.

3.3.2.3 Treatment of Incomplete or Unavailable Information

As noted above, the estimates of emissions rely on models and forecasts that contain numerous assumptions and data that are uncertain. Examples of areas in which information is incomplete or unavailable include future emissions rates, vehicle manufacturers' decisions on vehicle technology and design, the mix of vehicle types and model years, emissions from fuel refining and distribution, and economic factors. A full-scale photochemical air quality modeling analysis to estimate the ambient concentrations of PM, ozone, and air toxics was not conducted. The lack of air quality modeling data limited the conclusions that could be made about health and environmental impacts associated with each alternative. Instead, screening-level estimates of health outcomes in the form of cases per ton of criteria pollutant emissions reduced, and of monetized health benefits, in the form of dollars per ton of criteria pollutant emissions reduced, were used to approximate the health benefits associated with each alternative. The use of such dollars-per-ton numbers, however, does not account for all potential health and environmental benefits, which leads to an underestimate of total criteria pollutant benefits.

Where information in the analysis included in the FEIS is incomplete or unavailable, NHTSA has relied on CEQ regulations regarding incomplete or unavailable information. See 40 CFR § 1502.22(b). NHTSA has used the best available models and supporting data. The models used for the FEIS were subjected to scientific review and have received the approval of the agencies that sponsored their development. NHTSA believes that the FEIS assumptions regarding uncertain conditions reflect the best available information and are valid and sufficient for this analysis.

3.3.2.4 Allocation of Exhaust Emissions to Nonattainment Areas

The Volpe model provided national emissions estimates. The national emissions were allocated to the county level using VMT data and projected population for each county. Passenger car and light truck VMT was determined for all counties in the United States with data from the National County Database (NCD) included in the National Mobile Inventory Model (NMIM) (EPA 2006d). NMIM contains MOBILE6.2 and other models, and all parameters necessary to estimate on- and off-road mobile emissions in the United States. EPA uses NMIM in its rulemakings and NMIM is the best available tool for this purpose. The passenger car and light truck VMT data was queried from the NCD for all counties as the sum over all roadway types in each county, for all passenger-car and light-truck types included in MOBILE6.2. The VMT data used in the NCD were projected from traffic counts taken by counties and states on major roadways, and therefore are subject to some uncertainty. Most nonattainment areas comprise one or more counties, and because the county-level VMT are aggregated for each nonattainment, this uncertainty carries over to the estimates of VMT within each nonattainment area.

Over time, some counties will grow faster than others, and VMT growth rates will also vary. NTHSA accounted for differing growth rates by adjusting each county's fraction of national VMT according to United States Census population trends projected for 2007 through 2012 (the latest projection year available). Emissions for each county were calculated as national emissions times the population-adjusted fraction of national VMT that occurred in the county. This method assumes that population growth patterns across U.S. urban areas will follow 2007 through 2012 trends to 2035, and that per capita VMT will remain unchanged at the county level. For example, areas that currently are growing rapidly are assumed to continue to grow rapidly, and areas that currently have high per capita VMT are assumed to continue to have high per capita VMT. Because changes in urban growth patterns can alter driving behavior in an area, this adjustment introduces some uncertainty into the nonattainment area-level VMT estimates. This uncertainty increases as the projection period lengthens, such as analysis year 2035 compared to 2015. The adjusted VMT was used to derive the county-level emissions from the national emissions. From the county-level emissions, the emissions for each nonattainment area were derived by summing the emissions for the counties in each nonattainment area.

The geographical definitions of ozone and $PM_{2.5}$ nonattainment areas came from the current EPA Greenbook list (EPA 2008b). For nonattainment areas that include portions of counties, we calculated the proportion of county population that falls within the nonattainment area boundary as a proxy for the proportion of county VMT that occurs within the nonattainment area boundary. This method assumes that per capita VMT is constant within each county, so that the proportion of county population in the partial county area reflects the VMT in that area. Partial county boundaries were taken from geographic information system files based on 2006 nonattainment area definitions. In some cases, partial counties within nonattainment areas as currently defined were not included in the 2006 nonattainment areas. In those cases, we did not add any part of the missing counties' VMT to our nonattainment area totals, on the basis that partial counties added to nonattainment areas between 2006 and 2008 likely represent relatively small additions to total nonattainment area VMT. Several urban areas are in nonattainment for both ozone and $PM_{2.5}$. Where boundary areas differ between the two pollutants, we use the ozone nonattainment area boundary, which is larger in all cases.

Table 3.3-2 lists the current nonattainment and maintenance areas.

Table 3.3-2

Nonattainment Areas for Ozone and $PM_{2.5}$

	Classification a/		General Conformity Threshold b/	
Nonattainment/Maintenance Area	**O_3**	**$PM_{2.5}$**	**O_3**	**$PM_{2.5}$**
Albany-Schenectady-Troy, NY	Subpart 1	-	100	-
Allegan Co., MI	Subpart 1	-	100	-
Amador and Calavaras Cos. (Central Mountain Counties), CA	Subpart 1	-	100	-
Atlanta, GA	Moderate	Nonattainment	100	100
Baltimore, MD	Moderate	Nonattainment	100	100
Baton Rouge, LA	Moderate	-	100	-
Beaumont/Port Arthur, TX	Moderate	-	100	-
Birmingham, AL	-	Nonattainment	-	100
Boston-Lawrence-Worcester (E. MA), MA	Moderate	-	100	-
Boston-Manchester-Portsmouth, MA-SE. NH	Moderate	-	100	-
Buffalo-Niagara Falls, NY	Subpart 1	-	100	-
Canton-Massillon, OH	-	Nonattainment	-	100
Charleston, WV	-	Nonattainment	-	100
Charlotte-Gastonia-Rock Hill, NC-SC	Moderate	-	100	-
Chattanooga, AL-TN-GA	-	Nonattainment	-	100
Chicago-Gary-Lake Co., IL-IN	Moderate	Nonattainment	100	100
Chico, CA	Subpart 1	-	100	-
Cincinnati-Hamilton, OH-KY-IN	Subpart 1	Nonattainment	100	100
Clearfield and Indiana Cos., PA	Subpart 1	-	100	-
Cleveland-Akron-Lorain, OH	Moderate	Nonattainment	100	100
Columbus, OH	Subpart 1	Nonattainment	100	100
Dallas-Fort Worth, TX	Moderate	-	100	-
Dayton-Springfield, OH	-	Nonattainment	-	100
Denver-Boulder-Greeley-Ft. Collins, CO	Subpart 1	-	100	-
Detroit-Ann Arbor, MI	Marginal	Nonattainment	100	100
Door Co., WI	Subpart 1	-	100	-
Essex Co., NY (Whiteface Mountain)	Subpart 1	-	100	-
Evansville, IN	-	Nonattainment	-	100

Table 3.3-2 (cont'd)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Classification a/		General Conformity Threshold b/	
	O_3	$PM_{2.5}$	O_3	$PM_{2.5}$
Greater Connecticut, CT	Moderate	-	100	-
Greene Co., PA	Subpart 1	-	100	-
Greensboro-Winston Salem-High Point, NC	-	Nonattainment	-	100
Harrisburg-Lebanon-Carlisle, PA	-	Nonattainment	-	100
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	Subpart 1	-	100	-
Hickory, NC	-	Nonattainment	-	100
Houston-Galveston-Brazoria, TX	Moderate	-	100	-
Huntington-Ashland, WV-KY-OH	-	Nonattainment	-	100
Imperial Co., CA	Moderate	-	100	-
Indianapolis, IN	-	Nonattainment	-	100
Jamestown, NY	Subpart 1	-	100	-
Jefferson Co., NY	Moderate	-	100	-
Johnstown, PA	-	Nonattainment	-	100
Kern Co. (Eastern Kern), CA	Subpart 1	-	100	-
Knoxville, TN	Subpart 1	Nonattainment	100	100
Lancaster, PA	-	Nonattainment	-	100
Las Vegas, NV	Subpart 1	-	100	-
Libby, MT	-	Nonattainment	-	100
Liberty-Clairton, PA	-	Nonattainment	-	100
Los Angeles South Coast Air Basin, CA	Severe 17	Nonattainment	25	100
Los Angeles-San Bernardino Cos. (W. Mojave Desert), CA	Moderate	-	100	-
Louisville, KY-IN	-	Nonattainment	-	100
Macon, GA	-	Nonattainment	-	100
Manitowoc Co., WI	Subpart 1	-	100	-
Mariposa & Tuolumne Cos. (Southern Mountain Counties), CA	Subpart 1	-	100	-
Martinsburg, WV-Hagerstown, MD	-	Nonattainment	-	100
Memphis, TN-AR	Moderate	-	100	-
Milwaukee-Racine, WI	Moderate	-	100	-
Nevada (Western Part), CA	Subpart 1	-	100	-
New York-N. New Jersey-Long Island, NY-NJ-CT	Moderate	Nonattainment	100	100
Parkersburg-Marietta, WV-OH	-	Nonattainment	-	100
Philadelphia-Wilmington-Atlantic City, PA-DE-MD-NJ	Moderate	Nonattainment	100	100
Phoenix-Mesa, AZ	Subpart 1	-	100	-
Pittsburgh-Beaver Valley, PA	Subpart 1	Nonattainment	100	100
Poughkeepsie, NY	Moderate	Nonattainment	100	100
Providence (All RI), RI	Moderate	-	100	-
Reading, PA	-	Nonattainment	-	100
Riverside Co., CA (Coachella Valley)	Serious	-	50	-
Rochester, NY	Subpart 1	-	100	-
Rome, GA	-	Nonattainment	-	100
Sacramento Metro, CA	Serious	-	50	-
San Diego, CA	Subpart 1	-	100	-
San Francisco Bay Area, CA	Marginal	-	100	-

Table 3.3-2 (cont'd)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Classification a/		General Conformity Threshold b/	
	O_3	$PM_{2.5}$	O_3	$PM_{2.5}$
San Joaquin Valley, CA	Serious	Nonattainment	50	100
Sheboygan, WI	Moderate	-	100	-
Springfield (Western MA), MA	Moderate	-	100	-
St. Louis, MO-IL	Moderate	Nonattainment	100	100
Steubenville-Weirton, OH-WV	-	Nonattainment	-	100
Sutter County (Sutter Buttes), CA	Subpart 1	-	100	-
Ventura Co., CA	Moderate	-	100	-
Washington, DC-MD-VA	Moderate	Nonattainment	100	100
Washington County (Hagerstown), MD	-	Nonattainment	-	100
Wheeling, WV-OH	-	Nonattainment	-	100
York, PA	-	Nonattainment	-	100

a/ Pollutants for which the area is designated nonattainment or maintenance as of 2008, and severity classification.
b/ Tons per year of VOCs or NO_x in ozone nonattainment areas; primary $PM_{2.5}$ in $PM_{2.5}$ nonattainment areas.
Source: EPA 2008b.

3.3.2.4.1 Allocation of Upstream Emissions to Nonattainment Areas

Upstream emissions from light-duty vehicles (LDV) are generated when fuel products are produced, processed, and transported. Upstream emissions are typically divided into four categories:

- Feedstock Recovery (petroleum extraction)
- Feedstock Transportation
- Fuel Refining
- Fuel Transportation, Storage, and Distribution (T&S&D)

Feedstock recovery refers to the extraction or production of fuel feedstocks. In the case of petroleum, this is the stage of crude oil extraction. During the next stage, feedstock transportation, crude oil is shipped to refineries. Fuel refining refers to the processing of crude oil into gasoline and diesel. T&S&D refers to the movement of gasoline and diesel from refineries to bulk terminals, storage at bulk terminals, and transportation of fuel from bulk terminals to retail outlets. Emissions of pollutants at each stage are associated with expenditure of energy and spillage and evaporation of fuel products.

The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model (Argonne 2002) estimates upstream emissions associated with various vehicle fuel pathways for light-duty vehicles in the United States. GREET includes various assumptions about the production and transportation of feedstocks and fuels. The model assumes that more than half of the crude oil supplied to U.S. refineries arrives by ocean tanker from foreign countries and Alaska. More than a third of crude oil is produced domestically. Once in the lower 48 states, almost all (92 percent) of crude oil is transported to refineries by pipeline.

The model assumes that nearly all (96 percent) of gasoline and diesel consumed in the United States comes from U.S. refineries. Around three quarters of that fuel is transported from refineries to bulk terminals by pipeline, an average distance of 400 miles. Smaller shares are transported by ocean tanker, barge, and rail. Fuel is transported from bulk terminals to retail outlets by truck an average distance of 30 miles. The current version of GREET does not account for the most recent EPA emissions standards for heavy trucks, locomotives, and marine vessels. For the analysis of upstream emissions, we updated the model inputs to account for the most recent EPA emissions standards. This update reduces the modeled upstream emissions from fuel transport, and therefore lessens the effect of the alternatives in reducing upstream emissions.

GREET and Volpe modeling provided changes in upstream emissions of NO_x, PM, VOCs, SO_x, and CO and four air toxics (acetaldehyde, benzene, butadiene, DPM, and formaldehyde) associated with the proposed action and alternatives. The Volpe model shows that nationwide upstream emissions would be reduced by all of the alternatives examined. Increasing the fuel economy of light duty vehicles will cause less fuel to be consumed, which will in turn reduce upstream emissions of criteria pollutants associated with feedstock and fuel production, processing, and transportation.

The analysis of upstream emissions considered only emissions occurring domestically and did not consider emissions occurring internationally, such as during transport of crude oil or refined gasoline to the United States. The upstream emissions data used in the GREET model assumed that, first, 50 percent of the fuel savings with the alternatives would reduce imports of refined gasoline, and therefore would reduce domestic emissions only during fuel T&S&D and would not reduce emissions from feedstock recovery, feedstock transportation, and fuel refining. Second, 90 percent of the reduction in domestic fuel refining reduces imports of crude petroleum (and therefore does not reduce domestic emissions from feedstock recovery and feedstock transportation), while only 10 percent reduces domestic production of crude petroleum (which does reduce domestic emissions from feedstock recovery and feedstock transportation). NHTSA estimated these percentages using several scenarios from EIA's *Annual Energy Outlook* (AEO) (EIA 2008a).

To analyze the impact of the alternatives on individual nonattainment areas, we allocated emissions reductions to geographic areas according to the following methodology:

- Feedstock Recovery – We assumed that little to no extraction of crude oil occurs in nonattainment areas. Of the top 50 highest producing oil fields in the United States, only nine are in nonattainment areas. These nine fields account for just 10 percent of domestic production, or 3 percent of total crude-oil imports and domestic production (EIA 2006, EIa 2008b). Therefore, NHTSA ignored emissions reductions from feedstock recovery in nonattainment areas.

- Feedstock Transportation – We assumed that little to no crude oil is transported through nonattainment areas. Most refineries are outside of, or on the outskirts of, urban areas. Crude oil is typically transported hundreds of miles from extraction points and ports to reach refineries. Most transportation is by ocean tanker and pipeline. Probably only a very small proportion of criteria pollutants emitted in the transport of crude oil occur in nonattainment areas. Therefore, NHTSA ignored emissions reductions from feedstock transportation in nonattainment areas.

- Fuel Refining – Fuel refining is the largest source of upstream emissions of criteria pollutants. Depending on the specific fuel and pollutant, fuel refining accounts for between one third and three quarters of all upstream emissions (based on outputs of the Volpe model). NHTSA compiled a list of all crude oil refineries in the United States along with their locations and refining capacity, and then calculated each nonattainment area's share of total nationwide refining capacity (NPRA 2008, EIA 2008e). It is assumed that fuel refining will decrease uniformly across all refineries nationwide as a result of the alternatives. For the nonattainment areas examined, we estimated the change in emissions from fuel refining as a share of the total national emissions, proportional to the area's share of national refining capacity.

- Fuel T&S&D – Based on the assumptions of the GREET model, we assume that most T&S&D emissions occur near the point of fuel sale and use. The pipelines that carry fuel from refineries to bulk hubs are a relatively low emissions mode. The trucks that carry the fuel to retail outlets are likely to be the largest source of emissions in this category. If the average distance a truck hauls the fuel is 30 miles, then the truck is likely to emit most criteria pollutants within the same airshed as that in which the fuel will be purchased and used. NHTSA used county-level light-duty VMT data from EPA's NMIM to estimate the proportion of national fuel demand in each nonattainment area, and population forecasts by county to account for likely shifts in demand in future years, as discussed above. Finally, we apportioned the national T&S&D emissions to nonattainment areas based on their total share of national fuel demand.

Because we ignore emissions changes from the first two upstream stages, our assumptions produce conservative estimates of emissions reductions in nonattainment areas.

For acetaldehyde, benzene, butadiene, and formaldehyde, the GREET modeling provided proportions of total upstream emissions by only two categories: feedstock recovery and transportation, and fuel refining and T&S&D. No split between emissions from fuel refining and emissions from T&S&D was provided. NHTSA assumed that all upstream emissions of these pollutants from fuel refining and T&S&D occur during fuel refining. This assumption results in over-assignment of emissions of these pollutants to nonattainment areas that have refineries and under-assignment of emissions to those that have none.

The GREET model also provided no information on upstream emissions of acrolein; therefore, we did not apply upstream emissions reductions for acrolein. As a result, the emissions of acrolein given in the FEIS are conservative (high) because they account only for the increase due to the rebound effect.

3.3.2.4.2 Health Outcomes and Costs

This section describes NHTSA's approach to addressing public comments on the need to provide more quantitative estimates of adverse health effects of conventional air pollutants associated with each alternative.

Adverse Health Impact Evaluation

The EPA *Report to Congress on The Benefits and Cost of the Clean Air Act 1990 to 2010* (EPA-410-R-99-001) (EPA 1999a) documents a quantitative assessment of air pollutant emissions impacts in 1990, 2000, and 2010 from implementation of the 1970 Clean Air Act, 1977 Amendments (CAAA), and the 1990 Amendments. The assessment includes air quality modeling of the impacts associated with and without implementation of the Clean Air Act and quantifying health-related outcomes on a nationwide basis. Appendix D of the EPA report to Congress describes the basis and methodology used to assess the impacts on human health from the effects of changes in criteria air pollutants. The study found substantial health benefits from implementation of the CAAA, especially as a consequence of reductions in fine particulate matter ($PM_{2.5}$). In particular, incidences of mortality, chronic bronchitis, and asthma are associated with changes in $PM_{2.5}$ concentrations. Thus, an approximation of changes in $PM_{2.5}$ emissions can be used to characterize impacts on the most adverse health effects for mortality, chronic bronchitis, emergency room visits for asthma, and work-loss days. Other health endpoints have more complex relationships, either with other pollutants or by undergoing non-linear atmospheric transformation processes, which would require air quality modeling, exposure modeling, and application of unit risk factors to assess final health impacts.

In EPA's report (Appendix D,[6] Table D-21) endpoint outcomes for mortality, chromic bronchitis, emergency room visits for asthma, and work-loss days are reported on a nationwide basis for 2010 for the 5^{th}, mean, and 95^{th} percentiles. The report also quantifies the nationwide changes in $PM_{2.5}$ from pre-CAAA and post-CAAA for 2010 by source category (utility, point, area, non-road, and on-road motor vehicle). Because the CAFE standards will impact emissions nationwide and the CAAA also acts nationwide, it is anticipated that spatial patterns of mobile source emissions will have similar spatial distributions. Thus, in this assessment we use this information from Table 2-3 from the EPA report for pre- and post-CAAA $PM_{2.5}$ emissions reduction changes from motor vehicles to estimate adverse health impacts from changes in motor vehicle $PM_{2.5}$ emissions. Table 2-3 shows that emissions of $PM_{2.5}$ are reduced by 90,000 tons per year with implementation of the CAAA and are 30 percent (90,000/300,000) of the total $PM_{2.5}$ emissions reduction. This fraction would then be used with the endpoint values in Table D-21 (*e.g.*, mean mortality end point, MME_{CAAA}, along with the emissions reductions between alternatives (*e.g.*, Alternative 1 [No Action] and Alternative 6 [Total Costs Equal Total Benefits], $PM_{2.5\ A1\text{-}A6}$) to determine the mean mortality endpoint between alternatives.

This can be expressed mathematically as:

$$MME_{CAAA} \times (0.30) \times (PM_{2.5\ A1\text{-}An}/90{,}000) = MME_{A1\text{-}An}$$

Where n refers to the each of the alternatives:

A1 is the No Action Alternative and
An is the alternative number.

For example, the mean mortality (number of deaths > 30 years of age) avoided in 2010 for post-CAAA versus pre-CAAA is 23,000 (see Table D-21). In 2035, Alternative 3 (Optimized) would reduce $PM_{2.5}$ emissions by 498 tons per year compared to Alternative 1 (No Action) (see Table 3.3-3 in Section 3.3.3.2.1). Then the number of deaths avoided with Alternative 3 is (23,000) x (0.30) x (498/90,000) = 38.

This procedure is applied for each year analyzed (2015, 2020, 2025, and 2035) for each alternative for the mean health outcome, which provides an estimate of the credible interval of the number of avoided cases for each endpoint.

[6] The approach used in this study followed the design of EPA's retrospective Section 812 study (EPA 1997b) using a sequence of linked analytical models (emissions, air quality, and health benefits) to estimate benefits. The most important aspects of the health benefit analysis are the forecasted change in pollutant concentrations over the study period and the concentration response functions that quantify the relationship between the forecasted changes in exposure and expected change in specific health outcomes. Further details on the underlying assumptions and uncertainty in the pre- and post-CAAA scenarios are discussed in Appendix A (emissions), Appendix C (air quality models) and Appendix D (health benefit models) in EPA (1999a).

Underlying Assumptions

The assumptions used in the analysis are based on extrapolation of the EPA 1999b health impact numbers to this analysis:

- That motor vehicle related changes pre- and post-CAAA have the same spatial distribution in motor vehicle emissions as in the FEIS.
- That the health effects scale linearly with the emissions and that the PM health effects are attributable to primary $PM_{2.5}$ emissions. This is conservative because the secondary PM formation is responsible for a portion of the $PM_{2.5}$. Also, not considering the associated reductions in other air pollutants in the CAAA study might underestimate the health benefits of the CAAA reductions.
- That at least for $PM_{2.5}$ we can assign the pre-CAAA and post-CAAA motor vehicle emissions proportionately to the other source categories. This is a reasonable assumption because nearly all of the $PM_{2.5}$ in 2010 pre- and post-CAAA is from on-road, non-road, and area sources. These are generally low-level sources close to populations.
- The population distribution across the United States is the same now as it was when the analysis was done for the CAAA report, and the future population projections would be the same (because the change in incidence is calculated for each population grid cell).
- The baseline mortality and respiratory disease rate have remained the same. The prior analysis used county-specific incidence rates and national incidence rates, and baseline incidence rates from the health studies.
- That the CAAA analysis assumed that the concentration-response (C-R) relationships should only be applied to those subpopulations matching the original study population. This might underestimate the whole population benefits of reductions in pollutant exposures.

Although more recent data are available on air pollution and mortality effects, the studies used here are generally considered to be appropriate for air quality impact analysis. These studies have been used in other EPA documents published since 1999, in analyses for the private sector, and by international health agencies.

Economic Impacts Evaluation

The EPA Office of Transportation and Air Quality (OTAQ) funded a study (EPA 2003) that examined the economic impacts from future changes in VMT. The study looked at 10-percent increase and 10-percent decrease in VMT nationwide, and evaluated the economic costs through air quality modeling of emissions changes in the motor vehicle fleet. The study examined the economic impacts from changes in ambient PM concentrations and ozone. The study looked at target years 2015, 2020, and earlier years. For this analysis, we use 2015 and 2020 and the associated economic impacts associated with a 10-percent decrease in VMT for 2015 and 2020 associated with the air quality impacts on ozone and particulate matter. The associated changes in air emissions from the study are available for on-road motor vehicles for 2015 and 2020.

Table 3-2 of the OTAQ study (EPA 2003) provides an estimate of the daily average emissions changes for NO_x, VOCs, SO_2 and $PM_{2.5}$ for all on-road vehicles separated into light and heavy-duty vehicles. The study developed an ACCESS™-database display tool that has information on a wide variety of economic scenarios, including the economic costs over the entire U.S. modeling domain for each analysis year. This information, in conjunction with the emissions changes calculated from Table 3.2 of the OTAQ report can be used to estimate the economic impacts for each of the alternative emissions changes in the FEIS (see Table 3.3-4) in a manner analogous to the health impact assessment. However, because the economic impacts from the EPA/OTAQ study are only available for ozone and particulate matter, an assumption was made as to the emissions contribution from each of the major emissions types: SO_2, VOCs, NO_x, $PM_{2.5}$, and NO_x. For ozone, the principal precursors are NO_x and VOCs. EPA's policy for addressing $PM_{2.5}$ concentrations is to include the precursor emissions of NO_x, $PM_{2.5}$, and SO_2 (EPA 2007a). As a first approximation, we split the emissions change for NO_x equally between ozone and PM formation. This enables an economic impact analysis for each alternative for each year and can be expressed mathematically for ozone as:

$$E_{A1\text{-}An,\ YYYY,\ O3} = (0.5*NOX_{A1\text{-}An,\ YYYY} + VOC_{A1\text{-}An,YYYY})/(0.5*NOX_{-10\%,YYYY} + VOC_{-10\%,YYYY}) * E_{-10\%,YYYY,O3}$$

Where:

E = dollar value of economic impact in year 2000 dollars
A1 = Alternative 1 (No Action)
An = the alternative number
VOC = emissions rate for volatile organic compounds
NO_x = emissions rate for nitrogen oxides
O_3 = ozone
YYYY = analysis year
10% = 10 percent reduction scenario

So for example, in 2020, the 10-percent VMT reduction in the EPA/OTAQ study found a 12.73 million dollar economic improvement. The sum of one-half NO_x emissions and VOCs for the EPA/OTAQ study is 2,281 tons per day, while the sum of one-half NO_x emissions and VOCs for Alternative 1 (No Action) versus Alternative 3 (Optimized) in 2020 High Scenario cumulative is only 206 tons per day. Thus, the economic impact between Alternative 1 and Alternative 3 can be determined as follows:

$$(206)/(2{,}281) \times (12.73 \text{ million dollars}) = 1.15 \text{ million dollars}$$

This same procedure is applied for 2015 and a similar approach is used to estimate the impacts for 2025 and 2035, but with the base year emissions based on the best available future year of 2020 year.

The same approach can be applied for $PM_{2.5}$, but instead of VOCs, both SO_2 and $PM_{2.5}$ emissions are added. Expressed mathematically,

$$E_{A1\text{-}An,\ YYYY,\ PM2.5} = (0.5*NOX_{A1\text{-}An,\ YYYY} + SO_{2A1\text{-}An,YYYY} + PM_{2.5A1\text{-}An,YYYY})/(0.5*NOX_{-10\%,YYYY} + SO_{2\text{-}10\%,YYYY} + PM_{2.5\text{-}10\%,YYYY}) * E_{-10\%,YYYY,,PM2.5}$$

Where:

E = dollar value of economic impact in year 2000 dollars
A1 = Alternative 1 (No Action)
An = the alternative number
$PM_{2.5}$ = emissions rate for particulate matter less than 2.5 microns

SO_2 = emissions rate for sulfur dioxide
NO_x = emissions rates for nitrogen oxides
YYYY = analysis year
10% = 10 percent reduction scenario

Underlying Assumptions

The assumptions used in the analysis are based on the EPA/OTAQ 2003 social costs of air pollution analysis, as follows:

- That motor vehicle emissions changes from the 10-percent reduction in VMT are spatially distributed the same in the FEIS. This assumes that the VMT reductions are spread equally as a percent reduction of baseline VMT and that the fuel economy improvements are approximately proportional to the VMT.
- That the economic effects scale linearly with the emissions changes.
- That the ozone and particulate matter changes capture the economic effects that emissions contribution for ozone is principally from NO_x and VOCs, that the important precursor for $PM_{2.5}$ is the emissions of NO_x, and SO_2, and as a first approximation, that the emissions change for NO_x is equal between ozone and PM formation.
- The population distribution across the United States is the same now as it was when the analysis was done for the EPA/OTAQ study and the future population projections would be the same.
- The 10-percent change in VMT is assumed proportionality to the vehicle emissions change. This is not strictly true, because emissions associated with different vehicle classes do vary within each class, but these changes are relatively small.
- Assuming linear scaling of emissions with only a 10-percent reduction in VMT allows an estimate of the associated economic impact, assuming linear economic effects.
- That the concentration-response (C-R) functions as used in the EPA/OTAQ and Abt Associates (2001) are appropriate for the FEIS. Both studies focus on changes in motor vehicle emissions, so C-R functions should behave similarly.
- The unit dollar values of the economic endpoints used in the EPA/OTAQ study for the value of a statistical life, willingness to pay to reduce chronic bronchitis, value of hospital admissions due to respiratory problems, and other respiratory ailments not causing hospital admissions.

3.3.3 Environmental Consequences

3.3.3.1 Results of the Emissions Analysis

The CAA has been a success in reducing emissions from on-road mobile sources. As discussed in Section 3.3.1, pollutant emissions from vehicles have been declining since 1970 and EPA projects that they will continue to decline. However, as future trends show, vehicle travel is having a smaller and smaller impact on emissions as a result of stricter EPA standards for vehicle emissions and the chemical composition of fuels, even with additional growth in VMT (Smith 2002). This general trend will continue, to a greater or lesser degree, with implementation of any of the alternative CAFE standards. The analysis by alternative in this section shows that the alternative CAFE standards will lead to both reductions and increases in emissions from passenger cars and light trucks, compared to current trends without the alternative CAFE standards. The amounts of the reductions and increases would vary by pollutant, calendar year, and alternative CAFE standard. The more restrictive alternatives generally would result in greater emissions reductions compared to the No Action Alternative. Under some of the action alternatives there would be emissions increases that would exceed the general conformity thresholds in some nonattainment areas.

Sections 3.3.3.2 through 3.3.3.8 describe the results of the emissions analysis for Alternatives 1 through 7 for the Reference Case.

3.3.3.2 Reference Case Alternative 1: No Action

3.3.3.2.1 Criteria Pollutants

With the No Action Alternative, the CAFE standards would remain at the MY 2010 level in future years. Current trends in the levels of emissions from vehicles would continue, with emissions continuing to decline due to the EPA emissions standards, despite a growth in total VMT. The EPA vehicle emissions standards regulate all criteria pollutants except SO_2, which is regulated through fuel sulfur content. The No Action Alternative would not change the current CAFE standards and so would not result in any change in criteria pollutant emissions, other than current trends, in nonattainment and maintenance areas throughout the United States.

Table 3.3-3 summarizes the total national emissions from passenger cars and light trucks for the No Action Alternative for each of the criteria pollutants and analysis years. The action alternatives (Alternatives 2 through 7) are presented left to right in order of increasing fuel economy requirements. Figure 3.3-2 illustrates this information graphically. Table 3.3-3 and Figure 3.3-2 show that emissions change very little between the No Action Alternative and Alternatives 2 and 3. In the case of PM, SO_X, NO_x, and VOC, the No Action Alternative results in the highest emissions. Emissions of PM, SO_X, NO_x, and VOC generally decline as fuel economy standards increase across alternatives. In the case of CO, emissions under Alternative 2 or 3 are slightly higher than under the No Action Alternative. Emissions of CO decline as fuel economy standards increase across Alternatives 4 through 7.

Table 3.3-3

Reference Case Alternative CAFE Standards
Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

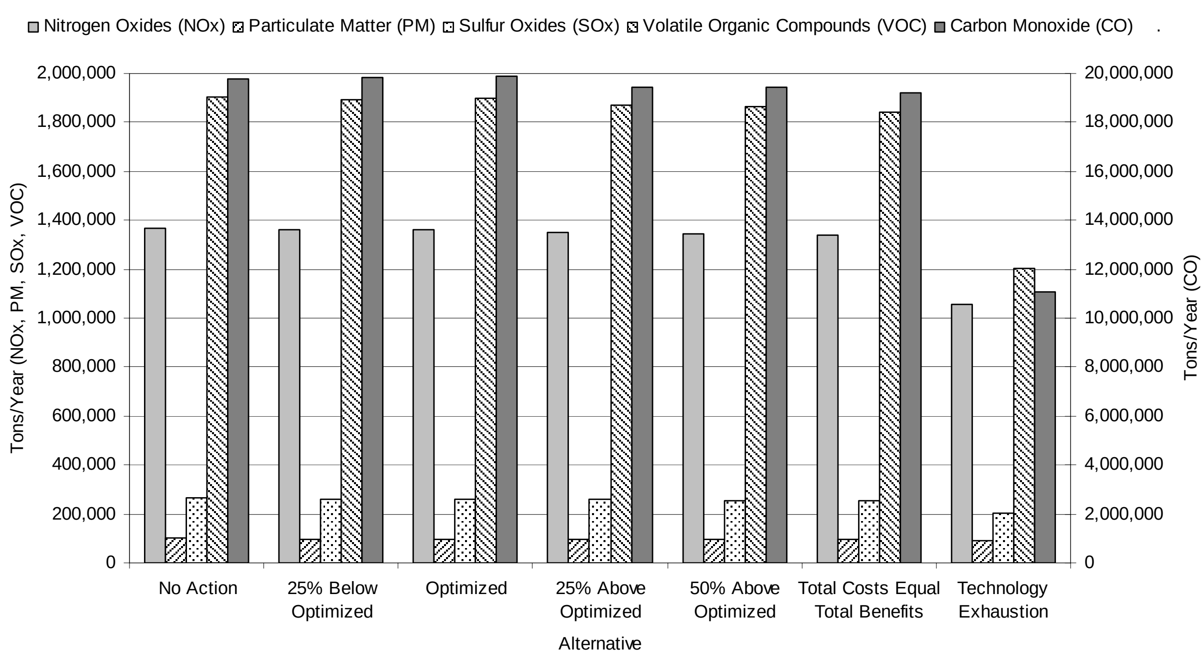
Pollutant and Year	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Carbon monoxide (CO)							
2015	20,241,797	20,253,448	20,257,990	20,228,142	20,224,747	20,189,468	19,529,683
2020	18,133,965	18,161,733	18,180,168	18,056,231	18,041,063	17,951,050	15,292,056
2025	18,103,174	18,147,381	18,181,664	17,945,665	17,916,463	17,771,020	12,734,499
2035	19,745,847	19,809,449	19,866,650	19,460,737	19,411,428	19,219,623	11,050,380
Nitrogen oxides (NO_x)							
2015	2,305,222	2,303,592	2,303,383	2,303,044	2,302,880	2,302,005	2,287,093
2020	1,670,131	1,665,605	1,665,327	1,663,051	1,662,166	1,658,899	1,591,775
2025	1,426,220	1,419,408	1,419,329	1,413,528	1,411,801	1,406,061	1,257,625
2035	1,369,135	1,360,018	1,360,519	1,347,773	1,344,759	1,336,616	1,057,996

Table 3.3-3 (cont'd)

Reference Case Alternative CAFE Standards
Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Particulate matter ($PM_{2.5}$)							
2015	80,400	80,255	80,243	80,154	80,125	80,063	78,983
2020	82,456	81,999	81,968	81,713	81,620	81,578	78,508
2025	87,471	86,748	86,701	86,309	86,162	86,145	81,455
2035	99,707	98,692	98,625	98,064	97,853	97,861	91,101
Sulfur Oxides (SO_x)							
2015	208,833	207,885	207,789	207,454	207,308	206,810	196,733
2020	217,490	214,628	214,365	213,513	213,006	212,032	186,949
2025	232,179	227,690	227,288	226,014	225,200	223,848	186,356
2035	265,792	259,517	258,951	257,164	255,984	254,228	203,047
Volatile organic compounds (VOCs)							
2015	2,261,550	2,259,725	2,259,693	2,257,466	2,256,869	2,253,612	2,185,850
2020	1,896,683	1,890,797	1,890,924	1,883,693	1,881,584	1,873,852	1,671,209
2025	1,817,495	1,808,487	1,809,038	1,795,600	1,791,963	1,779,392	1,417,725
2035	1,906,119	1,894,399	1,896,272	1,869,506	1,863,351	1,844,280	1,205,722

Figure 3.3-2. Reference Case Alternative CAFE Standards Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks for 2035 (tons/year)



Total emissions are composed of four components: tailpipe emissions and upstream emissions for light duty vehicles, and tailpipe emissions and upstream emissions for light-duty trucks. To show the relationship among these four components for criteria pollutants, Table 3.3-4 breaks down the total emissions of criteria pollutants by component for calendar year 2035.

Table 3.3-4

Reference Case Alternative CAFE Standards
Nationwide Criteria Pollutant Emissions in 2035 from Passenger Cars and Light Trucks, by Vehicle Type (tons/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Carbon Monoxide (CO)							
Car Tailpipe	8,232,048	8,259,930	8,262,246	8,264,154	8,257,155	8,062,037	5,340,998
Car Upstream	58,993	57,008	56,921	56,842	56,690	56,400	46,240
Truck Tailpipe	11,385,451	11,424,837	11,480,102	11,072,930	11,031,252	11,035,398	5,609,016
Truck Upstream	69,355	67,674	67,381	66,811	66,330	65,788	54,127
Total	19,745,847	19,809,449	19,866,650	19,460,737	19,411,428	19,219,623	11,050,380
Nitrogen Oxides (NO_x)							
Car Tailpipe	265,972	266,933	267,007	267,064	266,875	261,223	182,669
Car Upstream	198,946	192,270	191,976	191,710	191,205	190,362	157,962
Truck Tailpipe	670,063	672,334	674,063	663,283	662,549	662,733	531,460
Truck Upstream	234,154	228,481	227,473	225,716	224,129	222,299	185,905
Total	1,369,135	1,360,018	1,360,519	1,347,773	1,344,759	1,336,616	1,057,996
Particulate Matter ($PM_{2.5}$)							
Car Tailpipe	26,878	27,077	27,085	27,092	27,122	27,430	32,798
Car Upstream	21,270	20,550	20,519	20,490	20,433	20,291	16,108
Truck Tailpipe	26,626	26,737	26,794	26,505	26,504	26,541	23,618
Truck Upstream	24,933	24,328	24,228	23,977	23,794	23,598	18,577
Total	99,707	98,692	98,625	98,064	97,853	97,861	91,101
Sulfur Oxides (SO_x)							
Car Tailpipe	16,297	16,365	16,370	16,374	16,367	16,094	12,432
Car Upstream	103,558	100,068	99,915	99,777	99,507	98,946	80,413
Truck Tailpipe	24,289	24,385	24,474	23,883	23,837	23,866	16,449
Truck Upstream	121,649	118,699	118,192	117,131	116,274	115,321	93,753
Total	265,792	259,517	258,951	257,164	255,984	254,228	203,047
Volatile Organic Compounds (VOCs)							
Car Tailpipe	503,670	505,435	505,573	505,662	505,301	494,490	342,794
Car Upstream	254,720	245,658	245,280	244,938	244,029	238,717	138,880
Truck Tailpipe	856,201	858,940	861,713	842,568	840,777	840,185	591,527
Truck Upstream	291,528	284,366	283,707	276,339	273,244	270,888	132,522
Total	1,906,119	1,894,399	1,896,272	1,869,506	1,863,351	1,844,280	1,205,722

Table 3.3-5 lists the net change in nationwide emissions from passenger cars and light trucks for the No Action Alternative for each of the criteria pollutants and analysis years. The table presents the action alternatives (Alternatives 2 through 7) left to right in order of increasing fuel economy requirements. In Table 3.3-5 the nationwide emissions reductions generally become greater from left to right, reflecting the increasing fuel economy requirements that are assumed under successive alternatives. Emissions of CO under Alternatives 2 and 3 are exceptions, showing increases compared to the No Action Alternative.

Table 3.3-5

Reference Case Alternative CAFE Standards
Nationwide Changes in Criteria Pollutant Emissions from Passenger Cars and Light Trucks
(tons/year) a/ b/

Pollutant and Year	Alt. 1 No Action c/	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Carbon Monoxide (CO)							
2015	0	11,651	16,193	-13,655	-17,049	-52,329	-712,114
2020	0	27,768	46,202	-77,734	-92,902	-182,915	-2,841,909
2025	0	44,207	78,490	-157,510	-186,711	-332,154	-5,368,675
2035	0	63,602	120,803	-285,110	-334,419	-526,225	-8,695,467
Nitrogen Oxides (NO_x)							
2015	0	-1,630	-1,839	-2,178	-2,342	-3,217	-18,130
2020	0	-4,526	-4,804	-7,080	-7,965	-11,232	-78,356
2025	0	-6,812	-6,891	-12,692	-14,419	-20,159	-168,595
2035	0	-9,117	-8,616	-21,363	-24,376	-32,519	-311,140
Particulate Matter ($PM_{2.5}$)							
2015	0	-146	-157	-246	-275	-337	-1,418
2020	0	-457	-488	-743	-836	-879	-3,948
2025	0	-722	-770	-1,162	-1,309	-1,326	-6,016
2035	0	-1,015	-1,082	-1,643	-1,854	-1,846	-8,606
Sulfur Oxides (SO_x)							
2015	0	-947	-1,043	-1,379	-1,525	-2,023	-12,099
2020	0	-2,862	-3,125	-3,977	-4,484	-5,458	-30,541
2025	0	-4,489	-4,891	-6,165	-6,979	-8,332	-45,823
2035	0	-6,275	-6,842	-8,628	-9,808	-11,565	-62,746
Volatile Organic Compounds (VOCs)							
2015	0	-1,825	-1,857	-4,084	-4,681	-7,938	-75,700
2020	0	-5,886	-5,758	-12,990	-15,099	-22,830	-225,474
2025	0	-9,008	-8,457	-21,895	-25,532	-38,103	-399,770
2035	0	-11,721	-9,847	-36,613	-42,768	-61,839	-700,397

a/ Emissions changes have been rounded to the nearest whole number.
b/ Negative emissions changes indicate reductions; positive emissions changes are increases.
c/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

3.3.3.2.2 Air Toxics

Under Alternative 1, No Action, the CAFE standards would remain at the MY 2010 level in future years. As with the criteria pollutants, current trends in the levels of air toxics emissions from vehicles would continue, with emissions continuing to decline due to the EPA emissions standards, despite a growth in total VMT. An exception to this general trend is DPM, for which emissions are projected to increase over time with the No Action Alternative. Also, the trends of declining emissions of benzene and formaldehyde are projected to reverse by 2035 absent other regulatory action, although emissions of benzene and formaldehyde in 2035 with the No Action Alternative will still be well below existing levels. The EPA regulates air toxics from motor vehicles through vehicle emissions standards and fuel quality standards, as discussed in Section 3.3.1. The No Action Alternative would not change the current CAFE standards and therefore would not result in any change in toxic air pollutant emissions, other than current trends, in nonattainment and maintenance areas throughout the United States.

Table 3.3-6 summarizes the total national emissions of air toxics from passenger cars and light trucks under the No Action Alternative for each of the pollutants and analysis years. Figure 3.3-3 lists the total national emissions of air toxics from passenger cars and light trucks by alternative. Emissions of benzene, 1,3-butadiene, and DPM are generally highest with the No Action Alternative and decrease with successive alternatives as fuel economy requirements increase. Emissions of formaldehyde, on the other hand, generally increase with successive alternatives and are highest with Alternative 7. The trend for acetaldehyde across the alternatives is mixed. Table 3.3-6 shows increases for acrolein generally with successive alternatives because data on upstream emissions reductions were not available. The emissions for acrolein in Table 3.3-6 reflect only the changes due to the rebound effect and technological changes

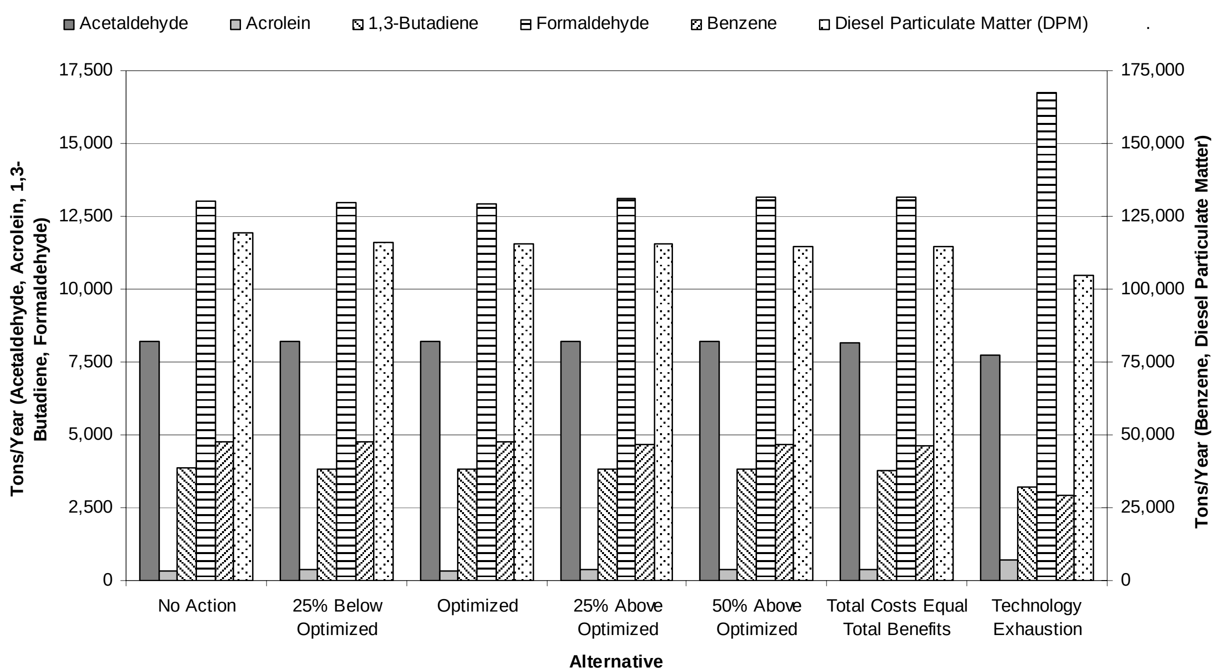
Table 3.3-6

Reference Case Alternative CAFE Standards
Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Acetaldehyde							
2015	11,982	11,978	11,976	11,985	11,987	11,991	12,093
2020	9,420	9,415	9,412	9,431	9,433	9,424	9,585
2025	8,401	8,396	8,395	8,408	8,409	8,388	8,372
2035	8,209	8,206	8,208	8,198	8,197	8,165	7,733
Acrolein a/							
2015	569	569	569	571	571	574	626
2020	429	430	429	436	437	442	596
2025	371	372	371	382	383	390	634
2035	351	354	353	367	369	378	720
Benzene							
2015	64,524	64,510	64,514	64,458	64,447	64,374	62,953
2020	51,781	51,731	51,751	51,531	51,490	51,310	46,246
2025	47,378	47,304	47,348	46,919	46,843	46,550	36,937
2035	47,515	47,428	47,517	46,703	46,570	46,154	29,324
1,3-butadiene							
2015	6,134	6,133	6,133	6,133	6,134	6,133	6,141
2020	4,698	4,689	4,689	4,687	4,685	4,680	4,617
2025	4,092	4,069	4,068	4,061	4,059	4,044	3,815
2035	3,885	3,834	3,834	3,818	3,815	3,781	3,231
Diesel particulate patter (DPM)							
2015	94,873	94,358	94,294	94,200	94,133	94,036	92,008
2020	98,292	96,762	96,587	96,387	96,154	95,993	91,105
2025	104,603	102,211	101,945	101,659	101,286	101,083	93,862
2035	119,499	116,161	115,786	115,400	114,858	114,592	104,644
Formaldehyde							
2015	17,382	17,359	17,351	17,388	17,393	17,421	18,018
2020	14,106	14,056	14,037	14,147	14,158	14,183	15,975
2025	12,930	12,862	12,835	12,995	13,010	13,035	15,713
2035	13,035	12,949	12,915	13,122	13,142	13,169	16,745

a/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

Figure 3.3-3. Reference Case Alternative CAFE Standards Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks for 2035 (tons/year)



analyzed in the Volpe model. Because the upstream emissions reductions result from the decline in the amount of fuel processed, it is reasonable that upstream acrolein emissions actually should vary as the other pollutants' upstream emissions do. Thus, the acrolein emissions given in Table 3.3-6 are an upper-bound estimate.

Total emissions are composed of four components: tailpipe emissions and upstream emissions for light duty vehicles, and tailpipe emissions and upstream emissions for light-duty trucks. To show the relationship among these four components for toxic air pollutants, Table 3.3-7 breaks down the total emissions of toxic air pollutants by component for calendar year 2035. The unavailability of data on upstream emissions of acrolein, as discussed in relation to Table 3.3-6, is evident in the zero values reported for upstream acrolein emissions in Table 3.3-7.

Table 3.3-8 lists the net change in nationwide emissions from passenger cars and light trucks for each of the air toxic pollutants and analysis years. After the No Action Alternative (Alternative 1), the action alternatives (Alternatives 2 through 7) are presented left to right in order of increasing fuel economy requirements. In Table 3.3-8, the nationwide emissions changes are uneven with respect to pollutant and alternative though most demonstrate reductions, reflecting the changes in VMT and emissions by cars versus trucks and gasoline versus diesel engines that are projected to occur with the increasing fuel economy requirements assumed under successive alternatives. Data on upstream emissions reductions were not available for acrolein, as noted above. Thus, the acrolein emissions changes given in Table 3.3-8 are an upper-bound estimate.

Table 3.3-7

Reference Case Alternative CAFE Standards
Nationwide Toxic Air Pollutant Emissions in 2035 from Passenger Cars and Light Trucks, by Vehicle Type (tons/year)

Pollutant and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Acetaldehyde							
Car Tailpipe	2,350	2,361	2,361	2,362	2,362	2,335	1,999
Car Upstream	509	491	491	490	488	485	378
Truck Tailpipe	4,755	4,773	4,777	4,774	4,779	4,782	4,923
Truck Upstream	595	581	578	572	567	563	433
Total	8,209	8,206	8,208	8,198	8,197	8,165	7,733
Acrolein a/							
Car Tailpipe	110	112	112	112	113	121	252
Car Upstream	0	0	0	0	0	0	0
Truck Tailpipe	241	242	241	254	257	257	467
Truck Upstream	0	0	0	0	0	0	0
Total	351	354	353	367	369	378	720
Benzene							
Car Tailpipe	14,071	14,118	14,122	14,125	14,113	13,780	9,100
Car Upstream	3,447	3,328	3,323	3,318	3,307	3,261	2,268
Truck Tailpipe	26,000	26,083	26,187	25,442	25,368	25,363	15,516
Truck Upstream	3,996	3,898	3,886	3,817	3,782	3,750	2,440
Total	47,515	47,428	47,517	46,703	46,570	46,154	29,324
1,3-butadiene							
Car Tailpipe	1,190	1,198	1,200	1,197	1,196	1,198	1,114
Car Upstream	156	144	143	141	140	138	115
Truck Tailpipe	2,355	2,319	2,320	2,311	2,313	2,285	1,873
Truck Upstream	183	174	171	168	166	160	130
Total	3,885	3,834	3,834	3,818	3,815	3,781	3,231
Diesel particulate matter (DPM)							
Car Tailpipe	56	129	129	129	165	804	10,409
Car Upstream	54,828	52,967	52,885	52,812	52,662	52,256	40,933
Truck Tailpipe	424	433	391	772	826	832	6,396
Truck Upstream	64,191	62,632	62,380	61,686	61,205	60,700	46,906
Total	119,499	116,161	115,786	115,400	114,858	114,592	104,644
Formaldehyde							
Car Tailpipe	2,630	2,652	2,653	2,653	2,658	2,711	3,581
Car Upstream	2,153	2,080	2,077	2,074	2,068	2,054	1,628
Truck Tailpipe	5,729	5,755	5,734	5,968	6,008	6,016	9,660
Truck Upstream	2,523	2,462	2,452	2,426	2,408	2,388	1,875
Total	13,035	12,949	12,915	13,122	13,142	13,169	16,745

a/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

Table 3.3-8

Reference Case Alternative CAFE Standards Nationwide Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) a/ b/

Pollutant and Year	Alt. 1 No Action c/	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Acetaldehyde							
2015	0	-4	-6	3	5	9	111
2020	0	-5	-8	10	12	4	164
2025	0	-5	-6	7	8	-13	-29
2035	0	-3	-1	-11	-12	-44	-475
Acrolein d/							
2015	0	0	0	2	2	5	57
2020	0	1	0	7	8	12	167
2025	0	2	1	11	13	19	264
2035	0	3	1	15	18	27	368
Benzene							
2015	0	-13	-10	-66	-76	-150	-1,570
2020	0	-50	-30	-250	-291	-471	-5,535
2025	0	-74	-30	-459	-535	-828	-10,441
2035	0	-87	2	-812	-945	-1,361	-18,191
1,3-butadiene							
2015	0	-1	-1	-1	-1	-1	7
2020	0	-9	-10	-12	-13	-19	-81
2025	0	-23	-24	-31	-33	-48	-277
2035	0	-51	-52	-67	-70	-104	-654
Diesel particulate matter (DPM)							
2015	0	-515	-579	-673	-740	-837	-2,865
2020	0	-1,530	-1,704	-1,905	-2,138	-2,298	-7,187
2025	0	-2,392	-2,658	-2,944	-3,317	-3,519	-10,740
2035	0	-3,339	-3,713	-4,100	-4,641	-4,907	-14,855
Formaldehyde							
2015	0	-24	-32	6	11	39	636
2020	0	-50	-69	42	52	77	1,870
2025	0	-68	-95	65	80	105	2,783
2035	0	-86	-120	87	106	133	3,709

a/ Emissions changes have been rounded to the nearest whole number.
b/ Negative emissions changes indicate reductions; positive emissions changes are increases.
c/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions from the action alternatives are compared.
d/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

3.3.3.2.3 Health Outcomes and Costs

Under Alternative 1, No Action, the CAFE standards would remain at the MY 2010 level in future years. Current trends in the levels of criteria pollutants and air toxics emissions from vehicles would continue, with emissions continuing to decline due to the EPA emissions standards, despite a growth in total VMT. The human health effects and health-related costs that occur under current trends would continue, and are expected to decline in the future as a result of declines in pollutant emissions. The No Action Alternative would not result in any other increase or decrease in human health effects and health-related costs throughout the United States.

3.3.3.3 Reference Case Alternative 2: 25 Percent Below Optimized

3.3.3.3.1 Criteria Pollutants

Under the 25 Percent Below Optimized Alternative (Alternative 2), generally the CAFE standards would require increased fuel economy compared to the No Action Alternative (Alternative 1). Alternative 2 would increase fuel economy less than would Alternatives 3 through 7. There would be reductions in nationwide emissions of NO_x, $PM_{2.5}$, SO_x, and VOC under Alternative 2 compared to the No Action Alternative. Depending on the year, NO_x emissions would be reduced 0.1 to 0.7 percent, $PM_{2.5}$ emissions would be reduced 0.2 to 1.0 percent, SO_x emissions would be reduced 0.5 to 2.4 percent, and VOC emissions would be reduced 0.1 to 0.6 percent. There would be increases of CO emissions. CO emissions would increase 0.1 to 1.3 percent with Alternative 2 depending on the year.

At the nationwide level, the reduction in upstream emissions of criteria air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. For example, a nonattainment area that contains petroleum refining facilities, such as Houston-Galveston-Brazoria, Texas, would experience more reductions in upstream emissions than an area that has none. Net emissions reductions can occur if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect. With Alternative 2, all nonattainment areas would experience reductions in emissions of NO_x, SO_x and VOC. Most nonattainment areas would experience increases of CO and $PM_{2.5}$ emissions. The increases in CO and $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Although $PM_{2.5}$ emissions would increase in most nonattainment areas the increase in each area is quite small. The decreases in nationwide $PM_{2.5}$ emissions are the result of the decreases in upstream emissions and do not occur in all nonattainment areas. Although $PM_{2.5}$ emissions would decrease in fewer nonattainment areas the decreases in each area are much larger. The net result is decreased $PM_{2.5}$ emissions nationwide.

Tables in Appendix B-2 list the emissions reductions for each nonattainment area. Table 3.3-9 summarizes the criteria air pollutant results by nonattainment area.

Table 3.3-9

Reference Case Alternative CAFE Standards
Changes in Criteria Pollutant Emissions from Passenger Cars and Light Trucks,
Maximum Changes by Nonattainment Area a/

Criteria Pollutant	Increase/ Decrease	Change (tons/year)	Year	Alt. No.	Nonattainment Area
CO	Maximum Increase	5,956	2035	3	Los Angeles South Coast Air Basin, CA
	Maximum Decrease	-432,141	2035	7	Los Angeles South Coast Air Basin, CA
NO_x	Maximum Increase	1	2035	3	Charlotte-Gastonia-Rock Hill, NC-SC
	Maximum Decrease	-16,115	2035	7	Los Angeles South Coast Air Basin, CA
$PM_{2.5}$	Maximum Increase	62	2035	7	Atlanta, GA
	Maximum Decrease	-1,344	2035	7	Houston-Galveston-Brazoria, TX
SO_x	Maximum Increase	No SO_x increases			
	Maximum Decrease	-5,624	2035	7	Houston-Galveston-Brazoria, TX
VOCs	Maximum Increase	No VOC increases			
	Maximum Decrease	-35,062	2035	7	Los Angeles South Coast Air Basin, CA

a/ Emissions changes have been rounded to the nearest whole number.

3.3.3.3.2 Air Toxics

There would be reductions in nationwide emissions of all toxic air pollutants (except acrolein) under Alternative 2 compared to the No Action Alternative.

Alternative 2 would have the same or higher emissions of acetaldehyde, acrolein, 1,3-butadiene, DPM, and formaldehyde, but lower emissions of benzene, compared to Alternative 3. Compared to Alternatives 4 through 7, Alternative 2 would have higher emissions of benzene, 1,3-butadiene (except in 2015), and DPM, but lower emissions of acrolein and formaldehyde, and mixed results for acetaldehyde depending on the year and alternative. At the nationwide level, the reduction in upstream emissions of toxic air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, as noted above, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. For example, a nonattainment area that contains petroleum refining facilities, such as Houston-Galveston-Brazoria, Texas, would experience more reductions in upstream emissions than an area that has none. Net emissions reductions can occur if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect.

Under Alternative 2, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2). However, the sizes of the emissions increases would be quite small, as shown in Appendix B-2, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.3.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide under Alternative 2 compared to the No Action Alternative (see Table 3.3-10). These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. In comparison to the No Action Alternative, Alternative 2 would reduce mortalities by 78 and the number of work-loss days by 13,877 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-11 lists the corresponding reductions in health costs under Alternative 2 compared to the No Action Alternative. Alternative 2 would reduce health costs by $173 million in 2035.

Table 3.3-10

Reference Case Alternative CAFE Standards
Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions from Passenger Cars and Light Trucks (cases/year) a/

Health Outcome and Year	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action b/	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Mortality (ages 30 and older)							
2015	0	-11	-12	-19	-21	-26	-109
2020	0	-35	-37	-57	-64	-67	-303
2025	0	-55	-59	-89	-100	-102	-461
2035	0	-78	-83	-126	-142	-142	-660
Chronic bronchitis							
2015	0	-10	-10	-16	-18	-22	-95
2020	0	-30	-33	-50	-56	-59	-263
2025	0	-48	-51	-77	-87	-88	-401
2035	0	-68	-72	-110	-124	-123	-574

Table 3.3-10 (cont'd)

Reference Case Alternative CAFE Standards
Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions
from Passenger Cars and Light Trucks (cases/year) a/

Health Outcome and Year	Alt. 1 No Action b/	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Emergency room visits for asthma							
2015	0	-2	-3	-4	-4	-5	-23
2020	0	-7	-8	-12	-13	-14	-63
2025	0	-12	-12	-19	-21	-21	-96
2035	0	-16	-17	-26	-30	-30	-138
Work-loss days							
2015	0	-1,991	-2,147	-3,362	-3,756	-4,603	-19,376
2020	0	-6,251	-6,675	-10,159	-11,428	-12,007	-53,957
2025	0	-9,874	-10,523	-15,885	-17,886	-18,116	-82,216
2035	0	-13,877	-14,789	-22,456	-25,339	-25,233	-117,617

a/ Negative changes indicate reductions; positive emissions changes are increases.
b/ Changes in health outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions under the action alternatives are compared.

Table 3.3-11

Reference Case Alternative CAFE Standards
Nationwide Changes in Health Costs from Criteria Pollutant Emissions
from Passenger Cars and Light Trucks (U.S. million dollars/year) a/

Year	Alt. 1 No Action b/	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
2015	0	-20	-22	-29	-31	-42	-239
2020	0	-82	-88	-121	-136	-175	-1,081
2025	0	-126	-133	-200	-227	-289	-1,997
2035	0	-173	-179	-307	-349	-435	-3,329

a/ Negative changes indicate economic benefit; positive emissions changes are economic costs.
b/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions under the action alternatives are compared.

3.3.3.4 Reference Case Alternative 3: Optimized

3.3.3.4.1 Criteria Pollutants

Under the Optimized Alternative (Alternative 3), generally the CAFE standards would increase fuel economy more than would Alternative 2 but less than would Alternatives 4 through 7. There would be reductions in nationwide emissions of NO_x, $PM_{2.5}$, SO_x, and VOC under Alternative 3 compared to the No Action Alternative. Depending on the year, NO_x emissions would be reduced 0.1 to 0.6 percent,

$PM_{2.5}$ emissions would be reduced 0.2 to 1.1 percent SO_x emissions would be reduced 0.5 to 2.6 percent, and VOC emissions would be reduced 0.1 to 0.5 percent. These emissions reductions are generally greater (except for VOC) than would occur with Alternative 2 but less than would occur with Alternatives 4 through 7. There would be increases of CO emissions. CO emissions would increase 0.1 to 0.6 percent depending on the year. With Alternative 3, all nonattainment areas would experience reductions in emissions of SO_x and VOC, and almost all would experience reductions in NO_x emissions. Most nonattainment areas would experience increases of CO and $PM_{2.5}$ emissions. The increases in CO and $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Although $PM_{2.5}$ emissions would increase in most nonattainment areas the increase in each area is quite small. The decreases in nationwide $PM_{2.5}$ emissions are the result of the decreases in upstream emissions and do not occur in all nonattainment areas. Although $PM_{2.5}$ emissions would decrease in fewer nonattainment areas the decreases in each area are much larger. The net result is decreased $PM_{2.5}$ emissions nationwide.

Tables in Appendix B-2 list the emissions reductions for each nonattainment area. Table 3.3-12 summaries the criteria air pollutant results by nonattainment area.

Table 3.3-12

Reference Case Alternative CAFE Standards
Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area

Hazardous Air Pollutant	Increase/Decrease	Change (tons/year)	Year	Alt. No.	Nonattainment Area
Acetaldehyde	Maximum increase	11	2020	7	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum decrease	-41	2035	7	Houston-Galveston-Brazoria, TX
Acrolein	Maximum increase	18	2035	7	Los Angeles South Coast Air Basin, CA
	Maximum decrease	-0.02	2015	3	Los Angeles South Coast Air Basin, CA
Benzene	Maximum increase	7	2035	3	Atlanta, GA
	Maximum decrease	-960	2035	7	Los Angeles South Coast Air Basin, CA
1,3-butadiene	Maximum increase	1	2015	7	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum decrease	-35	2035	7	Los Angeles South Coast Air Basin, CA
Diesel particulate matter	Maximum increase	No increase			
	Maximum decrease	-697	2035	7	Los Angeles South Coast Air Basin, CA
Formaldehyde	Maximum increase	161	2035	7	Los Angeles South Coast Air Basin, CA
	Maximum decrease	-72	2035	7	Houston-Galveston-Brazoria, TX

a/ Emissions changes have been rounded to the nearest whole number except to present values greater than zero but less than one.

3.3.3.4.2 Air Toxics

Alternative 3 would reduce air toxics emissions compared to the No Action Alternative for all air toxics (except acrolein in all analysis years and benzene in 2035). Alternative 3 would have higher emissions of benzene, 1,3-butadiene (except in 2015), and DPM compared to Alternatives 4 through 7. Alternative 3 would have lower emissions of acrolein and formaldehyde compared to Alternatives 4 through 7, and mixed results for acetaldehyde depending on the year and alternative.

At the nationwide level, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect.

However, as with Alternative 2, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 3, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2). However, the sizes of the emissions increases would be quite small, as shown in Appendix B-2, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.4.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide with the Optimized Alternative compared to the No Action Alternative, as shown in Table 3.3-10. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. In comparison to the No Action Alternative, Alternative 3 would reduce mortalities by 83 and the number of work-loss days by 14,789 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-11 lists the corresponding reductions in health costs under Alternative 3 compared to the No Action Alternative. Alternative 3 would reduce health costs by $179 million in 2035.

3.3.3.5 Reference Case Alternative 4: 25 Percent Above Optimized

3.3.3.5.1 Criteria Pollutants

Under the 25 Percent Above Optimized Alternative (Alternative 4), the CAFE standards would increase fuel economy more than would Alternatives 1 through 3 but less than would Alternatives 5 through 7. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 4. Percent reductions would range from 0.1 to 3.2, depending on the year and pollutant. These emissions reductions are greater than would occur with Alternative 3 but less than would occur with Alternatives 5 through 7. With Alternative 4, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_x and VOC. Most nonattainment areas would experience increases of $PM_{2.5}$ emissions in 2015 and 2020 compared to the No Action Alternative. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

3.3.3.5.2 Air Toxics

Alternative 4 would reduce air toxics emissions of acetaldehyde (in 2035), benzene, 1,3-butadiene, and DPM, but would increase emissions of acetaldehyde (except in 2035), acrolein, and formaldehyde compared to the No Action Alternative.

Alternative 4 would have higher emissions of benzene, 1,3-butadiene (except in 2015), and DPM compared to Alternatives 5 through 7. Alternative 4 would have lower emissions of acrolein and formaldehyde compared to Alternatives 5 through 7, and mixed results for acetaldehyde depending on the year and alternative.

At the nationwide level, emissions of toxic air pollutants might decrease, because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with Alternative 3, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 4, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2). However, the sizes of the emissions increases would be quite small, as shown in Appendix B-2. Potential air quality impacts from these increases would be minor, because the VMT and emissions increases would be distributed throughout each nonattainment area.

3.3.3.5.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide under Alternative 4 compared to the No Action Alternative, as shown in Table 3.3-10. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. In comparison to the No Action Alternative, Alternative 4 would reduce mortalities by 126 and the number of work-loss days by 22,456 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-11 lists the corresponding reductions in health costs under Alternative 4 compared to the No Action Alternative. Alternative 4 would reduce health costs by $307 million in 2035.

3.3.3.6 Reference Case Alternative 5: 50 Percent Above Optimized

3.3.3.6.1 Criteria Pollutants

Under the 50 Percent Above Optimized Alternative (Alternative 5), the CAFE standards would increase fuel economy more than would Alternatives 1 through 4 but less than would Alternatives 6 and 7. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 5. Reductions would be greater than under Alternative 4 but less than under Alternatives 6 and 7. Percent reductions would range from 0.1 to 3.7 compared to the No Action Alternative, depending on the year and pollutant. All individual nonattainment areas would experience reductions in emissions of CO, NO_x, SO_x, and VOCs. $PM_{2.5}$ emissions would increase in most nonattainment areas in 2015 and 2020 and would decrease in some compared to the No Action Alternative. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

3.3.3.6.2 Air Toxics

Alternative 5 would reduce air toxics emissions of acetaldehyde (in 2035), benzene, 1,3-butadiene, and DPM, but would increase emissions of acetaldehyde (except 2035), acrolein, and formaldehyde compared to the No Action Alternative. Alternative 5 would have higher emissions of benzene, 1,3-butadiene (except for Alternative 7 in 2015), and DPM compared to Alternatives 6 and 7. Alternative 5 would have lower emissions of acrolein and formaldehyde compared to Alternatives 6 and 7, and mixed results for acetaldehyde depending on the year and alternative.

At the nationwide level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with the Alternative 4, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 5, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2). However, the sizes of the emissions increases would be quite small, as shown in Appendix B-2, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.6.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide under Alternative 5 compared to the No Action Alternative, as shown in Table 3.3-10. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. Compared to the No Action Alternative, Alternative 5 would reduce mortalities by 142 and the number of work-loss days by 25,339 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-11 lists the corresponding reductions in health costs under

Alternative 5 compared to the No Action Alternative. Alternative 5 would reduce health costs by $349 million in 2035.

3.3.3.7 Reference Case Alternative 6: Total Costs Equal Total Benefits

3.3.3.7.1 Criteria Pollutants

Under the Total Costs Equal Total Benefits Alternative (Alternative 6), the CAFE standards would increase fuel economy more than would Alternatives 1 through 5 but less than would Alternative 7. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 6 compared to the No Action Alternative. Reductions would be greater than under Alternative 5 (except for $PM_{2.5}$ in 2035) but less than under Alternative 7. Compared to the No Action Alternative, percent reductions would range from 0.1 to 4.4, depending on the year and pollutant. All individual nonattainment areas would experience reductions in emissions of CO, NO_x, SO_x, and VOCs. $PM_{2.5}$ emissions would increase in most nonattainment areas and decrease in some compared to the No Action Alternative. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

3.3.3.7.2 Air Toxics

Alternative 6 would reduce air toxics emissions of acetaldehyde (in 2025 and 2035), benzene, 1,3-butadiene, and DPM, but would increase emissions of acetaldehyde (in 2015 and 2020), acrolein, and formaldehyde compared to the No Action Alternative. Alternative 6 would have higher emissions of acetaldehyde (in 2025 and 2035), benzene, 1,3-butadiene (except in 2015), and DPM compared to Alternative 7. Alternative 6 would have lower emissions of acetaldehyde (in 2015 and 2020), acrolein, 1,3-butadiene (except in 2015), and formaldehyde compared to Alternative 7.

At the nationwide level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with the Alternative 6, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 6, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2). However, the sizes of the emissions increases would be quite small, as shown in Appendix B-2, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.7.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide under Alternative 6 compared to the No Action Alternative, as shown in Table 3.3-10. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. Compared to the No Action Alternative, the Alternative 6 would reduce mortalities by 142 and the number of work-loss days by 25,233 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-11 lists the corresponding reductions in health costs under Alternative 6 compared to the No Action Alternative. Alternative 6 would reduce health costs by $435 million in 2035.

3.3.3.8 Reference Case Alternative 7: Technology Exhaustion

3.3.3.8.1 Criteria Pollutants

Under the Technology Exhaustion Alternative (Alternative 7), the CAFE standards would increase fuel economy more than all the other alternatives. There would be greater reductions in nationwide emissions of criteria pollutants under Alternative 7 than with any other alternative: between 0.8 percent and 44 percent compared to the No Action Alternative, depending on year and pollutant. All individual nonattainment areas would experience reductions in emissions of CO, NO_x, SO_x, and VOCs. $PM_{2.5}$ emissions would increase in most nonattainment areas and decrease in some compared to the No Action Alternative. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

3.3.3.8.2 Air Toxics

Alternative 7 would reduce air toxics emissions of acetaldehyde (in 2025 and 2035), benzene, 1,3-butadiene (except in 2015), and DPM, but would increase emissions of acetaldehyde (in 2015 and 2020), acrolein, 1,3-butadiene (in 2015), and formaldehyde compared to the No Action Alternative.

At the nationwide level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with the Alternative 6, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 7, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2). In general, of all the Alternatives, Alternative 7 results in the largest emissions changes (either increases or decreases) relative to the No Action Alternative. As shown in Appendix B-2, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.8.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide under Alternative 7 compared to the No Action Alternative, as shown in Table 3.3-10. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. Compared to the No Action Alternative, Alternative 7 would reduce mortalities by 660 and the number of work-loss days by 117,617 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-11 lists the corresponding reductions in health costs under Alternative 7 compared to the No Action Alternative. Alternative 7 would reduce health costs by $3.329 billion in 2035.

3.3.4 Input Scenarios

3.3.4.1 Results of the Emissions Analysis

The CAA has been a success in reducing emissions from on-road mobile sources. As discussed in Section 3.3.1, pollutant emissions from vehicles have been declining since 1970, and EPA projects that they will continue to decline. This trend will continue regardless of the alternative chosen for future CAFE standards. The analysis by alternatives in this section shows that the alternative CAFE standards from the High, Mid-1, and Mid-2 Scenarios would lead to further reductions in emissions from passenger cars and light trucks. The amount of the reductions would vary by alternative. The more restrictive High Scenario alternatives would result in greater emissions reductions compared to the No Action Alternative. Under all of the High Scenario action alternatives, there are no emissions increases that would exceed any of the general conformity thresholds.

3.3.4.2 High Scenario Alternative 1: No Action

3.3.4.2.1 Criteria Pollutants

With the High Scenario No Action Alternative, the CAFE standards would remain at the MY 2010 level in future years. Current trends in the levels of emissions from vehicles would continue, with emissions continuing to decline due to the EPA emissions standards, despite a growth in total VMT. The EPA vehicle emissions standards regulate all criteria pollutants except SO_2, which is regulated through fuel sulfur content. The High Scenario No Action Alternative would not change the current CAFE standards and so would not result in any change in criteria pollutant emissions, other than current trends, in nonattainment and maintenance areas throughout the United States.

Table 3.3-13 summarizes the total national emissions from passenger cars and light trucks for the High Scenario No Action Alternative for each of the criteria pollutants and analysis years. The table presents the other High Scenario alternatives (Alternatives 2 through 7) left to right in order of increasing fuel economy requirements. Table 3.3-13 shows that the No Action Alternative has the highest emissions of all the High Scenario alternatives for all criteria pollutants.

Table 3.3-13

High Scenario Alternative CAFE Standards
Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

Pollutant and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Carbon monoxide (CO)							
2015	18,861,709	18,819,943	18,808,145	18,754,377	18,733,187	18,676,711	18,198,147
2020	16,619,854	16,400,691	16,407,324	16,205,551	16,099,145	15,924,287	14,015,233
2025	16,403,499	15,959,939	16,005,225	15,620,887	15,415,228	15,106,788	11,538,880
2035	17,713,991	16,946,492	17,052,955	16,475,978	16,127,830	15,629,753	9,913,291
Nitrogen oxides (NO_x)							
2015	2,148,052	2,144,337	2,143,274	2,141,461	2,140,580	2,139,457	2,131,158
2020	1,530,682	1,516,245	1,514,017	1,507,360	1,504,399	1,499,924	1,458,868
2025	1,292,315	1,264,972	1,262,749	1,249,455	1,243,068	1,233,920	1,139,549
2035	1,228,251	1,181,455	1,180,414	1,159,073	1,146,599	1,129,532	949,127
Particulate matter ($PM_{2.5}$)							
2015	74,919	74,512	74,388	74,358	74,277	74,101	73,597
2020	75,571	74,304	74,071	74,100	73,822	73,539	71,953
2025	79,258	77,281	76,963	77,052	76,611	76,253	73,807
2035	89,447	86,654	86,251	86,389	85,756	85,318	81,727
Sulfur oxides (SO_x)							
2015	194,594	192,146	191,518	190,557	189,965	189,139	183,320
2020	199,331	191,631	190,421	188,360	186,988	185,366	171,340
2025	210,380	198,302	196,642	193,696	191,711	189,468	168,860
2035	238,442	221,475	219,361	215,533	212,881	209,978	182,153
Volatile organic compounds (VOCs)							
2015	2,107,357	2,098,536	2,096,674	2,089,984	2,087,215	2,082,262	2,036,819
2020	1,738,318	1,707,595	1,705,389	1,687,741	1,679,750	1,666,745	1,531,670
2025	1,646,853	1,593,668	1,592,155	1,561,539	1,547,465	1,525,528	1,284,617
2035	1,709,979	1,620,442	1,621,526	1,572,211	1,546,659	1,507,558	1,081,653

Table 3.3-14 lists the net change in nationwide emissions from passenger cars and light trucks for the High Scenario No Action Alternative for each of the criteria pollutants and analysis years. The table presents Alternatives 2 through 7 left to right in order of increasing fuel economy requirements. In Table 3.3-14, the nationwide emissions reductions tend to become greater from left to right, reflecting the increasing fuel economy requirements that are assumed under successive High Scenario alternatives.

Table 3.3-14

High Scenario Alternative CAFE Standards
Nationwide Changes in Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) a/ b/

Pollutant and Year	Alt. 1 No Action c/	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Carbon monoxide (CO)							
2015	0	-41,765	-53,563	-107,331	-128,521	-184,997	-663,562
2020	0	-219,163	-212,530	-414,303	-520,709	-695,567	-2,604,621
2025	0	-443,561	-398,274	-782,612	-988,271	-1,296,712	-4,864,620
2035	0	-767,499	-661,036	-1,238,012	-1,586,160	-2,084,237	-7,800,700
Nitrogen oxides (NO_x)							
2015	0	-3,715	-4,778	-6,591	-7,472	-8,595	-16,893
2020	0	-14,437	-16,665	-23,322	-26,283	-30,758	-71,814
2025	0	-27,343	-29,565	-42,859	-49,247	-58,394	-152,765
2035	0	-46,796	-47,837	-69,178	-81,652	-98,719	-279,123
Particulate matter ($PM_{2.5}$)							
2015	0	-407	-531	-561	-642	-817	-1,321
2020	0	-1,268	-1,501	-1,471	-1,750	-2,032	-3,618
2025	0	-1,977	-2,295	-2,206	-2,647	-3,005	-5,451
2035	0	-2,793	-3,196	-3,058	-3,691	-4,130	-7,721
Sulfur oxides (SO_x)							
2015	0	-2,448	-3,077	-4,037	-4,629	-5,455	-11,274
2020	0	-7,699	-8,910	-10,971	-12,343	-13,964	-27,991
2025	0	-12,079	-13,738	-16,685	-18,670	-20,913	-41,521
2035	0	-16,967	-19,081	-22,909	-25,562	-28,464	-56,289
Volatile organic compounds (VOCs)							
2015	0	-8,821	-10,683	-17,373	-20,143	-25,095	-70,539
2020	0	-30,723	-32,929	-50,576	-58,568	-71,573	-206,648
2025	0	-53,185	-54,699	-85,314	-99,389	-121,326	-362,236
2035	0	-89,537	-88,453	-137,767	-163,320	-202,421	-628,326

a/ Emissions changes have been rounded to the nearest whole number.
b/ Negative changes indicate reductions; positive emissions changes are increases.
c/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions under the action alternatives are compared.

3.3.4.2.2 Air Toxics

With the High Scenario No Action Alternative, the CAFE standards would remain at the MY 2010 level in future years. As with the criteria pollutants, current trends in the levels of air toxics emissions from vehicles would continue, with emissions continuing to decline due to the EPA emissions standards, despite a growth in total VMT. The EPA regulates air toxics from motor vehicles through vehicle emissions standards and fuel quality standards, as discussed in Section 3.3.1. The High Scenario No Action Alternative would not change the current CAFE standards and therefore would not result in any change in toxic air pollutant emissions, other than current trends, in nonattainment and maintenance areas throughout the United States.

Table 3.3-15 summarizes the total national emissions of air toxics from passenger cars and light trucks with the High Scenario No Action Alternative for each of the pollutants and analysis years. The Table presents Alternatives 2 through 7 left to right in order of increasing fuel economy requirements. Emissions of acetaldehyde (except in 2015 and 2020), benzene, 1,3-butadiene (except in 2015), and DPM

Table 3.3-15

High Scenario Alternative CAFE Standards
Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

Pollutant and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Acetaldehyde							
2015	11,165	11,174	11,177	11,176	11,180	11,194	11,268
2020	8,634	8,651	8,649	8,630	8,644	8,658	8,784
2025	7,613	7,612	7,612	7,565	7,576	7,577	7,586
2035	7,364	7,318	7,326	7,244	7,239	7,211	6,938
Acrolein a/							
2015	530	535	536	540	542	546	583
2020	393	410	410	421	428	438	547
2025	336	364	363	381	391	405	575
2035	315	356	353	379	393	412	646
Benzene							
2015	60,125	59,974	59,938	59,809	59,756	59,640	58,661
2020	47,458	46,853	46,823	46,428	46,220	45,882	42,385
2025	42,930	41,796	41,810	41,077	40,678	40,081	33,469
2035	42,626	40,639	40,753	39,588	38,860	37,822	26,306
1,3-butadiene							
2015	6,134	6,134	6,133	6,133	6,134	6,134	6,141
2020	4,698	4,689	4,688	4,683	4,679	4,672	4,617
2025	4,092	4,064	4,064	4,048	4,034	4,014	3,815
2035	3,885	3,815	3,821	3,790	3,754	3,709	3,231
Diesel particulate matter (DPM)							
2015	88,405	87,309	87,001	86,862	86,662	86,383	85,735
2020	90,085	86,724	86,018	85,878	85,419	85,009	83,498
2025	94,782	89,537	88,510	88,394	87,730	87,230	85,050
2035	107,203	99,856	98,495	98,385	97,499	96,932	93,876
Formaldehyde							
2015	16,197	16,228	16,237	16,264	16,282	16,346	16,790
2020	12,928	13,044	13,027	13,086	13,173	13,300	14,641
2025	11,716	11,893	11,857	11,946	12,080	12,250	14,238
2035	11,694	11,933	11,878	12,000	12,178	12,394	15,022

a/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

are generally highest under the No Action Alternative. Emissions of acetaldehyde (in 2015 and 2020), acrolein, and formaldehyde are generally lowest with High Scenario Alternative 1. Table 3.3-15 shows increases for acrolein with High Scenario Alternatives 2 through 7, because data on upstream emissions reductions were not available. The emissions for acrolein in Table 3.3-15 reflect only the increases due to the rebound effect and manufacturer changes in response to the fuel economy standards. Thus, the acrolein emissions given in Table 3.3-15 are an upper-bound estimate.

Table 3.3-16 lists the net change in nationwide emissions from passenger cars and light trucks for the High Scenario No Action Alternative for each of the air toxic pollutants and analysis years. The table presents Alternatives 2 through 7 left to right in order of increasing fuel economy requirements. In Table 3.3-16 the nationwide emissions reductions or increases tend to become greater from left to right, reflecting the increasing fuel economy requirements that are assumed under successive alternatives, except for the cases noted above and for acrolein.

Table 3.3-16

High Scenario Alternative CAFE Standards Nationwide Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) a/ b/

Pollutant and Year	Alt. 1 No Action c/	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Acetaldehyde							
2015	0	9	12	11	15	29	103
2020	0	17	15	-4	10	24	151
2025	0	0	0	-48	-36	-35	-27
2035	0	-46	-37	-120	-125	-153	-426
Acrolein d/							
2015	0	5	6	10	12	16	53
2020	0	17	17	28	34	44	153
2025	0	28	27	45	55	69	239
2035	0	40	38	64	77	97	330
Benzene							
2015	0	-150	-187	-316	-369	-484	-1,463
2020	0	-605	-634	-1,030	-1,238	-1,575	-5,073
2025	0	-1,134	-1,119	-1,853	-2,252	-2,849	-9,461
2035	0	-1,986	-1,872	-3,037	-3,766	-4,803	-16,320
1,3-butadiene							
2015	0	0	-1	-1	0	-1	7
2020	0	-9	-11	-15	-19	-27	-81
2025	0	-29	-28	-44	-58	-79	-277
2035	0	-71	-64	-95	-131	-177	-654
Diesel particulate matter (DPM)							
2015	0	-1,095	-1,403	-1,543	-1,743	-2,021	-2,670
2020	0	-3,361	-4,067	-4,206	-4,665	-5,075	-6,587
2025	0	-5,245	-6,271	-6,387	-7,052	-7,552	-9,732
2035	0	-7,346	-8,707	-8,818	-9,704	-10,271	-13,326
Formaldehyde							
2015	0	31	39	66	85	148	592
2020	0	117	99	158	246	372	1,714
2025	0	177	141	230	364	534	2,522
2035	0	239	185	306	484	700	3,328

a/ Emissions changes have been rounded to the nearest whole number.
b/ Negative changes indicate reductions; positive emissions changes are increases.
c/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions under the action alternatives are compared.
d/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

3.3.4.2.3 Health Outcomes and Costs

With the High Scenario No Action Alternative, the CAFE standards would remain at the MY 2010 level in future years. Current trends in the levels of criteria pollutants and air toxics emissions from vehicles would continue, with emissions continuing to decline due to the EPA emissions standards, despite a growth in total VMT. The human health effects and health-related costs that occur under current trends would continue and are expected to decline in the future as a result of declines in pollutant emissions. The High Scenario No Action Alternative would not result in any other increase or decrease in human health effects and health-related costs throughout the United States.

3.3.4.3 High Scenario Alternative 2: 25 Percent Below Optimized

3.3.4.3.1 Criteria Pollutants

With High Scenario Alternative 2, the CAFE standards would require increased fuel economy compared to the High Scenario No Action Alternative. Generally, High Scenario Alternative 2 would increase fuel economy less than would High Scenario Alternatives 3 through 7. There would be reductions in nationwide emissions of criteria pollutants with High Scenario Alternative 2 compared to the High Scenario No Action Alternative in 2020. High Scenario Alternative 2 would reduce emissions less than would High Scenario Alternatives 3 through 7.

All individual nonattainment areas would experience reductions in emissions of all criteria pollutants except $PM_{2.5}$ for all analysis years. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. Emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas with the High Scenario as a result of the combined effects of technology changes introduced by manufacturers in response to CAFE standards, the rebound effect, and travel-demand changes due to population changes. Appendix B-2 contains tables that list the emissions reductions for each nonattainment area. Table 3.3-17 summarizes maximum and minimum criteria air pollutant results by nonattainment area.

Table 3.3-17

High Scenario Alternative CAFE Standards
Changes in Criteria Pollutant Emissions from Passenger Cars and Light Trucks,
Maximum Changes by Nonattainment Area a/

Criteria Pollutant	Increase/ Decrease	Change (tons/year)	Year	Alt. No.	Nonattainment Area
CO	Maximum increase	No increase			
	Maximum decrease	-387,673	2035	7	Los Angeles South Coast Air Basin, CA
NO_x	Maximum increase	No increase			
	Maximum decrease	-14,457	2035	7	Los Angeles South Coast Air Basin, CA
$PM_{2.5}$	Maximum increase	56	2035	7	Atlanta, GA
	Maximum decrease	-1,206	2035	7	Houston-Galveston-Brazoria, TX
SO_x	Maximum increase	No increase			
	Maximum decrease	-5,045	2035	7	Houston-Galveston-Brazoria, TX
VOCs	Maximum increase	No increase			
	Maximum decrease	-31,454	2035	7	Los Angeles South Coast Air Basin, CA

a/ Emissions changes have been rounded to the nearest whole number.

3.3.4.3.2 Air Toxics

There would be reductions in nationwide emissions of benzene, 1,3-butadiene, and DPM under the High Scenario Alternative 2 compared to the High Scenario No Action Alternative. There would be increases in nationwide emissions of acetaldehyde (except in 2025 and 2035), acrolein, and formaldehyde compared to the High Scenario No Action Alternative.

The High Scenario Alternative 2 would have generally higher emissions than would High Scenario Alternatives 3 through 7 for acetaldehyde (in 2025 and 2035 except Alternative 3), benzene (except Alternative 3 in 2025 and 2035), 1,3-butadiene (except Alternative 3 in 2025 and 2035), and DPM. High Scenario Alternative 2 would have generally lower emissions than would High Scenario Alternatives 3 through 7 for acetaldehyde (in 2015), acrolein, and formaldehyde (except Alternative 3 in 2020-2035). Emissions under the High Scenario tend to be lower than those under the Reference Case for Alternative 2.

At the nationwide level, the reduction in upstream emissions of toxic air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Net emissions reductions can occur if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect. With High Scenario Alternative 2, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2). Table 3.3-18 summarizes the maximum and minimum criteria air pollutant results by nonattainment area.

Table 3.3-18

High Scenario Alternative CAFE Standards
Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks,
Maximum Changes by Nonattainment Area a/

Hazardous Air Pollutant	Increase/Decrease	Change (tons/year)	Year	Alt. No.	Nonattainment Area
Acetaldehyde	Maximum Increase	10	2020	7	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-37	2035	7	Houston-Galveston-Brazoria, TX
Acrolein	Maximum Increase	16	2035	7	Los Angeles South Coast Air Basin, CA
	Maximum Decrease	No decreases (upstream emissions decreases not included for acrolein)			
Benzene	Maximum Increase	No increases			
	Maximum Decrease	-862	2035	7	Los Angeles South Coast Air Basin, CA
1,3-butadiene	Maximum Increase	1	2015	7	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-35	2035	7	Los Angeles South Coast Air Basin, CA
Diesel particulate matter	Maximum Increase	No increases			
	Maximum Decrease	-625	2035	7	Los Angeles South Coast Air Basin, CA
Formaldehyde	Maximum Increase	145	2035	7	Los Angeles South Coast Air Basin, CA
	Maximum Decrease	-65	2035	7	Houston-Galveston-Brazoria, TX

a/ Emissions changes have been rounded to the nearest whole number.

3.3.4.3.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide with High Scenario Alternative 2 compared to the High Scenario No Action Alternative, as shown in Table 3.3-19. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. In comparison to the High Scenario No Action Alternative, High Scenario Alternative 2 would reduce mortalities by 214 and the number of work-loss days by 38,172 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-20 lists the corresponding reductions in health costs with High Scenario Alternative 2 compared to the High Scenario No Action Alternative. High Scenario Alternative 2 would reduce health costs by $632 million in 2035.

Table 3.3-19

High Scenario Alternative CAFE Standards
Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions from Passenger Cars and Light Trucks (cases/year) a/

Health Outcome and Year	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action b/	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Mortality (ages 30 and older)							
2015	0	-31	-41	-43	-49	-63	-101
2020	0	-97	-115	-113	-134	-156	-277
2025	0	-152	-176	-169	-203	-230	-418
2035	0	-214	-245	-234	-283	-317	-592
Chronic bronchitis							
2015	0	-27	-35	-37	-43	-54	-88
2020	0	-85	-100	-98	-117	-135	-241
2025	0	-132	-153	-147	-176	-200	-363
2035	0	-186	-213	-204	-246	-275	-515
Emergency-room visits for asthma							
2015	0	-7	-8	-9	-10	-13	-21
2020	0	-20	-24	-24	-28	-33	-58
2025	0	-32	-37	-35	-42	-48	-87
2035	0	-45	-51	-49	-59	-66	-124
Work-loss days							
2015	0	-5,563	-7,257	-7,665	-8,769	-11,169	-18,055
2020	0	-17,326	-20,508	-20,108	-23,915	-27,776	-49,452
2025	0	-27,021	-31,365	-30,153	-36,181	-41,072	-74,497
2035	0	-38,172	-43,678	-41,794	-50,445	-56,437	-105,514

a/ Negative changes indicate reductions; positive emissions changes are increases.
b/ Changes in health outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions under the action alternatives are compared.

Table 3.3-20

**High Scenario Alternative CAFE Standards
Nationwide Changes in Health Costs from Criteria Pollutant Emissions
from Passenger Cars and Light Trucks (U.S. million dollars/year) a/**

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Year	No Action b/	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
2015	0	-50	-63	-84	-95	-112	-223
2020	0	-237	-275	-353	-399	-460	-990
2025	0	-406	-451	-591	-673	-779	-1,809
2035	0	-632	-677	-888	-1,027	-1,202	-2,987

a/ Negative changes indicate economic benefit; positive emissions changes are economic costs.
b/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions under the action alternatives are compared.

3.3.4.4 High Scenario Alternative 3: Optimized

3.3.4.4.1 Criteria Pollutants

With High Scenario Alternative 3, generally the CAFE standards would increase fuel economy more than would the High Scenario No Action Alternative and High Scenario Alternative 2, but less than would High Scenario Alternatives 4 through 7. There would be greater reductions in nationwide emissions of criteria pollutants with High Scenario Alternative 3 compared to High Scenario Alternative 2, except for CO in 2020-2035 and VOC in 2035. High Scenario Alternative 3 would reduce emissions less than would High Scenario Alternatives 4 through 7, except that High Scenario Alternative 3 would reduce $PM_{2.5}$ emissions more than would High Scenario Alternative 4 in 2020-2035.

All individual nonattainment areas would experience reductions in emissions of all criteria pollutants, except for $PM_{2.5}$, for all analysis years. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. Emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas with the High Scenarios as a result of the combined effects of technology changes introduced by manufacturers in response to CAFE standards, the rebound effect, and travel-demand changes due to population changes. Appendix B-2 contains tables that list the emissions reductions for each nonattainment area.

3.3.4.4.2 Air Toxics

There would be reductions in nationwide emissions of benzene, 1,3-butadiene, and DPM under the High Scenario Alternative 3 compared to the High Scenario No Action Alternative. There would be increases in nationwide emissions of acetaldehyde (except in 2025 and 2035), acrolein, and formaldehyde compared to the High Scenario No Action Alternative.

The High Scenario Alternative 3 would have generally higher emissions than would High Scenario Alternatives 4 through 7 for acetaldehyde (in 2025 and 2035), benzene, 1,3-butadiene, and DPM. High Scenario Alternative 3 would have generally lower emissions than would High Scenario Alternatives 4 through 7 for acetaldehyde (in 2015 except Alternative 4 and 2020 except Alternatives 4 and 5), acrolein, and formaldehyde. Emissions under the High Scenario tend to be lower than those under the Reference Case for Alternative 3.

At the nationwide level, the reduction in upstream emissions of toxic air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Net emissions reductions can occur if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect. With High Scenario Alternative 3, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2).

3.3.4.4.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide with High Scenario Alternative 3 compared to the No Action Alternative, as shown in Table 3.3-19. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. In comparison to the High Scenario No Action Alternative, High Scenario Alternative 3 would reduce mortalities by 245 and the number of work-loss days by 43,678 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-20 lists the corresponding reductions in health costs with High Scenario Alternative 3 compared to the No Action Alternative. High Scenario Alternative 3 would reduce health costs by $677 million in 2035.

3.3.4.5 High Scenario Alternative 4: 25 Percent Above Optimized

3.3.4.5.1 Criteria Pollutants

With High Scenario Alternative 4, generally the CAFE standards would increase fuel economy more than would High Scenarios Alternatives 1 through 3 but less than would High Scenario Alternatives 5 through 7. There would be greater reductions in nationwide emissions of criteria pollutants with High Scenario Alternative 4 than with High Scenario Alternatives 1 through 3 (except for $PM_{2.5}$ in 2020-2035). High Scenario Alternative 4 would produce smaller reductions in criteria pollutant emissions than with High Scenario Alternatives 5 through 7.

All individual nonattainment areas would experience reductions in emissions of all criteria pollutants, except $PM_{2.5}$, for all analysis years, compared to the High Scenario No Action Alternative. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. Emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas with the High Scenarios because of the combined effects of technology changes introduced by manufacturers in response to CAFE standards, the rebound effect, and travel-demand changes due to population changes. Appendix B-2 contains tables that list the emissions reductions for each nonattainment area.

3.3.4.5.2 Air Toxics

There would be reductions in nationwide emissions of acetaldehyde (except in 2015), benzene, 1,3-butadiene, and DPM under the High Scenario Alternative 4 compared to the High Scenario No Action Alternative. There would be increases in nationwide emissions of acetaldehyde (in 2015), acrolein, and formaldehyde compared to the High Scenario No Action Alternative.

The High Scenario Alternative 4 would have generally higher emissions than would High Scenario Alternatives 5 through 7 for acetaldehyde (in 2035), benzene, 1,3-butadiene (except in 2015), and DPM. High Scenario Alternative 4 would have generally lower emissions than would High Scenario Alternatives 5 through 7 for acetaldehyde (except in 2035), acrolein, and formaldehyde. Emissions under the High Scenario tend to be lower than those under the Reference Case for Alternative 4.

At the nationwide level, the reduction in upstream emissions of toxic air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Net emissions reductions can occur if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect. With High Scenario Alternative 4, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2).

3.3.4.5.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide with High Scenario Alternative 4 compared to the No Action Alternative, as shown in Table 3.3-19. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. In comparison to the High Scenario No Action Alternative, High Scenario Alternative 4 would reduce mortalities by 234 and the number of work-loss days by 41,794 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-20 lists the corresponding reductions in health costs with High Scenario Alternative 4 compared to the High Scenario No Action Alternative. High Scenario Alternative 4 would reduce health costs by $888 million in 2035.

3.3.4.6 High Scenario Alternative 5: 50 Percent Above Optimized

3.3.4.6.1 Criteria Pollutants

With High Scenario Alternative 5, the CAFE standards would increase fuel economy more than would High Scenario Alternatives 1 through 4 but less than would High Scenario Alternatives 6 and 7. There would be greater reductions in nationwide emissions of all criteria pollutants with High Scenario Alternative 5 than with High Scenario Alternatives 1 through 4. There would be smaller reductions than with High Scenario Alternatives 6 and 7.

All individual nonattainment areas would experience reductions in emissions of all criteria pollutants, except for $PM_{2.5}$, for all analysis years. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. Emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas with the High Scenarios as a result of the combined effects of technology changes introduced by manufacturers in response to CAFE standards, the rebound effect, and travel-demand changes due to population changes. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

3.3.4.6.2 Air Toxics

There would be reductions in nationwide emissions of acetaldehyde (except in 2015 and 2020), benzene, 1,3-butadiene (except in 2015), and DPM under the High Scenario Alternative 5 compared to the High Scenario No Action Alternative. There would be increases in nationwide emissions of acetaldehyde (in 2015 and 2020), acrolein, and formaldehyde compared to the High Scenario No Action Alternative.

The High Scenario Alternative 5 would have generally higher emissions than would High Scenario Alternatives 6 through 7 for acetaldehyde (in 2035), benzene, 1,3-butadiene (except in 2015), and DPM. High Scenario Alternative 5 would have generally lower emissions than would High Scenario Alternatives 6 through 7 for acetaldehyde (except in 2035), acrolein, and formaldehyde. Emissions under the High Scenario tend to be lower than those under the Reference Case for Alternative 5.

At the nationwide level, the reduction in upstream emissions of toxic air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Net emissions reductions can occur if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect. With High Scenario Alternative 5, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2).

3.3.4.6.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide with High Scenario Alternative 5 compared to the High Scenario No Action Alternative, as shown in Table 3.3-19. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. In comparison to the High Scenario No Action Alternative, High Scenario Alternative 5 would reduce mortalities by 283 and the number of work-loss days by 50,445 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-20 lists the corresponding reductions in health costs with High Scenario Alternative 5. High Scenario Alternative 5 would reduce health costs by $1.027 billion in 2035.

3.3.4.7 High Scenario Alternative 6: Total Costs Equal Total Benefits

3.3.4.7.1 Criteria Pollutants

With High Scenario Alternative 6, the CAFE standards would increase fuel economy more than would High Scenario Alternatives 1 through 5 but less than would High Scenario Alternative 7. There would be greater reductions in nationwide emissions of criteria pollutants with the High Scenario Alternative 6 than with High Scenario Alternatives 1 through 5. There would be lesser reductions than with High Scenario Alternative 7.

All individual nonattainment areas would experience reductions in emissions of all criteria pollutants except $PM_{2.5}$ for all analysis years. Emissions of criteria pollutants except $PM_{2.5}$ decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect and technology changes introduced by manufacturers in response to CAFE standards in every nonattainment area. Emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas with the High Scenarios as a result of the combined effects of technology changes introduced by manufacturers in response to CAFE standards, the rebound effect, and travel-demand changes due to population changes. Appendix B-2 contains tables that list the emissions reductions for each nonattainment area.

3.3.4.7.2 Air Toxics

There would be reductions in nationwide emissions of acetaldehyde (except in 2015 and 2020), benzene, 1,3-butadiene, and DPM under the High Scenario Alternative 6 compared to the High Scenario

No Action Alternative. There would be increases in nationwide emissions of acetaldehyde (in 2015 and 2020), acrolein, and formaldehyde compared to the High Scenario No Action Alternative.

The High Scenario Alternative 6 would have generally higher emissions than would High Scenario Alternative 7 for acetaldehyde (in 2035), benzene, 1,3-butadiene (except in 2015), and DPM. High Scenario Alternative 6 would have generally lower emissions than would High Scenario Alternative 7 for acetaldehyde (except in 2035), acrolein, 1,3-butadiene (in 2015), and formaldehyde. Emissions under the High Scenario tend to be lower than those under the Reference Case for Alternative 6.

At the nationwide level, the reduction in upstream emissions of toxic air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. For example, a nonattainment area that contains petroleum refining facilities, such as Houston-Galveston-Brazoria, Texas, would experience more reductions in upstream emissions than an area that has none. Net emissions reductions can occur if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect. With High Scenario Alternative 6, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2).

3.3.4.7.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide with High Scenario Alternative 6 compared to the High Scenario No Action Alternative, as shown in Table 3.3-19. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. In comparison to the High Scenario No Action Alternative, High Scenario Alternative 6 would reduce mortalities by 317 and the number of work-loss days by 56,437 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-20 lists the corresponding reductions in health costs with Alternative 6 compared to the High Scenario No Action Alternative. In comparison to the High Scenario No Action Alternative, High Scenario Alternative 6 would reduce health costs by $1.202 billion in 2035.

3.3.4.8 High Scenario Alternative 7: Technology Exhaustion

3.3.4.8.1 Criteria Pollutants

With the High Scenario Alternative 7, the CAFE standards would increase fuel economy the most of all the alternatives. There would be greater reductions in nationwide emissions of criteria pollutants with the High Scenario Alternative 7 than with any other alternative. All individual nonattainment areas would experience reductions in emissions of all criteria pollutants except $PM_{2.5}$ for all analysis years. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. Emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas under High Scenario Alternative 7 because of the combined effects of technology changes introduced by manufacturers in response to CAFE standards, the rebound effect, and travel-demand changes due to population changes. Appendix B-2 contains tables that list the emissions reductions for each nonattainment area.

3.3.4.8.2 Air Toxics

There would be reductions in nationwide emissions of acetaldehyde (in 2025 and 2035), benzene, 1,3-butadiene (except in 2015), and DPM with High Scenario Alternative 7 compared to the High Scenario No Action Alternative.

At the nationwide level, the reduction in upstream emissions of toxic air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Net emissions reductions can occur if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect. With High Scenario Alternative 7, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2).

3.3.4.8.3 Health Outcomes and Costs

There would be reductions in adverse health effects nationwide with High Scenario Alternative 7 compared to the High Scenario No Action Alternative, as shown in Table 3.3-19. These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. In comparison to the High Scenario No Action Alternative, High Scenario Alternative 7 would reduce mortalities by 592 and the number of work-loss days by 105,514 in 2035. Data are not available to estimate reliably the number of adverse health effects due to the other pollutants. Table 3.3-20 lists the corresponding reductions in health costs with High Scenario Alternative 7 compared to the High Scenario No Action Alternative. In comparison to the High Scenario No Action Alternative, High Scenario Alternative 7 would reduce health costs by $2.987 billion in 2035.

3.3.4.9 Mid-1 and Mid-2 Scenarios

For the Mid-1 Scenario, NHTSA used the AEO 2008 high fuel prices, a social cost of carbon of $33 per ton (2007 dollars), oil import externalities of $0.116 per gallon, and discount rates of 3 percent for the present value of carbon reduction benefits and 7 percent for other costs and benefits (*see* Table 2.2-1).

Compared to the Reference Case, total emissions of criteria and toxic air pollutants under the Mid-1 Scenario were generally lower for all alternatives. Emissions with the Mid-1 Scenario Alternative 6 were higher for acrolein in 2025 and 2035. Emissions with the Mid-1 Scenario Alternatives 2 through 6 were higher for 1,3-butadiene in some years. Most of the differences between the action alternatives and the No Action Alternative are greater under the Mid-1 Scenario than under the Reference Case. The emissions differences between the Reference Case and the Mid-1 Scenario reflect the differences in the forecast levels of fuel economy, VMT, and diesel vehicle share of the vehicle fleet.

For the Mid-2 Scenario, NHTSA used the AEO 2008 high fuel prices, a social cost of carbon of $2.00 per ton (2007 dollars), oil import externalities of $0.382 per gallon, and discount rates of 3 percent for the present value of carbon reduction benefits and 7 percent for other costs and benefits (*see* Table 2.2-1).

Compared to the Reference Case, total emissions of criteria and toxic air pollutants under the Mid-2 Scenario were lower for all action alternatives. Most of the differences between the action alternatives and the No Action Alternative are greater under the Mid-2 Scenario than under the Reference Case. The emissions differences between the Reference Case and the Mid-2 Scenario reflect the differences in the forecast levels of fuel economy, VMT, and diesel vehicle share of the vehicle fleet.

Emissions of criteria pollutants would be generally higher with the Mid-2 Scenario than with the Mid-1 Scenario for Alternatives 2 through 6, and equivalent for Alternative 7. Emissions of toxic air pollutants would be generally higher with the Mid-2 Scenario than with the Mid-1 Scenario for benzene, 1,3-butadiene, and DPM for Alternatives 2 through 6. Emissions of toxic air pollutants would be generally lower with the Mid-2 Scenario than with the Mid-1 Scenario for acrolein and formaldehyde for Alternatives 2 through 6. Results between the Mid-1 and Mid-2 Scenarios for acetaldehyde vary by year for Alternatives 2 through 6. Emissions of toxic air pollutants with the Mid-1 and Mid-2 Scenarios would be equivalent for Alternative 7.

Appendix B-2, Tables B2-97 through B2-113, list the full results from the Mid-1 and Mid-2 Scenarios.

3.4 CLIMATE

This section describes the environment the CAFE standards would affect. Because there is little precedent for addressing climate change within the structure of an EIS, several reasonable judgments were called for when deciding where to draw the line between the direct and indirect effects of the alternatives (Chapter 3) and the cumulative impacts associated with the alternatives (Chapter 4).

NHTSA determined that the scope of climate change issues covered in Chapter 3 would be more tailored than the scope of those in Chapter 4 in two respects: (1) the discussion in Chapter 3 focuses on impacts associated with GHGs only due to the MY 2011-2015 CAFE standards (which affect cars and light trucks built from 2010-2015, and are then assumed to remain in place at the MY 2015 levels from 2015 through 2100), and (2) the discussion of consequences focuses on emissions and effects on the climate system, for example, atmospheric CO_2 concentrations, temperature, sea level, and precipitation. Chapter 4 is broader in that it (1) covers foreseeable effects of the MY 2011-2015 standards, which include a set of more stringent CAFE standards for MY 2016-2020 (the MY 2020 levels would affect cars and light trucks built from 2020-2100), and (2) extends the discussion of consequences to include not only the effects on the climate system, but also the impacts of climate on key resources (such as freshwater resources, terrestrial ecosystems, coastal ecosystems). Thus, the reader is encouraged to explore the cumulative impacts discussion in Chapter 4 to fully understand NHTSA's approach to climate change in this FEIS.

Section 3.4.1 introduces key topics in GHGs and climate change, Section 3.4.2 outlines the methodology NHTSA used to evaluate climate effects, Section 3.4.3 describes the affected environment, and Section 3.4.4 describes consequences.

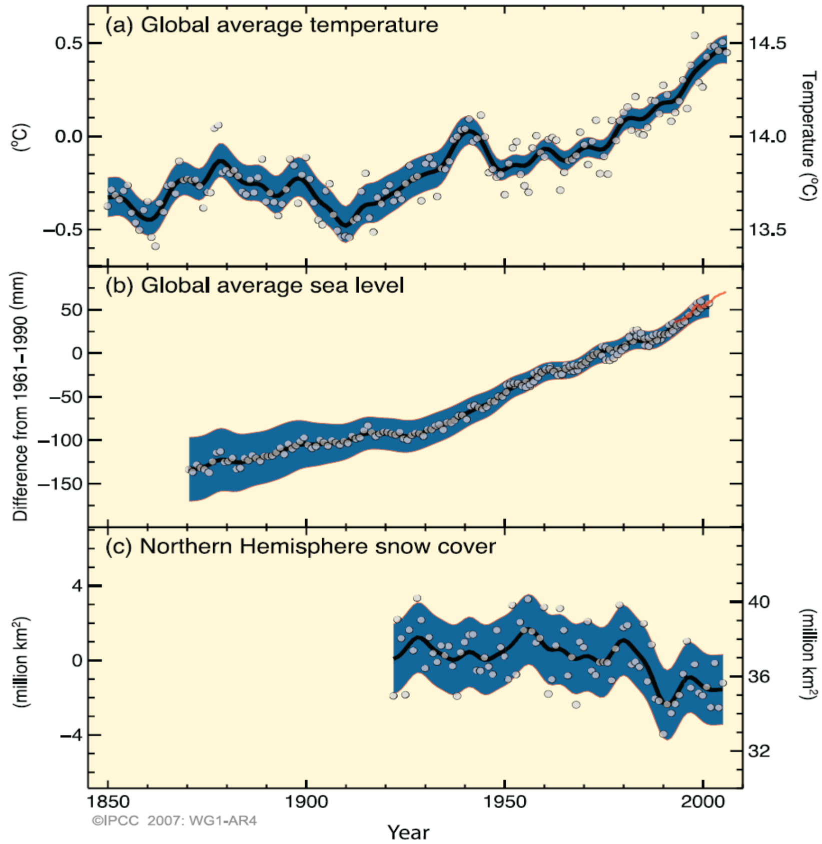
3.4.1 Introduction - Greenhouse Gases and Climate Change

A series of intensive and extensive analyses have been conducted by the Intergovernmental Panel on Climate Change (IPCC), the scientific body tasked by the United Nations to evaluate the risk of human-induced climate change, the U.S. Climate Change Science Program (USCCSP), and many other government-, non-government-, and industry-sponsored programs. Our discussion relies heavily on the most recent, thoroughly peer-reviewed, and credible assessments of global and U.S. climate change: the IPCC Fourth Assessment Report (*Climate Change 2007*), and reports by the USCCSP and the National Science and Technology Council that include the *Scientific Assessment of the Effects of Global Change on the United States* and Synthesis and Assessment Products. These sources and the studies they review are quoted frequently throughout this FEIS. Because new evidence is continuously emerging on the subject of climate change impacts, the discussions on climate impacts in this FEIS also draw on more recent studies, where possible.

3.4.1.1 What is Climate Change?

Global climate change refers to long-term fluctuations in global surface temperatures, precipitation, ice cover, sea levels, cloud cover, ocean temperatures and currents, and other climatic conditions. Scientific research has shown that in the past century, Earth's surface temperature has risen by an average of about 1.3 degrees Fahrenheit (°F) (0.74 degree Centigrade [°C]) (IPCC 2007c); sea levels have risen 6.7 inches (0.17 meter) (IPCC 2007c); Arctic sea ice has shrunk by 2.7 percent per decade, with larger decreases of 7.4 percent in summer, and mountain glaciers and snow cover have decreased (IPCC 2007c) (*see* Figure 3.4-1).

Figure 3.4-1. Changes in Temperature, Sea Level, and Northern Hemisphere Snow Cover (source: IPCC 2007c)



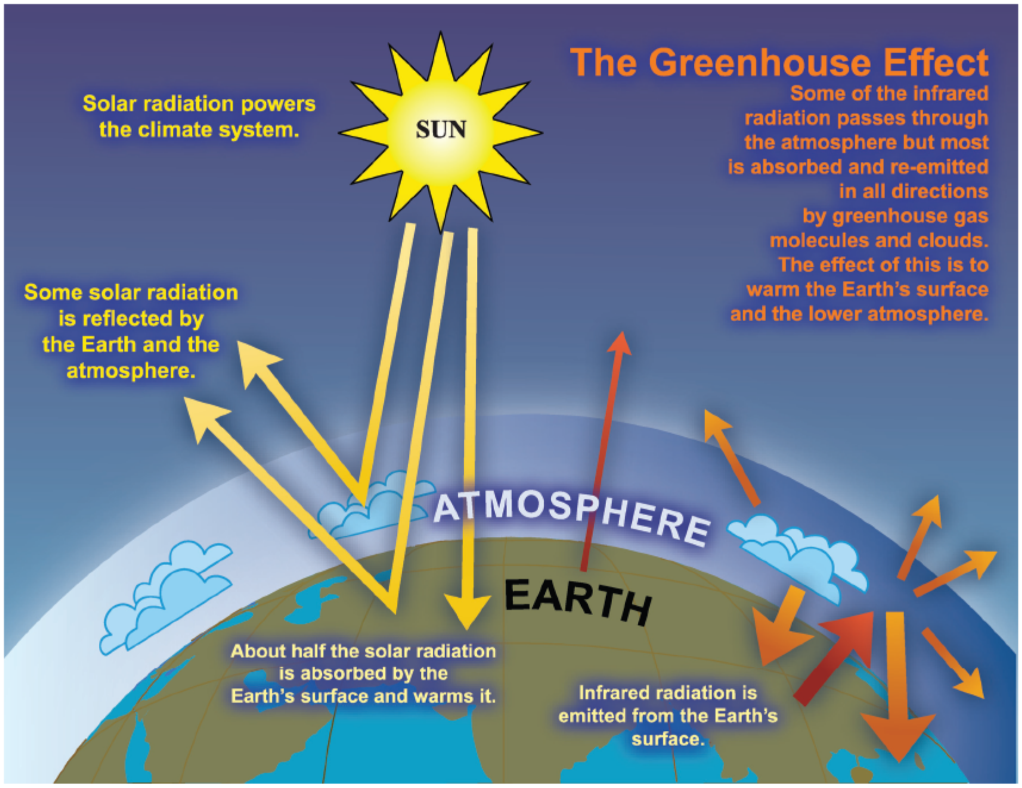
3.4.1.2 What Causes Climate Change?

Earth absorbs heat energy from the sun and returns some of this heat to space as terrestrial infrared radiation. GHGs trap heat in the troposphere (the atmosphere close to Earth's surface) and reradiate it back to Earth, thereby causing warming. This process—known as the "greenhouse effect"—is responsible for maintaining surface temperatures that are warm enough to sustain life (*see* Figure 3.4-2). Human activities, particularly fossil-fuel combustion, contribute to the presence of GHGs in the atmosphere. There are increasing concerns that the buildup of GHGs in the atmosphere is upsetting Earth's energy balance.

Most scientists now agree that this climate change is largely a result of GHG emissions from human activities. The IPCC recently asserted that, "Most of the observed increase in global average temperatures since the mid-20th Century is *very likely* due to the observed increase in anthropogenic [human-caused] greenhouse gas concentrations" (IPCC 2007c).[7]

[7] The IPCC uses standard terms to "define the likelihood of an outcome or result where this can be estimated probabilistically." The term "very likely," cited in italics above and elsewhere in this section, corresponds to a greater than 90-percent probability of an occurrence or outcome, whereas the term "likely" corresponds to a greater than 66-percent probability. This section uses these two terms; Section 4.5 uses and defines a more expansive set of IPCC terminology regarding likelihood

Figure 3.4-2. The Greenhouse Effect (source: Le Treut *et al.* 2007)



Most GHGs, including CO_2, methane (CH_4), nitrous oxide (N_2O), water vapor, and ozone, are naturally occurring. Human activities such as the combustion of fossil fuel, the production of agricultural commodities, and the harvesting of trees can contribute to increased concentrations of these gases in the atmosphere. In addition, a number of very potent anthropogenic (human-made) GHGs, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), are created and emitted through industrial processes.

3.4.1.3 What are the Anthropogenic Sources of Greenhouse Gases?

Human activities that emit GHGs to the atmosphere include the combustion of fossil fuels, industrial processes, solvent use, land-use change and forestry, agriculture production, and waste management. Atmospheric concentrations of CO_2, CH_4, and N_2O—the most important anthropogenic GHGs—have increased approximately 35, 150, and 18 percent, respectively, since the beginning of the Industrial Revolution in the mid-1700s (IPCC 2007c). The rise in GHGs in the past century is widely attributed to the combustion of fossil fuels (coal, petroleum, and gas) used to produce electricity, heat buildings, and run motor vehicles and planes, among other uses.

Contributions to the build-up of GHG in the atmosphere vary greatly from country to country, and depend heavily on the level of industrial and economic activity. The U.S. transportation sector contributed 31.3 percent of total U.S. CO_2 emissions in 2006 (EPA 2008a), with cars and light trucks accounting for 61.4 percent of total U.S. CO_2 emissions from transport (EPA 2008a). Thus, 19.2 percent of total U.S. CO_2 emissions come from cars and light trucks. With the United States accounting for 19.6 percent of global CO_2 emissions (WRI 2008), cars and light trucks in the United States account for roughly 3.8 percent of global CO_2 emissions.

3.4.1.4 Evidence of Climate Change

Observations and studies across the globe are reporting evidence that the earth is currently undergoing climatic change much more quickly than would be expected from natural variations. Global temperatures are increasing, with 11 of the hottest 12 years on record occurring over the past 12 years (IPCC 2007c). Sea levels have risen, caused by thermal expansion of the ocean and melting snow and ice. More frequent weather extremes such as droughts, floods, severe storms, and heat waves have also been observed (IPCC 2007c).

3.4.1.5 Future Climactic Trends and Expected Impacts

As the world population grows and developing countries industrialize, fossil fuel use and resulting GHG emissions are expected to grow substantially over the next century. Based on the current trajectory, the IPCC predicts that CO_2 concentrations could rise to more than three times the pre-industrial level by 2100 (Meehl *et al.* 2007).

Among other trends forecasted, the average global surface temperature is *likely* to rise 2.0 to 11.5 °F (1.1 to 6.4 °C) over the next century, accompanied by a *likely* sea level rise of approximately 0.6 to 1.9 feet (0.18 to 0.59 meter) (IPCC 2007c). In addition to rising temperatures and sea levels, climate change is expected to have many environmental, human health, and economic consequences.

For a more in-depth analysis on the future impacts of climate change on various sectors, *see* the Cumulative Impacts discussion in Chapter 4.

3.4.2 Affected Environment

This section describes the affected environment in terms of current and anticipated trends in GHG emissions and climate. Both emissions and climate involve very complex processes with considerable variability, which complicates the measurement and detection of change. Recent advances in the state of the science, however, are contributing to an increasing body of evidence that anthropogenic GHG emissions are affecting climate in detectable ways.

This section opens with a discussion of emissions, and then turns to climate. Both discussions start with a description of conditions in the United States, followed by a description in the global environment. As global conditions are a macrocosm of U.S. conditions, many themes in the U.S. discussions reappear in the global discussions.[8]

3.4.2.1 Greenhouse Gas Emissions (Historic and Current)

3.4.2.1.1 U.S. Emissions

GHG emissions for the United States in 2006 were estimated at 7,054 million metric tons of carbon dioxide ($MMTCO_2$) equivalent[9] (EPA 2008a), and, as noted earlier, comprise about 15 to 20

[8] For NEPA purposes, it is appropriate for NHTSA to consider global environmental impacts. *See* CEQ, *Council on Environmental Quality Guidance on NEPA Analyses for Transboundary Impacts* (July 1, 1997), *available at* http://ceq.hss.doe.gov/nepa/regs/transguide.html (last visited June 16, 2008) (stating that "agencies must include analysis of reasonably foreseeable transboundary effects of proposed actions in their [NEPA] analysis of proposed actions in the United States").
[9] Each GHG has a different level of radiative forcing, that is, the ability to trap heat. To compare their relative contributions, gases are converted to carbon dioxide equivalent using their unique global warming potential (GWP).

percent of total global emissions[10] (WRI 2008). Annual U.S. emissions, which have increased 15 percent since 1990 and typically increase each year, are heavily influenced by "general economic conditions, energy prices, weather, and the availability of non-fossil alternatives" (EPA 2008a).

Carbon dioxide is by far the primary GHG emitted in the United States, representing nearly 85 percent of all U.S. GHG emissions in 2006 (EPA 2008a). The other gases include CH_4, N_2O, and a variety of fluorinated gases, including HFCs, PFCs, and SF_6. The fluorinated gases are collectively referred to as high global warming potential (GWP) gases. Methane accounts for 8 percent of the remaining GHGs on a GWP-weighted basis, followed by N_2O (5 percent), and the high-GWP gases (2 percent) (EPA 2008a).

GHGs are emitted from a wide variety of sectors, including energy, industrial processes, waste, agriculture, and forestry. Most U.S. emissions are from the energy sector, largely due to CO_2 emissions from the combustion of fossil fuels, which alone account for 80 percent of total U.S. emissions (EPA 2008a). These emissions are due to fuels consumed in the electric power (41 percent of fossil fuel emissions); transportation (33 percent); industry (15 percent); residential (6 percent); and commercial (4 percent) sectors (EPA 2008a). However, when U.S. CO_2 emissions are apportioned by end use, transportation is the single leading source of U.S. emissions from fossil fuels, at approximately one-third of total CO_2 emissions from fossil fuels (EPA 2008a).

Cars and light-duty trucks, which include SUVs, pickup trucks, and minivans, accounted for more than half of U.S. transportation emissions, and emissions from these vehicles have increased by 21 percent since 1990 (EPA 2008a). This increase was driven by two factors: an increase in travel demand and a relatively stagnant average fuel economy. Population growth and expansion, economic growth, and low fuel prices led to more miles traveled, while the rising popularity of SUVs and other light trucks resulted in a slight decline in average combined fuel economy of new cars and light trucks (EPA 2008a).

3.4.2.1.2 Global Emissions

Although humans have always contributed to some level of GHG emissions to the atmosphere through activities like farming and land clearing, substantial contributions did not begin until the mid-1700s, with the onset of the Industrial Revolution. People began burning coal, oil, and natural gas to light their homes, power trains and cars, and run factories and industrial operations. Today the burning of fossil fuels is still the predominant source of GHG emissions.

Levels of atmospheric CO_2 have been rising rapidly. For about 10,000 years prior to the Industrial Revolution, atmospheric CO_2 levels were 280 ppm (plus or minus 20 ppm). Since the Industrial Revolution, CO_2 levels have risen to 367 ppm in 1999 and to 379 ppm in 2005. In addition, other GHGs have been on the increase. Direct atmospheric measurements since 1970 have detected a 150-percent increase in CH_4 and an 18-percent increase in N_2O (IPCC 2007c).

In 2000, global GHG emissions were estimated at 44,378 $MMTCO_2$ equivalent, a 6-percent increase since 1990[11] (WRI 2008). In general, global GHG emissions have increased regularly, though annual increases vary according to a variety of factors (weather, energy prices, and economic factors).

As in the United States, the primary GHGs emitted globally are CO_2, CH_4, N_2O, and the fluorinated gases HFCs, PFCs, and SF_6. In 2000, CO_2 emissions comprised 79 percent of global

[10] The United States contributes about 20 percent of gross GHG emissions, but only 15 percent of net emissions, which take into account carbon sinks from forestry and agriculture.
[11] All GHG estimates cited in this section include contributions from land-use change and forestry, where applicable.

emissions on a GWP-weighted basis, followed by CH_4 (14 percent) and N_2O (7 percent). Collectively, fluorinated gases represented 1 percent of global emissions (WRI 2008).

Various sectors contribute to global GHG emissions, including energy, industrial processes, waste, agriculture, land-use change and forestry, and international bunkers. The energy sector is the largest contributor of global GHG emissions, accounting for 61 percent of global emissions in 2000. In this sector, the generation of electricity and heat accounts for 26 percent of total global emissions. The next highest contributors to emissions are land-use change and forestry (17 percent), agriculture (13 percent), and transportation (12 percent; this is included in the 61 percent for the energy sector) (WRI 2008).

Emissions from transportation are primarily due to the combustion of petroleum to power vehicles such as cars, trucks, trains, planes, and ships. In 2000, transportation represented 12 percent of total emissions and 15 percent of CO_2 emissions; transportation emissions have increased 11 percent since 1990 (WRI 2008).

3.4.2.2 Climate Change Effects and Impacts (Historic and Current)

3.4.2.2.1 U.S. Climate Change Effects

This section describes observed historical and current climate change effects and impacts for the United States. Much of the discussion that follows is drawn from the USCCSP's *Scientific Assessment of the Effects of Global Change on the United States* (CCSP 2008d) and citations therein.

Observed Changes to the Climate

The past decade has been the warmest in more than a century of direct observations, with average temperatures for the contiguous United States rising at a rate near 0.6 °F per decade in the past few decades. Since 1950, the frequency of heat waves has increased, although those recorded in the 1930s remain the most severe. There were also fewer unusually cold days in the past few decades with fewer severe cold waves for the most recent 10-year period in the record (CCSP 2008d).

Over the contiguous United States, total annual precipitation increased about 6 percent from 1901 to 2005, with the greatest increases occurring in the northern Midwest and the South; heavy precipitation also increased, primarily during the last three decades of the 20^{th} Century, and mainly over eastern regions. Most regions experienced decreases in drought severity and duration during the second half of the 20^{th} Century, although there was severe drought in the Southwest from 1999 to 2007; the Southeast has also recently experienced severe drought (CCSP 2008d).

Relative sea level is rising 0.8 to 1.2 inches per decade along most of the Atlantic and Gulf Coasts, and a few inches per decade along the Louisiana Coast (due to land subsidence); sea level is falling (due to land uplift) at the rate of a few inches per decade in parts of Alaska (CCSP 2008d).

Observed Impacts from the Changing Climate

Streamflow decreased about 20 percent over the past century in the central Rocky Mountain region, while in the East it increased 25 percent in the past 60 years. Annual peak streamflow (dominated by snowmelt) in western mountains is occurring at least a week earlier than in the middle of the 20^{th} Century. Winter streamflow is increasing in seasonal snow-covered basins and the fraction of annual precipitation falling as rain (rather than snow) has increased in the past half century (CCSP 2008d). Spring and summer snow cover has decreased in the West, and in mountainous regions of the western

United States, April snow water equivalent has declined 15 to 30 percent since 1950, particularly at lower elevations and primarily due to warming (Field *et al.* 2007 as cited in CCSP 2008d). However, total snow-cover area in the United States increased in the November-to-January season from 1915 to 2004 (CCSP 2008d).

Annual average Arctic sea ice extent decreased 2.7 plus or minus 0.6 percent per decade from 1978 to 2005. In 2007, sea ice extent was approximately 23 percent less than the previous all-time minimum observed in 2005. Average sea ice thickness in the central Arctic *very likely* has decreased up to approximately 3 feet from 1987 to 1997. These area and thickness reductions allow winds to generate stronger waves, which have increased shoreline erosion along the Alaskan coast. Alaska has also experienced permafrost thawing of up to 1.6 inches per year since 1992 (CCSP 2008d).

Rivers and lakes are freezing over later (at an average rate of 5.8 plus or minus 1.6 days per century) with ice breakup taking place earlier (at an average rate of 6.5 plus or minus 1.2 days per century). Loss of glacier mass is occurring in the Northwest and has been especially rapid in Alaska since the mid-1990s (CCSP 2008d).

Sea-level rise extends the zone of impact from storm surge and waves from tropical and other storms, causing coastal erosion and other damage. It is *likely* that the numbers of tropical storms, hurricanes, and major hurricanes each year in the North Atlantic have increased during the past 100 years (CCSP SAP 3.3 2008 as cited in CCSP 2008d) and that Atlantic sea-surface temperatures have increased over the same period; however, these trends are complicated by multi-decadal variability and data-quality issues. In addition, there is evidence of an increase in extreme wave-height characteristics over the past 2 decades, associated with more frequent and more intense hurricanes (CCSP 2008d).

3.4.2.2.2 Global Climate Change Effects

This section describes observed historical and current climate change effects and impacts at a global scale. As with the discussion of effects for the United States, much of the material that follows is drawn from the following studies, including the citations therein: the IPCC WGI *Summary for Policymakers* (IPCC 2007c) and the USCCSP *Scientific Assessment of the Effects of Global Change on the United States* (CCSP 2008d).

In their most recent assessment of climate change, the IPCC states that "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level" (IPCC 2007c).

<u>Observed Changes to the Climate</u>

Global temperatures have been increasing over the past century. The 100-year linear trend (1906 to 2005) is 0.13 plus or minus 0.03 °F per decade, while the corresponding 50-year linear trend of 0.23 plus or minus 0.05 °F per decade is nearly twice that (CCSP 2008d). Average Arctic temperatures have increased at almost twice the global average rate in the past 100 years. Permafrost top layer temperatures have generally increased since the 1980s (about 5 °F in the Arctic), while the maximum area covered by seasonal frozen ground has decreased since 1900 by about 7 percent in the Northern Hemisphere, with a decrease in spring of up to 15 percent (IPCC 2007c).

Extreme temperatures have been observed to change extensively over the past 50 years. Hot days, hot nights, and heat waves have become more frequent; cold days, cold nights, and frost have become less frequent (IPCC 2007c).

Average atmospheric water vapor content has increased since at least the 1980s over land and the oceans, and in the upper troposphere, largely consistent with air temperature increases. As a result, heavy precipitation events have increased in frequency over most land areas (CCSP 2008d).

Average ocean temperatures have increased since 1961 to depths of at least 10,000 feet, with the ocean absorbing more than 80 percent of the heat added to the climate system. As seawater warms, it expands and sea levels rise. Mountain glaciers, ice caps, and snow cover have declined on average, contributing to further sea-level rise. Losses from the Greenland and Antarctica ice sheets have *very likely* contributed to sea level rise from 1993 to 2003. Dynamical ice loss explains most of the Antarctic net mass loss and about half of the Greenland net mass loss; the other half occurred because melting has exceeded snowfall accumulation (IPCC 2007c).

Global average sea level rose at an average rate of 0.07 plus or minus 0.02 inch per year from 1961 to 2003 with the rate increasing to about 0.12 plus or minus 0.03 inch per year from 1993 to 2003. Total 20th-Century rise is estimated at 0.56 plus or minus 0.16 foot (IPCC 2007c). However, since the IPCC Fourth Assessment Report was published, a recent study improved the historical estimates of upper-ocean (300 meters and 700 meters) warming from 1950 to 2003 (by correcting for expendable bathy-thermographs instrument bias). Domingues *et al.* (2008) found the improved estimates demonstrate clear agreement with the decadal variability of the climate models that included volcanic forcing. Further, this study estimated the globally averaged sea-level trend from 1961 to 2003 to be 0.063 plus or minus 0.01 inch per year with a rise of 0.094 inch per year evident from 1993 to 2003, consistent with the estimated trend of 0.091 inch per year from tide gauges after taking into account thermal expansion in the upper-ocean and deep ocean, variations in the Antarctica and Greenland ice sheets, glaciers and ice caps, and terrestrial storage.

Observed Impacts from the Changing Climate

The IPCC concludes that, "At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones" (IPCC 2007c).

Long-term trends in global precipitation amounts have been observed since 1900. Precipitation has substantially increased in eastern parts of North and South America, northern Europe, and northern and central Asia. Drying has been observed in the Sahel, the Mediterranean, southern Africa, and parts of southern Asia. Spatial and temporal variability for precipitation is high, and data are limited for some regions (IPCC 2007c).

Droughts that are more intense and longer have been observed since the 1970s, particularly in the tropics and subtropics, and have been caused by higher temperatures and decreased precipitation. Changes in sea-surface temperatures, wind patterns, and decreased snowpack and snow cover have also been linked to droughts (IPCC 2007c).

Long-term trends in tropical cyclone activity have been reported, but there is no clear trend in the number of tropical cyclones each year. There is observational evidence for an increase in intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures. However, concerns over data quality and multi-decadal variability persist (IPCC 2007c). The World Meteorological Organization (WMO) Sixth International Workshop on Tropical Cyclones in 2006 agreed that "no firm conclusion can be made" on anthropogenic influence on tropical cyclone activity because "there is evidence both for and against the existence of a detectable anthropogenic signal in the tropical cyclone climate record" (WMO 2006a).

Other characteristics of the global climate have not changed. The diurnal temperature range has not changed from 1979 to 2004; day- and night-time temperatures have risen at similar rates. Antarctic sea-ice extent shows no substantial average trends – despite inter-annual variability and localized changes – consistent with the lack of warming across the region from average atmospheric temperatures. There is also insufficient evidence to determine whether trends exist in large-scale phenomena such as the meridional overturning circulation (a mechanism for heat transport in the North Atlantic Ocean, where warm waters are carried north and cold waters are carried toward the equator) or in small-scale phenomena such as tornadoes, hail, lightning, and dust storms (IPCC 2007c).

3.4.3 Methodology

The methodology NHTSA used to characterize the effects of the alternatives on climate has two key elements:

1. Analyzing the effects of the alternatives on GHG emissions
2. Analyzing how the GHG emissions affect the climate system (climate effects)

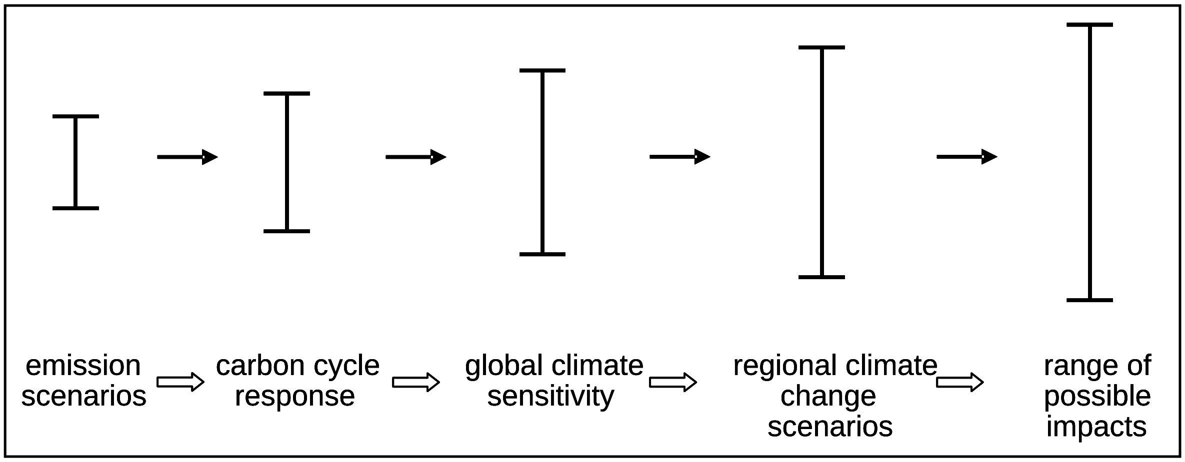
For both the effects on GHG emissions and the effects on the climate system, this FEIS expresses results – for each alternative – in terms of the environmental attribute being characterized (emissions, CO_2 concentrations, temperature, precipitation, and sea level). Comparisons between the No Action Alternative (Alternative 1) and each action alternative (Alternatives 2 through 7) are also presented to illustrate the differences in environmental effects among the alternative CAFE standards.

The methods used to characterize emissions and climate effects involve considerable uncertainty. Sources of uncertainty include the pace and effects of technology change in the transportation sector and other sectors that emit GHGs; changes in the future fuel supply that could affect emissions; sensitivity of climate to increased GHG concentrations; rate of change in the climate system in response to changing GHG concentrations; potential existence of thresholds in the climate system (which cannot be predicted or simulated); regional differences in the magnitude and rate of climate changes; and many other factors.

Moss and Schneider (2000) characterize the “cascade of uncertainty” in climate change simulations (Figure 3.4-3). As indicated in the figure, the emissions estimates used in this FEIS have narrower bands of uncertainty than the global climate effects, which are less uncertain than the regional climate change effects. The effects on climate are, in turn, less uncertain than the impacts of climate changes on affected resources (such as terrestrial and coastal ecosystems, human health, and other resources discussed in Section 4.5).

Where information in the analysis included in this FEIS is incomplete or unavailable, NHTSA has relied on the CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). The understanding of the climate system is incomplete; like any analysis of complex, long-term changes to support decisionmaking, evaluating reasonably foreseeable significant adverse impacts on the human environment involves many assumptions and uncertainties. This FEIS uses methods and data that represent the best available information on this topic, and have been subjected to peer review and scrutiny. In fact, the information cited throughout this section that is extracted from the IPCC and USCCSP has endured a more thorough and systematic review process than information on virtually any other topic in environmental science and policy. The MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change) model and the IPCC emissions scenarios described below are generally accepted in the scientific community.

Figure 3.4-3. Cascade of Uncertainty in Climate Change Simulations a/



a/ Source: Moss and Schneider (2000) – "Cascade of uncertainties typical in impact assessments showing the 'uncertainty explosion' as these ranges are multiplied to encompass a comprehensive range of future consequences, including physical, economic, social, and political impacts and policy responses."

NHTSA is aware of the USCCSP's recent release of the Final Report of Synthesis and Assessment Product (SAP) 3.1 regarding the strengths and limitations of climate models (CCSP 2008g). The reader might find the discussions in this draft Synthesis and Assessment Product useful to grasp a better understanding of the methodological limitations regarding modeling the environmental impacts of the proposed action and the range of alternatives on climate change.

3.4.3.1 Methodology for Modeling Greenhouse Gas Emissions

GHG emissions were estimated using the Volpe model, as described in Section 3.1.4. The emissions estimates include CO_2, CH_4, and N_2O emissions from both direct fuel combustion and upstream sources. The Volpe model also accounted for and estimated the following non-GHGs: SO_2, NO_x, CO, and VOCs.

The Volpe model assumes that major manufacturers will utilize all available technology before paying noncompliance civil penalties. In the more stringent alternatives, the Volpe model predicts that increasing numbers of manufacturers will run out of technology to apply and, theoretically, resort to penalty payment. Setting standards this high might not be technologically feasible, and doing so might not serve the need of the Nation to conserve fuel or reduce emissions.

Fuel savings from stricter CAFE standards also result in lower emissions of CO_2, the main GHG emitted as a result of refining, distribution, and use of transportation fuels.[12] There is a direct relationship between fuel economy and CO_2 emissions. Lower fuel consumption reduces CO_2 emissions directly because the primary source of transportation-related CO_2 emissions is fuel combustion in internal-combustion engines. NHTSA estimates reductions in CO_2 emissions resulting from fuel savings by assuming that the carbon content of gasoline, diesel, and other fuels is converted entirely to CO_2 during

[12] For this rulemaking, NHTSA estimated emissions of vehicular CO_2, CH_4, and N_2O emissions, but did not estimate vehicular emissions of HFCs. Methane and nitrous oxide account for less than 3 percent of the tailpipe GHG emissions from passenger cars and light trucks, and CO_2 emissions account for the remaining 97 percent. Of the total (including non-tailpipe) GHG emissions from passenger cars and light trucks, tailpipe CO_2 represents about 93.1 percent, tailpipe methane and nitrous oxide represent about 2.4 percent, and HFCs (from air conditioner leaks) represent about 4.5 percent. (Values calculated from EPA 2008a.)

the combustion process.[13] Reduced fuel consumption also reduces CO_2 emissions that result from the use of carbon-based energy sources during fuel production and distribution. NHTSA currently estimates the reductions in CO_2 emissions during each phase of fuel production and distribution using CO_2 emissions rates obtained from the GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model, using the previous assumptions about how fuel savings are reflected in reductions in each phase (NHTSA 2008b). The total reduction in CO_2 emissions from improving fuel economy under each alternative CAFE standard is the sum of the reductions in emissions from reduced fuel use and from lower fuel production and distribution.

3.4.3.2 Methodology for Estimating Climate Effects

This FEIS estimates and reports on four direct and indirect effects of climate change, driven by alternative scenarios of GHG emissions, including:

1. Changes in CO_2 concentrations
2. Changes in global mean surface temperature
3. Changes in regional temperature and precipitation
4. Changes in sea level

The change in CO_2 concentration is a direct effect of the changes in GHG emissions and influences each of the other factors.

This FEIS uses a climate model to estimate the changes in CO_2 concentrations, global mean surface temperature, and changes in sea level for each alternate CAFE standard and uses increases in global mean surface temperature combined with an approach and coefficients from the IPCC Fourth Assessment Report (IPCC 2007a) to estimate changes in global precipitation. NHTSA used MAGICC version 5.3 (Wigley 2003 to 2008) to estimate changes in key direct and indirect effects. The application of MAGICC version 5.3 uses the emissions estimates for CO_2, CH_4, and N_2O from the Volpe model. Sensitivity analyses were completed to examine the relationship among various CAFE alternatives, climate sensitivities, and scenarios of global emissions paths and the associated direct and indirect effects for each combination. These relationships can be used to infer the effect of emissions associated with the regulatory alternatives on direct and indirect climate effects.

Sections 3.4.3.2.1 through 3.4.3.2.4 describe MAGICC, the climate sensitivity analyses, and the emissions scenarios used in the analysis.

3.4.3.2.1 MAGICC Version 5.3

The selection of MAGICC for this analysis was driven by a number of factors, as follows:

- MAGICC has been used in the peer-reviewed literature to evaluate changes in global mean surface temperature and sea-level rise, including the IPCC Fourth Assessment Report for WGI (IPCC 2007a) in which it was used to scale the results from the atmospheric-ocean general circulation models (AOGCMs)[14] to estimate the global mean surface temperature and the sea-level rise for global emissions scenarios that the AOGCMs did not run.

[13] This assumption results in a slight overestimate of CO_2 emissions, because a small fraction of the carbon content of gasoline is emitted as carbon monoxide and unburned hydrocarbons. However, the magnitude of this overestimate is likely to be extremely small. This approach is consistent with the recommendation of the IPCC for "Tier 1" national GHG emissions inventories (IPCC 2006).
[14] For a discussion of AOGCMs, *see* WGI, Chapter 8 in IPCC (2007a).

- MAGICC is publicly available and is already populated with the Special Report on Emission Scenarios (SRES) scenarios. The SRES scenarios are long-term emissions scenarios representing different assumptions about key drivers of GHG emissions. They are described in more detail below.

- MAGICC was designed for the type of analysis performed in this FEIS.

- More complex AOGCMs are not designed for the type of sensitivity analysis performed here and are best used to provide results for groups of scenarios with much greater differences in emissions such as the B1 (low), A1B (medium), and A2 (high) scenarios.[15]

- MAGICC has been updated to version 5.3 to incorporate the science from the IPCC Fourth Assessment Report (Wigley 2003 to 2008).

For the analysis using MAGICC, we have assumed that global emissions consistent with the No Action Alternative (Alternative 1) follow the trajectory provided by the SRES A1B (medium) scenario.

3.4.3.2.2 Modeling Runs and Sensitivity Analyses

The modeling runs and climate sensitivity analyses are designed to use information on CAFE alternatives, climate sensitivities, and SRES emissions scenarios provided by the IPCC (IPCC 2007a)[16] to model relative changes in atmospheric concentrations, global mean surface temperature, precipitation, and sea-level rise.

The modeling runs are based on the results provided for the seven CAFE alternatives using the Reference Case Volpe model assumptions, a climate sensitivity of 3 °C for a doubling of CO_2 concentrations in the atmosphere, and the SRES A1B (medium) scenario.

The approach uses the following steps to estimate these changes:

1. NHTSA assumed that global emissions consistent with the No Action Alternative follow the trajectories provided by the SRES A1B scenario, providing results illustrating the uncertainty due to factors influencing future global emissions of GHGs.

2. NHTSA assumed that global emissions for the CAFE alternatives are equal to the global emissions from the No Action Alternative minus the emissions reductions from the Volpe model for CO_2, CH_4, N_2O, SO_2, NO_x, CO, and VOCs. All SO_2 reductions were applied to the Aerosol region 1 of MAGICC, which includes North America.

3. NHTSA used MAGICC 5.3 to estimate the changes in CO_2 concentrations, global mean surface temperature, and sea-level rise through 2100 using the No Action Alternative and CAFE alternatives developed in Steps 1 and 2 above.

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[15] The IPCC SRES scenarios were developed in the late 1990s and published in 2000 (Nakicenovic *et al.* 2000). The SRES scenarios were developed around four storylines. The A1 storyline included a strong commitment to market based solutions, high savings, high economic growth, and globalization. The A2 storyline differs from A1 with lower trade flows and slower rates of technological improvement. The B1 storyline includes a global integrated approach to sustainable development. The B2 storyline includes increased local awareness of environmental issues with strong efforts at the local level and less reliance on international institutions.

[16] The use of different emissions scenarios provides insight into the impact of alternative global emissions scenarios on the effect of the CAFE alternatives.

4. For the core results, NHTSA used the increase in global mean surface temperature, along with factors relating increase in global average precipitation to this increase in global mean surface temperature, to estimate the increase in global averaged precipitation for each CAFE alternative for the A1B (medium) scenario.

The approach uses the following steps to estimate the climate sensitivity of the results to the selection of the SRES global emissions scenario:

1. NHTSA assumed that global emissions consistent with the No Action Alternative follow four potential trajectories represented by the SRES A2, B1, B2, and A1FI scenarios. The results of these simulations illustrate the uncertainty due to factors influencing future global emissions of GHGs (that is, factors other than the CAFE rulemaking).

2. For each SRES scenario from Step 1, NHTSA assumed that global emissions for the CAFE alternatives are equal to the global emissions from the No Action Alternative minus the emissions reductions from the Volpe model for CO_2, CH_4, N_2O, SO_2, NO_x, CO, and VOCs. All SO_2 reductions were applied to the Aerosol region 1 of MAGICC, which includes North America.

3. NHTSA used MAGICC 5.3 to estimate the changes in CO_2 concentrations, global mean surface temperature, and sea-level rise through 2100 using the No Action Alternative and CAFE alternatives developed in Steps 1 and 2.

Section 3.4.4 presents the results of the model runs for the alternatives. Section 3.4.5 presents the results from similar runs in which the CAFE alternatives use the high- and mid-level Volpe model assumptions (for this analysis, called the High, Mid-1, and Mid-2 Scenarios), in effect providing a “CAFE assumption sensitivity analysis.”

3.4.3.2.3 Emissions Scenarios

As described above, MAGICC uses long-term emissions scenarios representing different assumptions about key drivers of GHG emissions. All scenarios used are based on the IPCC effort to develop a set of long-term (1990 to 2100) emissions scenarios to provide some standardization in climate-change modeling. The most widely used scenarios are those from the SRES (Nakicenovic *et al.* 2000).

The results rely primarily on the SRES scenario referred to as “A1B” to represent a Reference Case emissions scenario; that is, emissions for the No Action Alternative. NHTSA selected this scenario because it is regarded as a moderate emissions case and has been widely used in AOGCMs, including several AOGCM runs developed for the IPCC Fourth Assessment Report (IPCC 2007a).

NHTSA chose the A1B scenario based on the following factors:

- IPCC Working Group I evaluated the climate effects from A1B extensively in the Fourth Assessment Report (IPCC 2007a) and provides a basis for comparing the results from the analysis using MAGICC to those in the IPCC Fourth Assessment Report.

- The A1B and B2 scenarios are “middle-of-the-road” scenarios and provide the best comparison (see below) to the Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2008 and International Energy Outlook (IEO) 2008 forecasts of liquid energy use, and the AEO 2008/IEO 2008 provide the base assumptions for key parameters in the Volpe model scenarios.

The A1B (medium) scenario provides a global context for emissions of a full suite of GHGs and ozone precursors. There are some inconsistencies between the overall assumptions IPCC used in its SRES (Nakicenovic *et al.* 2000) to develop global emissions scenarios and the assumptions used in the Volpe model in terms of economic growth, energy prices, energy supply, and energy demand. However, these inconsistencies affect the characterization of each CAFE alternative in equal proportion, so the relative estimates provide a reasonable approximation of the differences in environmental impacts among the alternatives. NHTSA used the A1B scenario as the primary scenario for the evaluation of climate effects, but used the A2, B1, B2, and the A1FI scenarios to provide an evaluation of the sensitivity of the results to alternative emissions scenarios.[17]

Each of the alternatives was simulated by calculating the difference in annual GHG emissions in relation to the No Action Alternative and subtracting this change from the A1B (medium) scenario to generate modified global-scale emissions scenarios, which each show the effect of the various regulatory alternatives on the global emissions path. For example, emissions from U.S. autos and light trucks in 2020 under Alternative 1, No Action, are 1,651 $MMTCO_2$; the emissions in 2020 under the Optimized Alternative (Alternative 3) are 1,622 $MMTCO_2$. The difference is 29 $MMTCO_2$. Global emissions for the A1B (medium) scenario in 2020 are 46,339 $MMTCO_2$, and represent the No Action Alternative. Global emissions for the Optimized Alternative are 29 $MMTCO_2$ less, or 46,310 $MMTCO_2$.

NHTSA based its assumptions in the Volpe model for growth in the number of vehicles and miles driven for cars and light trucks in the United States on those in the AEO because the IPCC SRES results are reported for four global regions, including the OECD, and not for the United States separately. The EIA also published the IEO for 2008 (EIA 2008c), which provides a global forecast of energy use and CO_2 from energy use through 2030, and which is consistent with assumptions in the 2008 IEO.[18]

Figures 3.4-4 to 3.4-7 provide the forecast of gross domestic product (GDP), CO_2 emissions from energy use, primary energy use from the IEO 2008, and the five SRES scenarios for the world and OECD 90 region.[19] The GDP growth assumptions for A1B for the OECD are close to those of the IEO 2008, but the A1B scenario has much higher GDP growth outside the OECD. This leads to higher global primary energy use by 2030, as shown in Figure 3.4-6, with much of the increase in natural gas use and higher emissions of CO_2 as shown in Figure 3.4-5. The global primary liquids energy use in A1B and the IEO 2008 compare well considering that the IEO forecast for liquid fuels includes about 10 percent of the total in unconventional sources, which are accounted for elsewhere in the SRES scenarios.

The forecast estimates for the OECD 90 region vary differently than the global numbers. The EIA shows a similar increase in primary energy use in the OECD 90 region but much greater increase in the use of primary liquid fuels, even considering the reporting differences between the IEO and SRES.

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[17] From SRES, NHTSA used the A1B-AIM scenario to represent the A1B storyline, the A2-ASF scenario to represent the A2 storyline, the B1-IMAGE scenario to represent the B1 storyline, the B2-MESSAGE scenario to represent the B2 storyline, and the A1G-MINICAM scenario to represent the A1FI storyline.

[18] The IEO 2008 uses energy supply and consumption from the AEO 2008 for the United States and the same forecast for world oil prices.

[19] The IEO nuclear primary energy forecast numbers were adjusted to account for differences in reporting primary energy use for nuclear energy and all IEO energy-use estimates were converted to exajoules (EJ).

Figure 3.4-4. Average GDP Growth Rates (1990 to 2030)

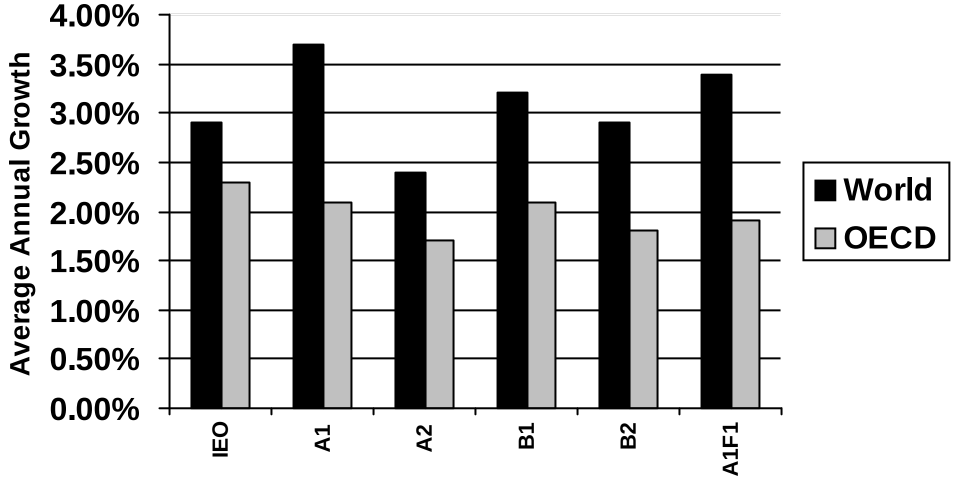


Figure 3.4-5. Global CO2 Emissions from Fossil Fuel Use

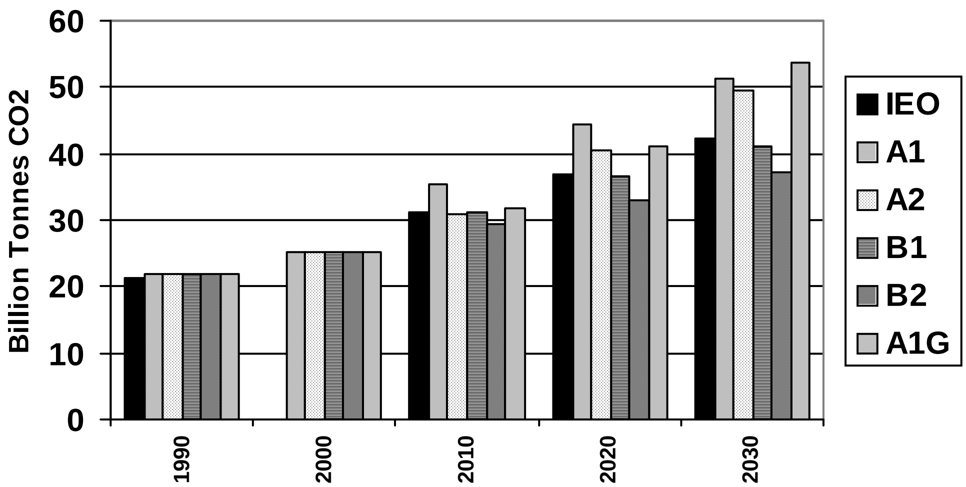


Figure 3.4-6. World Primary Energy Use Forecast

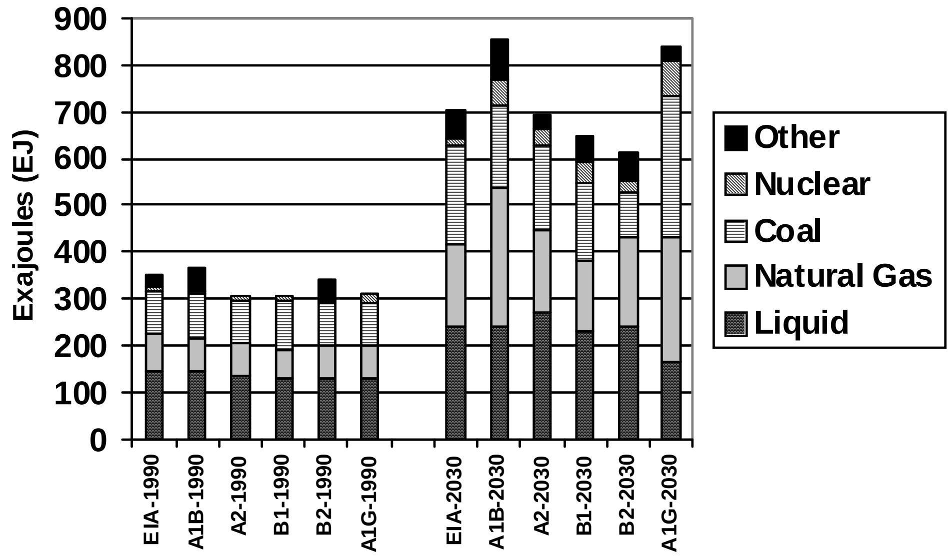
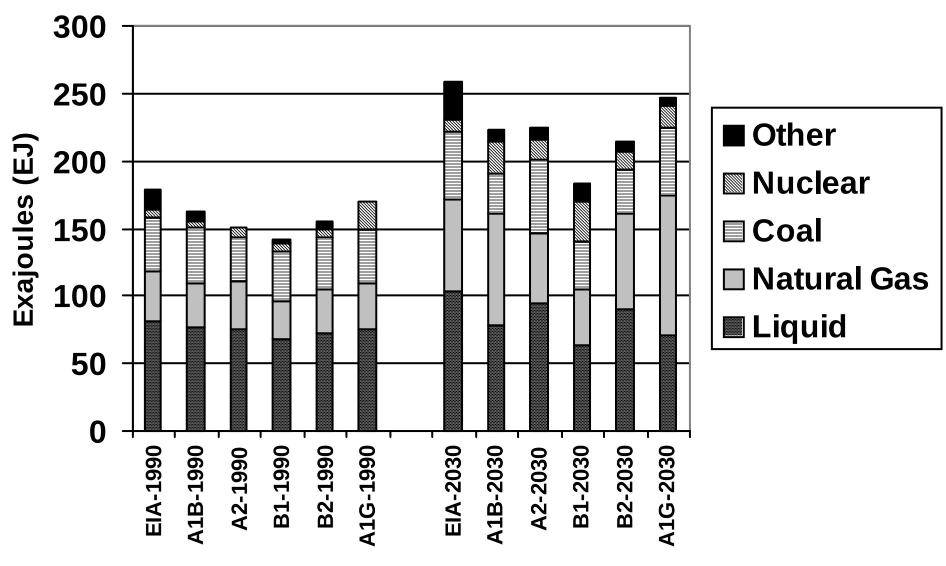


Figure 3.4-7. OECD90 Primary Energy Use Forecast[20]



Where information in the analysis included in this FEIS is incomplete or unavailable, NHTSA has relied on the CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). In this case, despite the inconsistencies between the IPCC assumptions on global trends

[20] The SRES results provide forecasts for countries that were members of the OECD in 1990 only. The IEO 1990 and 2030 estimates are scaled to reflect only countries in the OECD in 1990.

across all GHG-emitting sectors (and the drivers that affect them) and the particularities of the Volpe model on the U.S. transportation sector, the approach used is valid for this analysis. These inconsistencies affect all alternatives equally; therefore, they do not hinder a comparison of the alternatives in terms of their relative effects on climate.

The approaches focus on marginal changes in emissions that affect climate. Thus, the approaches result in a reasonable characterization of climate change for a given set of emissions reductions, regardless of the underlying details associated with those emissions reductions. The discussion that follows characterizes projected climate change under the No Action Alternative (Alternative 1) and the action alternatives (Alternatives 2 through 7).

The climate sensitivity analysis also uses the B1 (low), B2, A2 (high), and A1F1 emissions scenarios (Nakicenovic *et al.* 2000) as "reference" scenarios. This provides a basis for determining climate responses to varying levels of global emissions and climate sensitivities under for the Optimized Alternative (Alternative 3). Some responses of the climate system are believed to be non-linear; by using a range of emissions cases and climate sensitivities, the effects of the alternatives in relation to different reference cases can be estimated.

3.4.3.2.4 Tipping Points and Abrupt Climate Change

The phrase "tipping point" is most typically used, in the context of climate change and its consequences, to describe situations in which the climate system (the atmosphere, oceans, land, cryosphere,[21] and biosphere) reaches a point at which there is a disproportionately large or singular response in a climate-affected system as a result of only a moderate additional change in the inputs to that system (such as an increase in the CO_2 concentration). Exceeding one or more tipping points, which "occur when the climate system is forced to cross some threshold, triggering a translation to a new state at a rate determined by the climate system itself and faster than the cause" (Committee on Abrupt Climate Change 2002), could result in abrupt changes in the climate or any part of the climate system. These changes would likely produce impacts at a rate and intensity far greater than the slower, steady changes currently being observed (and in some cases, planned for) in the climate system.

The phrase tipping point is also used outside the climate modeling community. In addition to climate scientists, many others – including biologists, marine chemists, engineers, and policymakers – are concerned about tipping points, because it is not just the climate that can change abruptly. The same type of non-linear responses exists in the physical, environmental, and societal systems that climate affects. For example, ocean acidity resulting from an elevated atmospheric concentration of CO_2 might reach a point at which there would be a dramatic decline in coral ecosystems. Consideration of possible tipping points could therefore encompass sharp changes in climate-affected resources and not be restricted to climate change alone.

Using the broad definition of the term tipping point to include both climate change and its consequences, the scale of spatial responses can range from global (*e.g.*, a "supergreenhouse" atmosphere with higher temperatures worldwide), to continental or subcontinental changes (such as dramatically altering the Asian monsoon), to regional (*e.g.*, drying in the southwestern United States leading to increases in the frequency of fires, to local (such as loss of the Sierra Nevada snowpack). The definition of tipping point used by Lenton *et al.* (2008) (discussed below) specifically applies only to subcontinental or larger features, whereas public policy is concerned with a wider range of scales, as the IPCC analysis (discussed below) suggests.

[21] The cryosphere describes the portion of Earth's surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.

The temporal scales considered are also important. On crossing a tipping point, the evolution of the climate-affected system is no longer controlled by the time scale of the climate forcing (such as the heat absorption by GHGs), but rather is determined by its internal dynamics, which can either be much faster than the forcing, or substantially slower. The much faster case – abrupt climate change – might be said to occur when the:

- Rate of change is sharply greater than (or a different sign than) what has been prevailing over previous decades;
- State of the system exceeds the range of variations experienced in the past; or
- Rate has accelerated to a pace that exceeds the resources and ability of nations to respond to it.

Climate changes could occur in many ways as tipping points are reached. These mechanisms range from the appearance or unusual strengthening of positive feedbacks – self-reinforcing cycles – and reversible-phase transitions in climate-affected systems to irreversible-phase transitions – where a threshold has been crossed that could lead to either abrupt or unexpected changes in the rate or direction of change in climate-affected systems. Although climate models incorporate many positive (and negative, or dampening) feedback mechanisms, the magnitude of these effects and the threshold at which the feedback-related tipping points are reached are only roughly known, especially regarding global impacts. In addition, models of climate and climate-affected systems do not contain all feedback processes. Although substantial progress has been made in understanding the qualitative processes associated with tipping points, there are limits to the quantitative understanding of many of these systems.

In recent years, the concept of a tipping point – or a set of tipping points – in Earth's climate system has been attracting increased attention among climate scientists and policy makers. The following sections draw on perspectives from four key analyses of the issue and other relevant research: the IPCC, the USCCSP, paleoclimate[22] evidence, and Lenton *et al.* (2008). The section concludes with a brief comparative evaluation.

IPCC Perspectives on Tipping Points

In its Fourth Assessment Report, the IPCC addresses the issue of tipping points in the discussion of "major or abrupt climate changes" and highlights three large systems: the meridional overturning circulation (MOC) system that drives Atlantic Ocean circulation, the collapse of the West Antarctic ice sheet, and the loss of the Greenland ice sheet (Meehl *et al.* 2007). The IPCC states that there is uncertainty in the understanding of these systems but concludes that these systems are unlikely to reach their tipping points within the 21st Century (Meehl *et al.* 2007). The IPCC also mentions additional systems, as noted below, that might have tipping points, but does not include estimates for them.

The IPCC WGI report (Meehl *et al.* 2007) describes various climate and climate-affected systems that might undergo abrupt change, contribute to "climate surprises," or experience irreversible impacts. The systems that the IPCC described include:

- Atlantic MOC (AMOC) and other ocean circulation changes
- Arctic sea ice

[22] Paleoclimatology is the study of climate change through the physical evidence left on earth of historical global climate change (prior to the widespread availability of records to temperature, precipitation, and other data). *See generally* http://www.giss.nasa.gov/research/paleo/.

- Glaciers and ice caps
- Greenland and West Antarctic ice sheets
- Vegetation cover
- Atmospheric and ocean-atmosphere regimes

The IPCC Working Group II (WGII) report provides insight on the uncertainties surrounding tipping points, their systemic and impact thresholds, and the value judgments required to select a critical level of warming (Carter *et al.* 2007). The presence of these thresholds can also present their own physical and ecological limits and informational and cognitive barriers to adaptation (Adger *et al.* 2007). In the case of this FEIS, uncertainty prevents NHTSA from being able to quantify the impacts of the alternatives under consideration on specific tipping-point thresholds.

In the IPCC WG II report, certain thresholds are assumed and then used with analyses of emissions scenarios and stabilization targets to assess how certain impacts might be avoided (Schneider *et al.* 2007). For example, several authors hypothesize that a large-scale climatic event or other impacts (for example, widespread coral-reef bleaching; deglaciation of West Antarctica) would be likely if atmospheric CO_2 concentrations stabilize at levels exceeding 450 ppm, although the location of the tipping points and thresholds is uncertain (O'Neill and Oppenheimer 2002, Lowe *et al.* 2006, and Corfee-Morlot and Höhne 2003, all as cited in Schneider *et al.* 2007).

USCCSP Perspectives on Tipping Points

The USCCSP reaches similar conclusions in its report *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008). The USCCSP report summarizes scientific studies that suggest that there are several "triggers" of abrupt climate change and that "anthropogenic forcing *could* increase the risk of abrupt climate change;" however, "future abrupt changes cannot be predicted with confidence" because of the insufficiencies of current climate models, which reflect the limits of current understanding.[23] However, the USCCSP report does reiterate the conclusion that if it occurs, an abrupt climate change event would likely transpire over the course of many hundreds of years and that it is *"very unlikely"* that any abrupt climate change will occur "during the 21st century."

The USCCSP analysis considers the susceptibility of the same three systems to abrupt change as IPCC highlighted: the AMOC system that drives Atlantic Ocean circulation, the collapse of the West Antarctic ice sheet, and the loss of the Greenland ice sheet (National Science and Technology Council 2008). The USCCSP analysis also suggests that there are thresholds in non-climate systems influenced by CO_2 emissions, such as ocean acidification, where there could be a threshold beyond which existing coral reef ecosystems cannot survive (CCSP 2008e). The USCCSP report concludes that these impacts, including climate-related thresholds, could occur in groups as thresholds are crossed, but, due to the uncertainty, more research is needed to quantify the impacts of crossing particular thresholds and to determine when these thresholds would be reached (CCSP 2008e). A forthcoming USCCSP report, Synthesis and Assessment Product 3.4, "Abrupt Climate Change," will provide additional information on this topic, focusing on glaciers and ice sheets, hydrological change, the MOC, and methane releases.

[23] *See* U.S. Climate Change Science Program, Synthesis and Assessment Product 3.1 (Climate Models: An Assessment of Strengths and Limitations), Final Report (July 2008), *available at* http://www.climatescience.gov/Library/default.htm#sap.

Paleoclimate Evidence on Tipping Points

The paleoclimate record cited by IPCC, USCCSP, and others gives an indication of sea-level rise from previous ice-sheet melt, and the corresponding temperature for these periods. For example, geological evidence showing the presence of elevated beaches suggests that global sea level was 4 to 6 meters higher during the most recent interglacial period about 125,000 years ago (Jansen *et al.* 2007). Paleoclimatic reconstructions suggest that global average temperature then was about 1 °C (1.8 °F) warmer than during the present interglacial period (Hansen *et al.* 2007b). Corings from the ice sheets to determine their ages, supplemented by simulations of ice-sheet extent, suggest that large-scale retreat of the southern half of the Greenland ice sheet and other Arctic ice fields likely contributed roughly 2 to 4 meters of sea-level rise during the last interglacial, with most of any remainder likely coming from the Antarctic ice sheet (Jansen *et al.* 2007).

Paleoclimatic reconstructions also indicate occurrences of abrupt changes in the terrestrial, ice, and oceanic climatic records. For example, ice-core records suggest that temperatures atop the Greenland ice sheet warmed by 8 to 16 °C (14 to 29 °F) within a few decades during Dansgaard-Oeschger events,[24] which were likely caused by the North Atlantic Ocean being covered by catastrophic outflows of glacial meltwater from the North American ice sheet that was present during glacial times (Jansen *et al.* 2007). A more recent study (Steffensen *et al.* 2008) provides more detail, indicating that a there was a sharp warming over 1 to 3 years (that is, "abrupt climate change happens in [a] few years"), followed by a more gradual warming over 50 years.

Based on the IPCC estimates of temperature increases of approximately 2 to 4 °C in the next 100 years, MacCracken (2008) notes that paleoclimatic research indicates that corresponding sea-level rise could be 10 to 20 meters or more from the melting of the West Antarctic and Greenland ice sheets. The time required to melt the ice sheets is uncertain, ranging from decades to centuries or longer. MacCracken (2008) suggests that "significant sea level rise [over 1 meter] could happen relatively quickly," meaning less than a century. For example, the average rate of rise from 20 kiloannum[25] (ka) to 8 ka was about 1 meter per century, so there have been periods with high rates of rise, although the melting North American ice sheet was an order of magnitude larger than Greenland is today (MacCracken, personal communication, 2008). For the future, Hansen *et al.* (2007b) asserts that positive feedback mechanisms in the climate system have the potential to cause large and rapid shifts in climate and in factors like glacial melt and sea-level rise that are closely dependent on the climate; Rahmstorf (2007) presents a projected sea-level rise in 2100 of 0.5 to 1.4 meters above the 1990 level.

In a study utilizing model runs and paleoclimatic data,[26] Hansen *et al.* (2007b) conclude that "…a CO_2 level exceeding about 450 ppm is 'dangerous,'" where "dangerous" is defined by the authors to be global warming of more than 1 ºC (1.8 ºF) above the level in 2000, potentially leading to highly disruptive effects. Although this 450-ppm estimate has limitations and uncertainties, Hansen actually considers this estimate of dangerous CO_2 concentration to be an upper limit because it depends on several simplifying assumptions (Hansen 2008b). He warns that the limit might be lower and that a "safe" level

[24] Dansgaard-Oeschger events are very rapid climate changes—up to 7 °C in some 50 years—during the Quaternary geologic period, and especially during the most recent glacial cycle. (A Dictionary of Geography. Oxford University Press, 1992, 1997, 2004.)
[25] Kiloannum means "one thousand years ago."
[26] The authors compare the corresponding GHG concentrations and associated temperature increases to paleoclimatology research to demonstrate that abrupt changes have occurred in Earth's past, resulting from a similar range in increased temperature as those being predicted, and to argue the existence of a CO_2 concentration equivalent level (in atmospheric GHG concentration) at which the probability of abrupt, irreversible changes in climate-affected systems might occur.

of CO_2 could be 350 ppm – lower than the CO_2-equivalent concentration, including the offsetting effects of aerosols, is today (Hansen 2008b).

The range of views linking past and future sea-level rise is clearly broad, with uncertainty attributable to each view. Therefore, the forthcoming USCCSP report – Synthesis and Assessment Product 3.4, "Abrupt Climate Change" – should provide additional, more complete information on the issue.

Perspectives on Tipping Points from a Critical Review of the Literature and an Expert Elicitation as Presented by Lenton *et al.* (2008)

Building on the IPCC and USCCSP research, during a workshop titled "Tipping Points in the Earth System," experts identified several climate systems that have tipping points and conducted an expert elicitation involving 52 members of the international scientific community, many of whom participated in the IPCC. This study identified nine systems facing separate tipping points due to increased CO_2 and temperature levels that met four scientifically based criteria to be considered "policy-relevant potential future tipping elements in the climate system" (Lenton *et al.* 2008). Additional systems were identified but insufficient information precluded these systems from meeting the definition of policy relevant. The systems at risk that the researchers identified are:

- Arctic sea ice
- Greenland ice sheet
- West Antarctic ice sheet
- Atlantic thermohaline circulation (a component of the AMOC)
- El-Niño-Southern oscillation
- Indian summer monsoon
- Sahara/Sahel and West African monsoon
- Amazon rainforest
- Boreal forest

The discussion that follows is drawn primarily from the Lenton *et al.* (2008) study, including the citations therein.

Arctic sea ice. The surface of Arctic sea ice has a higher reflectivity (albedo) than the darker ocean surface. As sea ice melts from higher air and ocean temperatures, more of the ocean is exposed, which allows more radiation to be absorbed, amplifying the sea-ice melt. In summer, Arctic sea-ice loss could lead to the ice cap melting beyond a certain size/thickness, making it unstable and leading to an ice-free Arctic. Recent record ice losses and modeling studies have led some researchers to suggest that the summer Arctic will be ice free within a decade or less, that there is a critical threshold for summer Arctic sea-ice loss, and that this threshold has already been crossed (Borenstein and Joling 2008).

Greenland ice sheet. The Greenland ice sheet is also susceptible to positive feedbacks. Melting at the glacial margins lowers the edge of the ice sheet to elevations that are warmer and where more melting will occur. The IPCC estimated the Greenland ice sheet threshold for negative surface mass at 1.9 to 4.6 °C (3.4 to 8.3 °F) above pre-industrial temperature, well within the predicted temperature range for this century. Dynamic ice-melting processes, regional temperatures, warming surrounding oceans, and recent observations indicating that both Greenland and Antarctica are now losing mass have led researchers to conclude that the timescale for Greenland ice-shelf collapse is conceivably on a scale of hundreds rather than thousands of years.

West Antarctic ice sheet. The West Antarctic ice sheet is grounded below sea level and positive feedbacks could result from the loss of buttressing sea-ice shelves and the ingress of warmer ocean water. While centuries or millennia could to pass before a collapse, the thresholds for ocean and surface atmospheric warming temperature are likely to be crossed this century. A recent study of ice-core records suggests strong links between past West Antarctic climate, and potentially its ice sheet, to large-scale changes in global climate, particularly major El Niño events (Schneider and Steig 2008). It should be noted that ice-sheet loss, even over millennia, could cause the sea level to rise at a rate greater than 1 meter per century – more than five times the rate of rise during the 20^{th} Century. The level reached would be higher than has been the case during at least the past few thousand years when coastal cities were established.

Atlantic thermohaline circulation. The term thermohaline circulation (THC) refers to the physical driving mechanism of ocean circulation, resulting from fluxes of heat and freshwater across the sea surface, subsequent interior mixing of heat and salt, and geothermal heat sources. The MOC, discussed in the IPCC and USCCSP reports, is the observed response in an ocean basin to this type of ocean circulation coupled with wind-driven currents. The Lenton *et al.* (2008) paper refers to risk to the Atlantic THC instead of the AMOC because they are discussing the influence of climate change on the underlying cooling or freshwater forcing of the Atlantic Ocean circulation, even though this in turn dramatically affects the AMOC.

If enough freshwater enters the North Atlantic (such as from melting sea ice or the Greenland ice sheet), the density-driven sinking of North Atlantic waters might be reduced or even stopped, as evidence indicated occurred happened during the last glacial cycle. This would likely reduce the northward flow of energy in the Gulf Stream and result in less heat transport to the North Atlantic. At the same time, reduced formation of very cold water would likely slow the global ocean THC, leading to impacts on global climate and ocean currents. The IPCC review of the results of model simulations suggests that an abrupt transition of the Atlantic Ocean's component of the global THC is *very unlikely* this century. However, more recent modeling that includes increased freshwater inputs suggests there could be initial changes this century, with larger and more intense reductions in the overturning circulation persisting for many centuries (Mikolajewicz *et al.* 2007).

El-Niño-Southern oscillation (ENSO). The changes that might lead to increasingly persistent (and frequent) El Niño (or La Niña) conditions are particularly uncertain. Increases in ocean heat content could have an effect on ENSO conditions, but predictive and paleoclimate modeling studies do not agree on the magnitude, frequency, and direction of these effects. However, ENSO has substantial and large-scale effects on the global climate system.

Indian summer monsoon. The Indian summer monsoon is the result of land-to-ocean pressure gradients and advection of moisture from ocean to land. By warming the land more than the ocean, climate change generally strengthens the monsoon. However, reductions in the amount of solar radiation that is absorbed by the land surface, such as land-use change, generally weaken it. An albedo greater than roughly 50 percent is necessary to simulate the collapse of the Indian summer monsoon in a simple model (Zickfield *et al.* 2005). IPCC projections do not project passing a threshold this century, although paleoclimatic reconstructions do indicate that the monsoon has changed substantially in the past.

West African monsoon. Sahara/Sahel rainfall depends on the West African monsoon circulation, which is affected by sea-surface temperature. By warming the land more than the ocean and therefore causing greater upward movement of the air, GHG forcing is expected to draw more moist oceanic air inland and thereby increase rainfall in the region, which has been shown by some models. Other models, however, project a less productive monsoon. The reasons for this inconsistency are not clear.

Amazon rainforest. The recycling of precipitation in the Amazon rainforest means that deforestation, reductions in precipitation, a longer dry season, and increased summer temperature could cause forest dieback. These conditions are thought to be linked to a more persistent El Niño and an increase of global average temperature by 3 to 4 °C (5.4 to 6.8 °F). Important additional stressors also present include forest fires and human activity (such as land clearing). A critical threshold might exist in canopy cover, which could be reached through changes in land use or regional precipitation, ENSO variability, and global forcing.

Boreal Forest. The dieback of boreal forest could result from a combination of increased heat stress and water stress, leading to decreased reproduction rates, increased disease vulnerability, and subsequent fire. Although highly uncertain, studies suggest a global warming of 3 °C (5.4 °F) could be the threshold for loss of the boreal forest.

Comparative Evaluation

The Lenton *et al.* (2008) group's list differs slightly from that of the IPCC because of differences in definition and criteria, an attempt to be more explicit than the IPCC, and the inclusion of more recent studies. The scientists defined these tipping points as "tipping elements" and attempted to estimate when the tipping element of the various systems might be reached, ranging from about 1 year (rapid) to more than 300 years (slow). As with the IPCC and USCCSP conclusions, this group also concluded that the loss of the Greenland ice sheet, the collapse of the West Antarctic ice sheet, and the disruption of the Atlantic THC systems are not expected to cross their estimated tipping elements in this century (though actions this century could create enough momentum in the climate system to cross the threshold in future centuries[27]). However, this group determined that several other systems could reach a tipping threshold within the century: loss of Arctic sea ice, Indian summer monsoon disruption, Sahara/Sahel and West African monsoon changes, drying of the Amazon rainforest, and warming of the boreal forest.

Another factor that might accelerate climate change at rates faster than those currently observed is the possible shift of soil and vegetation-carbon feedbacks, causing the soil and vegetation to become carbon sources rather than carbon sinks. Currently, soil and vegetation act as sinks, absorbing carbon from the atmosphere as plant material and storing carbon in the soil when the plants die. However, by mid-century (about the time the IPCC predicts the global average temperature reaches 2 ºC (3.6 ºF) above pre-industrial levels), increasing temperatures and precipitation could cause increased rates of transpiration, resulting in soil and vegetation becoming a potential source of carbon emissions (Cox *et al.* 2000 as cited in Meehl *et al.* 2007). Warming could also thaw frozen Arctic soils (permafrost), causing the wet soils to emit more methane, a GHG. There is evidence that this process is already taking place (Walter *et al.* 2007). This additional research clarifies the concept of tipping points by further revealing that several climate systems might have tipping points that could occur within the century, and in some systems changes are currently being observed. However, uncertainties exist, especially for timing estimates, and the uncertainties are at least partly responsible for the broad spectrum of views regarding the tipping point. Exactly where these tipping points exist, and the levels at which they occur, are still a matter in need of further scientific investigation before precise quantitative conclusions can be made.

Where information in this FEIS analysis is incomplete or unavailable, as here due to current climate modeling limitations, NHTSA has relied on the CEQ regulations regarding incomplete or unavailable information. 40 CFR § 1502.22(b). CEQ regulations state, in part, that when an agency is evaluating "reasonably foreseeable significant adverse impacts on the human environment and …information relevant to…[the] impacts cannot be obtained because the overall costs of obtaining it are exorbitant or the means to obtain it are not known, the agency shall include within the [EIS]:

[27] *See* Lenton *et al.* (2008).

(1) a statement that such information is incomplete or unavailable;

(2) a statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment;

(3) a summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment; and

(4) The agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community. For the purposes of this section, "reasonably foreseeable" includes impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason."

40 CFR § 1502.22 (b)

This FEIS addresses the requirements of 40 CFR § 1502.22 appropriately. The above survey of the current state of climate science tipping points provides a "summary of existing credible scientific evidence which is relevant to evaluating the…adverse impacts of the CAFE standards." In *Colorado Environmental Coalition v. Dombeck,* the Tenth Circuit found that the ultimate goal of the agency is to ensure that the EIS's "form, content, and preparation foster both informed decision making and informed public participation" (185 F.3d 1162, 1172 [10th Cir. 1999] [quoting *Oregon Envtl. Council v. Kunzman*, 817 F.2d 484, 492 (9th Cir. 1987)]). The Tenth Circuit held that 40 CFR § 1502.22 could not be read as imposing a "data gathering requirement under circumstances where no such data exists." *Id.*

In this case, this FEIS acknowledges that information on tipping points or abrupt climate change is incomplete, and the state of the science does not allow for a characterization of how the CAFE alternatives influence these risks. This action alone, even as analyzed for the most stringent alternative, does not produce sufficient CO_2 emissions reductions to avert levels of abrupt and severe climate change. To the degree that the action in this rulemaking reduces the rate of CO_2 emissions, the rule contributes to the general reduction or delay of reaching these tipping-point thresholds. These conclusions are not meant to be read as expressing NHTSA's view that tipping points in climate-related systems are not areas of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] *of the proposed action*" (42 U.S.C. § 4332(2)(C)(i) [emphasis added]). The above discussion fulfills NHTSA's NEPA obligations regarding this issue.

3.4.4 Environmental Consequences

This section describes the consequences of the MY 2011-2015 CAFE standards in relation to GHG emissions and climate effects.

3.4.4.1 Greenhouse Gas Emissions

To estimate the emissions resulting from changes in passenger-car and light-truck CAFE standards, NHTSA uses the Volpe model (*see* Section 3.1.4 for a description of the model). The change in fuel use projected to result from each alternative CAFE standard determines the resulting impacts on total and petroleum energy use, which in turn affects the amount of CO_2 emissions. Reducing fuel use also lowers CO_2 emissions from the use of fossil carbon-based energy during crude oil extraction, transportation, and refining, and in the transportation, storage, and distribution of refined fuel. Because CO_2 accounts for such a large fraction of total GHGs emitted during fuel production and use – more than 95 percent, even after accounting for the higher global warming potentials of other GHGs – NHTSA's consideration of GHG impacts focuses on reductions in CO_2 emissions resulting from the savings in fuel use that accompany higher fuel economy.[28]

NHTSA estimated GHG emissions for each alternative using the Reference Case assumptions. In the discussion and table that follows, emissions reductions represent the differences in total annual emissions by all cars or light trucks in use between their estimated future levels under the No Action Alternative (Alternative 1) and each action alternative (Alternatives 2 through 7). Emissions reductions resulting from the CAFE standard for MY 2011-2015 cars and light trucks were estimated from 2010 to 2100. Reductions would begin in 2010, the first year that MY 2011 vehicles would be on the road. For each alternative, all vehicles after MY 2015 were assumed to meet the MY 2015 CAFE standards. Emissions were estimated for all alternatives through 2100, and these emissions were compared against the NPRM baseline (which assumes all vehicles after MY 2010 meet MY 2010 standards) to estimate emissions reductions. The Volpe model estimates emissions through the year 2060.[29] Annual emissions reductions from 2061-2100 were held constant at 2060 levels.

Table 3.4-1 and Figure 3.4-8 show total emissions and emissions reductions resulting from applying the seven alternatives to new passenger cars and light trucks from 2010 to 2100. Emissions for the period range from 193,212 $MMTCO_2$ for the Technology Exhaustion Alternative (Alternative 7) to 221,258 $MMTCO_2$ for the No Action Alternative. Compared to the No Action Alternative, projections of emissions reductions over the period 2010 to 2100 due to the MY 2011-2015 CAFE standards ranged from 5,922 to 28,047 $MMTCO_2$.[30] Compared to global emissions of 4,850,000 $MMTCO_2$ over this period (projected by the A1B-medium scenario), this rulemaking is expected to reduce global CO_2 emissions by about 0.1 to 0.6 percent.

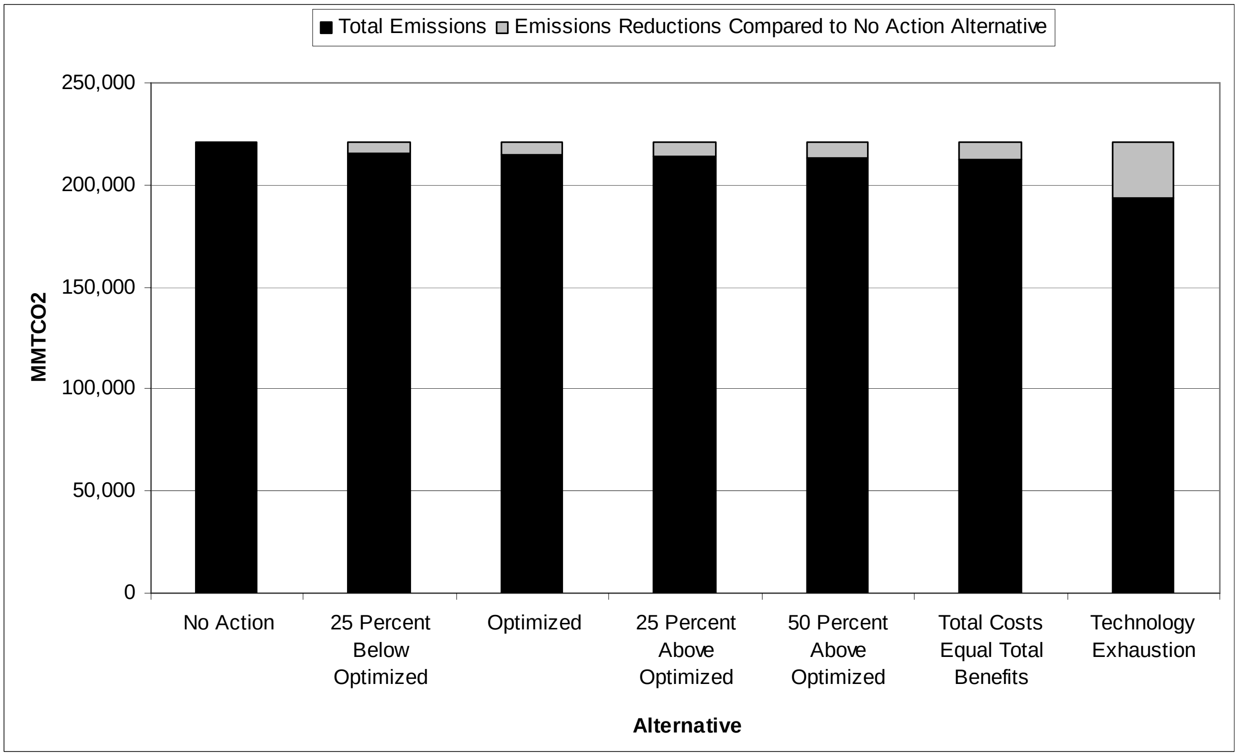
Table 3.4-1

Reference Case Emissions and Emissions Reductions Due to the MY 2011-2015 CAFE Standards from 2010-2100 ($MMTCO_2$)

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	221,258	0
2 25 Percent Below Optimized	215,337	5,922
3 Optimized	214,643	6,616
4 25 Percent Above Optimized	214,144	7,114
5 50 Percent Above Optimized	213,254	8,004
6 Total Costs Equal Total Benefits	212,345	8,913
7 Technology Exhaustion	193,212	28,047

[28] Although this section includes a discussion of CO_2 emissions only, the climate modeling discussion in Section 3.4.4.4 assesses the direct and indirect effects associated with emissions reductions of multiple gases, including CO_2, CH_4, N_2O, SO_2, CO, NO_x, and VOCs.
[29] *See* Section 3.1.3 for a summary of the scope and parameters of the Volpe model.
[30] The values here are summed from 2010 through 2100, and are thus considerably higher than the value of 520 $MMTCO_2$ cited in the NPRM for the Optimized Alternative (Alternative 3). The latter value is the reduction in CO_2 emissions by only MY 2011-2015 cars and light trucks over their lifetimes resulting from the optimized CAFE standards, measured as a reduction from the NPRM baseline of extending the CAFE standards for MY 2010 to apply to MY 2011-2015.

Figure 3.4-8. Reference Case Emissions and Emissions Reductions Due to the MY 2011-2015 CAFE Standards from 2010 to 2100 (MMTCO$_2$)



To get a sense of the relative impact of these reductions, it can be helpful to consider the relative importance of emissions from cars and light trucks as a whole and to compare them against emissions projections from the transportation sector, and expected or stated goals from existing programs designed to reduce CO_2 emissions.

As mentioned earlier, U.S. cars and light trucks account for 19.2 percent of CO_2 emissions in the United States. Thus, with the action alternatives reducing U.S. car and light truck CO_2 emissions by 2.7 to 12.7 percent, this would represent a reduction of 0.5 to 2.4 percent of total U.S. CO_2 emissions (assuming the relative contribution of cars and light trucks stays the same). Figure 3.4-9 shows projected annual emissions from cars and light trucks under the MY 2011-2015 alternative CAFE standards.

As Table 3.4-2 shows, total CO_2 emissions accounted for by the U.S. car and light-truck fleets are projected to increase substantially from their level in 2010 under the No Action Alternative, which would extend passenger car and light truck CAFE standards for MY 2010 to apply to all future model years. The table also shows that each of the action alternatives would reduce total car and light-truck CO_2 emissions in future years from their projected levels under the No Action Alternative. Progressively larger reductions in CO_2 emissions from their levels under the No Action Alternative are projected to occur during each future year as the action alternatives require successively higher fuel economy levels for MY 2011-2015 and later passenger cars and light-trucks.

Figure 3.4-9. Projected Reference Case Annual Emissions Under the MY 2011-2015 Alternative CAFE Standards ($MMTCO_2$)

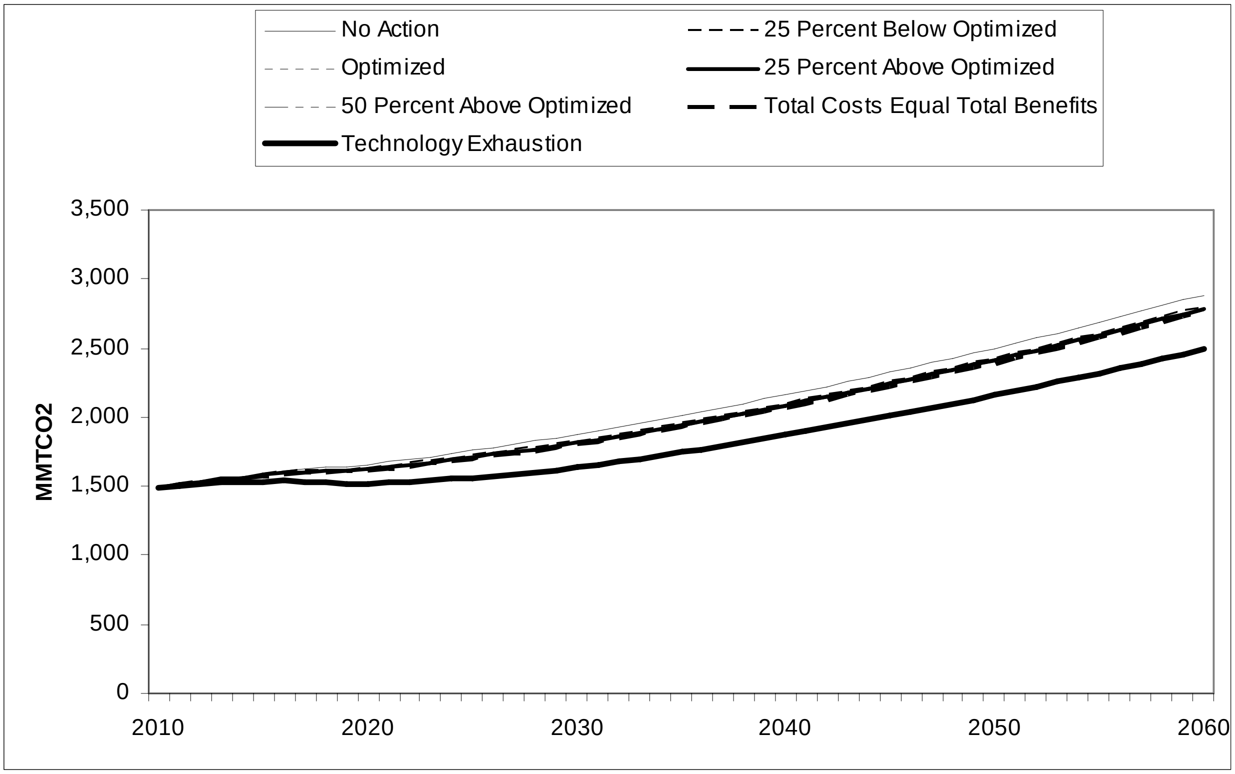


Table 3.4-2

Reference Case Nationwide Emissions of Greenhouse Gases from Passenger Cars and Light Trucks under Alternative CAFE Standards for MY 2011-2015 (MMT per Year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
GHG and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Carbon dioxide (CO_2)							
2010	1,487	1,487	1,487	1,487	1,487	1,487	1,487
2020	1,651	1,625	1,622	1,619	1,616	1,611	1,517
2030	1,876	1,825	1,820	1,815	1,808	1,800	1,636
2040	2,161	2,099	2,092	2,087	2,077	2,068	1,869
2050	2,500	2,427	2,419	2,413	2,402	2,391	2,158
2060	2,883	2,799	2,790	2,783	2,770	2,757	2,489
Methane (CH_4)							
2010	1.75	1.75	1.75	1.75	1.75	1.75	1.75
2020	1.94	1.91	1.90	1.90	1.90	1.89	1.75
2030	2.20	2.14	2.13	2.13	2.12	2.11	1.87
2040	2.53	2.46	2.45	2.45	2.43	2.42	2.13
2050	2.93	2.85	2.84	2.83	2.81	2.80	2.46
2060	3.38	3.28	3.27	3.26	3.25	3.23	2.83

Table 3.4-2 (cont'd)

Reference Case Nationwide Emissions of Greenhouse Gases from Passenger Cars and Light Trucks under Alternative CAFE Standards for MY 2011-2015 (MMT per Year)

GHG and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Nitrous oxide (N_2O)							
2010	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2020	0.05	0.05	0.05	0.04	0.04	0.04	0.03
2030	0.05	0.05	0.05	0.05	0.05	0.05	0.03
2040	0.06	0.06	0.06	0.05	0.05	0.05	0.03
2050	0.06	0.06	0.06	0.06	0.06	0.06	0.04
2060	0.07	0.07	0.07	0.07	0.07	0.07	0.04

However, Table 3.4-2 also shows that none of the action alternatives would reduce total CO_2 emissions accounted for by passenger cars and light trucks below the levels that are projected to occur in calendar year 2010. This is because forecasted growth in the number of cars and light trucks in use throughout the United States, combined with assumed increases in their average use, is projected to result in sufficiently rapid growth in total car and light truck travel to more than offset the increases in fuel economy that would result even under the Technology Exhaustion Alternative (Alternative 7). As a consequence, total fuel consumption by U.S. passenger cars and light trucks is projected to increase over the period shown in the table under each of the action alternatives. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks.

Emissions of CO_2, the primary gas that drives climate effects, from the U.S. car and light-truck fleet represented about 2.5 percent of total global emissions of all GHGs in 2000 (EPA 2008a; WRI 2008). Although substantial, this source contributes a small percentage of global emissions, and the relative contribution of CO_2 emissions from the U.S. light-vehicle fleet is expected to decline in the future. This expected decline is due primarily to rapid growth of emissions from developing economies (which result in part from growth in global transportation sector emissions). In the SRES A1B (medium) scenario (Nakicenovic *et al.* 2000), the share of liquid fuel use – mostly petroleum and biofuels – from Organization for Economic Cooperation and Development (OECD) countries (including the United States) declines from 60 percent in 2000 to 17 percent in 2100.

In its Annual Energy Outlook, EIA projects U.S. transportation CO_2 emissions to increase from 2,037 $MMTCO_2$ in 2010 to 2,682 $MMTCO_2$ in 2030,[31] with total U.S. emissions from transportation over this period at 49,287 $MMTCO_2$. Over this same period, the emissions reductions over the range of the new standards are projected to be 527 to 2,656 $MMTCO_2$, which would yield a 1- to 5-percent reduction from the transportation sector. The environmental impact from increasing fuel economy standards grows as new vehicles enter the fleet and older vehicles are retired. For example, in 2030, projected emissions reductions are 50 to 239 $MMTCO_2$, a 2- to 9-percent decrease from projected U.S. transportation emissions of 2,682 $MMTCO_2$ in 2030. It is important to note that the EIA did not take into account the

[31] AEO provides projections through 2030, not through 2100 (the relevant period for climate modeling).

expected effects of this rulemaking in their forecast (EIA 2007a), thus enabling a comparison of the impact of this rulemaking to U.S. transportation emissions under the No Action Alternative.

As another measure of the relative environmental impact of this rulemaking, these emissions reductions can be compared to existing programs designed to reduce GHG emissions in the United States. In 2007, Arizona, California, New Mexico, Oregon, and Washington formed the Western Climate Initiative (WCI) to develop regional strategies to address climate change. The WCI has a stated goal of reducing 350 $MMTCO_2$ equivalent over the period from 2009 to 2020 (WCI 2007a). Emissions levels in 2020 would represent a 33-percent reduction from the No Action Alternative and a 15-percent reduction from the beginning of the action (WCI 2007b). By comparison, this rulemaking is expected to reduce CO_2 emissions by 116 to 660 $MMTCO_2$ over the same period, with emissions levels in 2020 representing a 1- to 5-percent reduction from the future baseline emissions for cars and light trucks. Nine northeast and mid-Atlantic states have formed the Regional Greenhouse Gas Initiative (RGGI) to reduce CO_2 emissions from power plants in the northeast. Emissions reductions from 2006 to 2024 are estimated at 268 $MMTCO_2$ (RGGI 2006).[32] This represents a 23-percent reduction from the future baseline, and a 10-percent reduction from the beginning of the action (RGGI 2006). By comparison, NHTSA forecasts that this rulemaking would reduce CO_2 emissions by 252 to 1,334 $MMTCO_2$ over this period, with emissions levels in 2024 representing a 3- to 9-percent reduction from the future baseline emissions for cars and light trucks.

Two points are important to emphasize. First, emissions from sources addressed in the WCI and RGGI decrease compared to the beginning of the action, while emissions from cars and trucks continue to increase under this rulemaking due to increases in VMT. Second, these projections are only estimates, and the scope of these climate programs differs from that in this rulemaking in terms of geography, sector, and purpose.

The approach, goals, and methods of reductions vary between the NHTSA action and these regional GHG reduction initiatives. However, the expected end result – reduction of tons of CO_2 – of all of these initiatives are similar. The Stabilization Wedge Theory promulgated by Pacala and Socolow (2004) for climate change mitigation includes a graphical representation of the contributions of many GHG reduction initiatives and the ability for all of these "wedges," over time, to add up to a climate-change solution. The reductions from this rulemaking could be viewed in this context as one of many actions needed to reduce U.S. transportation emissions.

Where information in the analysis included in this FEIS is incomplete or unavailable, NHTSA has relied on the CEQ regulations regarding incomplete or unavailable information. *See* 40 CFR § 1502.22(b). In this case, the comparison of emissions reductions from the alternative CAFE standards to emissions reductions associated with other programs is intended to benefit decisionmakers by providing relative benchmarks, rather than absolute metrics, for selecting among alternatives. In summary, the alternatives analyzed here deliver GHG emissions reductions that are on the same scale as many of the most progressive and ambitious GHG emissions reduction programs underway in the United States.

3.4.4.2 Sensitivity Analysis

NTHSA performed sensitivity analyses to examine how changes in key economic assumptions affect the CAFE standards under the Optimized Alternative, and the resulting fuel savings and environmental impacts. Although the sensitivity analysis did not examine the effect of variations in economic assumptions on CAFE standards and their impacts under other action alternatives, three of the

[32] Emissions reductions were estimated by determining the difference between the RGGI Cap and the Phase III RGGI reference case. These estimates do not include offsets.

remaining five action alternatives would establish fuel economy standards that are based directly on those under the Optimized Alternative. In addition, CAFE standards under the alternative equating total costs and total benefits would also vary in response to changes in CAFE standards under the Optimized Alternative. Thus, it is reasonable to assume that fuel economy levels under each of those alternatives, and the resulting fuel savings and reductions in CO_2 emissions, will vary similarly to those under the Optimized Alternative in response to changes in economic assumptions.

The specific economic assumptions NHTSA varied in these sensitivity analyses were:

- The value of economic damages caused by CO_2 emissions (the "social cost of carbon")
- The discount rate applied to future benefits
- The level of military security outlays associated with variation in U.S. petroleum imports
- The magnitude of the fuel economy rebound effect

NHTSA performed sensitivity analyses of variations in CAFE standards, fuel savings, and reductions in CO_2 emissions in response to changes in these economic variables using the Optimized CAFE standards from both the Reference Case and the Mid-2 Scenario as bases. The primary difference between the Reference Case and the Mid-2 Scenario is that the former uses the AEO 2008 reference case forecast of fuel prices, while the latter uses fuel prices from the AEO 2008 high price case. All other economic assumptions were held constant in these analyses.

Sections 3.4.4.2.1 and 3.4.4.2.2 summarize how these changes in economic assumptions would affect CAFE standards and realized fuel economy levels under the Optimized Alternative, fuel savings compared to the No Action Alternative, and reductions in CO_2 emissions from those under the No Action Alternative for passenger cars and light trucks over the period 2010-2100.

3.4.4.2.1 Range of Input Values in Sensitivity Analysis

The sensitivity analyses first examined the effect of raising the value of reducing CO_2 emissions to $80 per metric ton CO_2. This figure corresponds to an increase of one standard deviation from the mean estimate of the social cost of carbon reported in a 2008 survey of more than 200 estimates of the SCC conducted by Tol.[33] Its derivation is described in detail in Section 10.2.2.3 of this FEIS.

Like the reference values of $2 per ton for the U.S. domestic benefit and $33 per ton for the global value of reducing CO_2 emissions, the alternative value of $80 per ton is assumed to increase at 2.4 percent annually beginning in 2007. Thus, over the lifetimes of MY 2011-15 passenger cars and light trucks, the value of reducing CO_2 emissions would average nearly $160 per ton.

The sensitivity analyses also examined the effect of discounting benefits other than those from reducing CO_2 emissions at an annual rate of 3 percent, rather than at the 7-percent rate used in the Reference Case and the Mid-2 Scenario. (In all cases, future benefits from reducing CO_2 emissions were discounted at the lower 3-percent rate, because these benefits will be experienced by future generations.) The 3-percent rate is more appropriate if manufacturers are assumed to recover costs for complying with higher CAFE standards from buyers in the form of higher prices for new vehicles (OMB 2003).

[33] Richard S.J. Tol (2008), The social cost of carbon: trends, outliers, and catastrophes, *Economics -- the Open-Access, Open-Assessment E-Journal*, **2** (25), 1-24.

Recognizing the uncertainty surrounding the effect of variations in U.S. oil imports on military activities in oil-producing regions, the sensitivity analyses also tested the effect of assuming that U.S. military spending would decline by $0.05 for each gallon by which CAFE standards reduce U.S. imports of crude petroleum or refined fuel. This estimate reflects the assumption that approximately one-third of expenses to support U.S. military activities in major oil-producing regions of the world are likely to vary in proportion to the scale of those activities. It contrasts with the assumption employed in the Reference Case and the Mid-2 Scenario that U.S. military outlays would be unaffected by the level of U.S. imports of crude petroleum or refined petroleum products.

Finally, the sensitivity analyses examined the consequences for fuel economy levels, fuel savings, and reductions in CO_2 emissions of rebound effects of 10 percent and 20 percent. These compare to the 15-percent value for the rebound effect used in the Reference Case and the Mid-2 Scenario. NHTSA's detailed analysis of 66 published estimates of the long-run rebound effect concluded that nearly two-thirds of those estimates fell within the range of 10 to 20 percent.

3.4.4.2.2 Sensitivity Analysis Results

Tables 3.4-3 and 3.4-4 illustrate the effects of these alternative assumptions on fuel economy levels under the Optimized Alternative, fuel savings compared to the No Action Alternative, and the resulting reductions in CO_2 emissions. Table 3.4-3 shows the effects of alternative economic assumptions on fuel economy, fuel savings, and reductions in CO_2 emissions in the Reference Case; Table 3.4-4 reports the effects of the same changes in economic assumptions for the Mid-2 Scenario.

Table 3.4-3

Sensitivity of Reference Case Results to Changes in Economic Assumptions

Economic Assumptions	Combined Car and Light Truck MPG (2015) a/	Fuel Savings 2010-2100 (billion gallons)	Reduction in CO_2 Emissions 2010-2100 (MMt)
Reference Case	29.6	634	6,616
CO_2 Reductions Valued @ $80/ton	33.3	1,570	15,716
3% Discount Rate	30.3	898	8,954
Military Security Savings @ $0.05/gal	29.6	643	6,715
10% Rebound Effect	29.6	630	6,571
20% Rebound Effect	29.1	494	5,105

a/ Industry-wide combined MPG required by passenger car and light truck CAFE standards for MY 2015.

Table 3.4-4

Sensitivity of Mid-2 Scenario Results to Changes in Economic Assumptions

Economic Assumptions	Combined Car and Light Truck MPG (2015) a/	Fuel Savings 2010-2100 (billion gallons)	Reduction in CO_2 Emissions 2010-2100 (MMt)
Mid-2 Scenario	31.8	1,588	16,467
CO_2 Reductions Valued @ $80/ton	33.5	1,887	19,532
3% Discount Rate	33.5	1,891	19,569
Military Security Savings @ $0.05/gal	31.8	1,591	16,496
10% Rebound Effect	31.7	1,570	16,264
20% Rebound Effect	30.3	1,286	13,449

a/ Industry-wide combined MPG required by passenger car and light truck CAFE standards for MY 2015.

As these tables illustrate, increasing the benefits from of reducing CO_2 emissions to $80 per ton would substantially increase fuel economy, fuel savings, and reductions in CO_2 emissions in both the Reference Case and the Mid-2 Scenario.

Table 3.4-3 shows that reducing the discount rate applied to future benefits (other than those from reducing CO_2 emissions, which are already discounted at 3 percent) from the 7 percent used in the Reference Case to 3 percent would result in modest increases in required fuel economy, fuel savings, and reductions in CO_2 emissions in the Reference Case. In the Mid-2 Scenario, however, Table 3.4-4 shows that lowering the discount rate to 3 percent would lead to a pronounced increase in required car and light truck fuel economy, and in the resulting fuel savings and reductions in CO_2 emissions.

In contrast, assuming that U.S. military outlays would decline by $0.05 for each gallon that CAFE standards reduce U.S. petroleum imports has almost no effect on fuel economy, fuel savings, or reductions in CO_2 emissions under either the Reference Case or the Mid-2 Scenario. Although the effects of this change on required fuel economy, fuel savings, and emissions reductions do have the expected direction, they are extremely small, and certainly well within the range of uncertainty in estimating them.

Finally, the tables show that reducing the rebound effect from the 15 percent assumed in both the Reference Case and the Mid-2 Scenario to 10 percent would have only a slight effect on fuel savings and reductions in CO_2 emissions. Although the reported effects of reducing the rebound effect to 10% are in the opposite direction from those expected, they are so small as to be well within the range of uncertainty in estimating these effects. In contrast, increasing the rebound effect from the 15 percent value used in the Reference Case and the Mid-2 Scenario to 20 percent would lower fuel savings and emissions reductions somewhat in both cases, as Tables 3.4-3 and 3.4-4 report.

3.4.4.3 Effect of Credit Flexibility on Emissions

Consistent with the Energy Independence and Security Act (EISA), NHTSA's NPRM not only proposed new CAFE standards for passenger cars and light trucks, but also revised provisions regarding the creation and application of CAFE credits. In this context, CAFE credits refer to flexibilities allowed under the Energy Policy and Conservation Act (EPCA) provisions governing use of Alternative Motor Fuels Act (AMFA) credits, allowable banked credits, and transfers of credits between the car and truck fleets allowed under EISA. The additional flexibility to transfer credits between manufacturing companies is addressed separately below. Because EPCA prohibits NHTSA from considering these flexibilities when determining the stringency of CAFE standards, NHTSA did not attempt to do so when it developed standards by using the Volpe model to estimate the stringency at which net benefits to society would be maximized.

Under the EISA, AMFA credits are being phased out. The allowable credits are reduced so that by 2020 such credits will no longer be allowed under law.

However, responding to the *Federal Register* notice regarding the scope of analysis required by NEPA, EPA and the California Attorney General have indicated that, notwithstanding EPCA's constraints regarding the context for the establishment of CAFE standards, NHTSA should attempt to account for the creation and application of CAFE credits when evaluating the effects of new CAFE standards.

As we explained in the NPRM, NHTSA believes that manufacturers are likely to take advantage of these flexibility mechanisms, thereby reducing benefits and costs. Regarding AMFA credits, for example, manufacturer product plans identify the models and quantities of flex-fuel vehicles they intend to build. While individual product plans are protected as confidential commercial information, in the aggregate they reveal that manufacturers could use AMFA credits to assist in compliance with the standards. Manufacturers building dual-fuel vehicles are entitled to a CAFE benefit of up to 1.2 mpg in 2011 to 2014 and 1.0 mpg in 2015 for each fleet. NHTSA tentatively estimates that the impact of the use of AMFA credits could result in an average reduction of approximately 0.9 mpg in each year for model years 2011 through 2015, and a related increase in CO_2 emissions. Regarding other than AMFA credits (*e.g.*, CAFE credits earned through over-compliance, credits transferred between fleets, and credits acquired from other manufacturers), we do not have a sound basis to predict the extent to which manufacturers might use them, particularly since the credit transfer and credit trading programs have been only recently authorized.

3.4.4.3.1 Difficulties in Quantifying Emissions Implications of Credits

Questions NHTSA might need to address in performing an analysis of potential credit use and the resulting emissions include the following:

- Would manufacturers that have never used CAFE flexibilities do so in the future?
- Would flexibility-induced increases in the sale of flexible-fuel vehicles (FFVs) lead to increases in the use of alternative fuels?
- Having earned CAFE credits in a given model year, in what model year would a given manufacturer most likely apply those credits?
- Having earned CAFE credits in one fleet (*i.e.*, passenger or nonpassenger), to which fleet would a given manufacturer most likely apply those credits?

Such questions are similar to, though possibly less tractable than the behavioral and strategic questions that would be entailed in attempting to represent manufacturers' ability to "pull ahead" the implementation of some technologies, and in attempting to estimate CAFE-induced changes in market shares. As discussed on pp. 24393 to 24394 of the NPRM, data and approaches are lacking on how to analyze manufacturers' ability to develop and strategically time the application of new technologies. Substantial concerns remain about how to develop a credible market share model for integration into the modeling system NHTSA has used to analyze the costs and effects of CAFE standards.

3.4.4.3.2 Market Behavior

Some manufacturers make substantial use of current flexibilities. Other manufacturers regularly exceed CAFE standards applicable to one or both fleets, and allow the corresponding excess CAFE credits to expire. Some manufacturers transfer earned CAFE credits to future (or past) model years, but do not produce FFVs and create corresponding CAFE credits. Finally, still other manufacturers regularly pay civil penalties for noncompliance, even when producing FFVs would substantially reduce the magnitude of those penalties.

Notwithstanding these uncertainties, NHTSA anticipates that manufacturers would make varied use of the flexibilities provided by EPCA, as amended by EISA. These flexibilities could result in somewhat lower benefits (that is, CO_2 emissions reductions) than estimated here, as manufacturers' actions would cause VMT levels, fuel consumption, and emissions to be higher than reported here. We expect that all of the seven alternatives reported here—including the No Action Alternative in relation to which the effects of the six action alternatives are measured—would be affected. Insofar as the No Action Alternative would be affected, it is even less certain how the net effects of each of the six action alternatives would change.

NHTSA expects that use of flexibilities would tend to be greater under more stringent standards. As stringency increases, the potential for manufacturers to face greater cost increases, and for some, depending on its level of technological implementation, costs could rise substantially. The economic advantage of employing allowed flexibilities increases and could affect manufacturer behavior in this regard. A critical factor in addressing the fuel and emissions impacts of such flexibilities is that the likely extent of utilization cannot be assumed constant across the alternatives.

3.4.4.3.3 Trading Between Companies

The allowable trading between manufacturers is categorically different from the case discussed above. The provisions in Section 104 of Title I of the EISA require that fuel savings, and thus, GHG emissions, be conserved in any trades between manufacturers. Therefore, there would not be an environmental impact of any such trades because any increases in fuel use or emissions would have to be offset by the manufacturer buying the credits.

3.4.4.4 Direct and Indirect Effects on Climate Change

Sections 3.4.4.3.1 through 3.4.4.3.4 describe the direct and indirect effects of the alternatives on climate change in relation to atmospheric CO_2 concentrations, temperature, precipitation, and sea-level rise.

3.4.4.4.1 Atmospheric CO_2 Concentrations

MAGICC is a simple climate model that is well calibrated to the mean of the multi-model ensemble results for three of the most commonly used emissions scenarios – B1 (low), A1B (medium), and A2 (high) from the IPCC SRES series – as shown in Table 3.4-5.[34] As the table indicates, the results of the model runs developed for this analysis agree relatively well with IPCC estimates for both CO_2 concentrations and surface temperature.

Table 3.4-5

Comparison of MAGICC Modeling Results and Reported IPCC Results (IPCC 2007a)

	CO_2 Concentration (ppm)		Global Mean Increase in Surface Temperature (°C)		Sea-level Rise (cm)	
Scenario	**IPCC WGI (2100)**	**MAGICC (2100)**	**IPCC WGI (2080-2099)**	**MAGICC (2090)**	**IPCC WGI (2090-2099) a/**	**MAGICC (2095)**
B1 (low)	550	538.3	1.79	1.81	28	26
A1B (medium)	715	717.2	2.65	2.76	35	35
A2 (high)	836	866.8	3.13	3.31	37	38

a/ The IPCC values represent the average of the 5- to 95-percent range of the rise of sea level between 1980 to 1989 and 2090 to 2099.

A comparison of sea-level rise from MAGICC 5.3 and the IPCC Fourth Assessment Report is presented in the release documentation for MAGICC 5.3 (Wigley 2003 to 2008). In Table 3 of the documentation, Wigley (2008) presents the results for six SRES scenarios, which show that the

[34] NHTSA used the default climate sensitivity in MAGICC of 3.0 °C.

comparable value for sea-level rise from MAGICC 5.3 (total sea-level rise minus estimates for contributions from non-melt sources such as warming of the permafrost) within 0.01 centimeter in 2095.

As discussed in Section 3.4.2, NHTSA used the SRES A1B (medium) scenario to represent the No Action Alternative in the MAGICC modeling runs. Table 3.4-6 and Figures 3.4-10 through 3.4.13 present the results of MAGICC simulations for the No Action Alternative and the six action alternatives, in terms of CO_2 concentrations and increases in global mean surface temperature in 2030, 2060, and 2100. As Figures 3.4-10 and 3.4-11 show, the reduction in the amount of increases in CO_2 concentrations and temperature from each of the action alternatives is just a fraction of the total increases in CO_2 concentrations and global mean surface temperature. However, the relative impact of the action alternatives is shown by the reduction in increase of both CO_2 concentrations and temperature under Alternative 7. As shown in Figures 3.3-12 and 3.4-13, the reduction in increase of CO_2 concentrations under Alternative 7 is nearly four times that of Alternative 2. Similarly, the reduction in increase of temperature under Alternative 7 is more than five times that of Alternative 2.

As shown in the table and figures, estimated CO_2 concentrations for 2100 range from 714.6 ppm under the most stringent alternative (Technology Exhaustion) to 717.2 ppm under the No Action Alternative. For 2030 and 2060, the range is even smaller. Because CO_2 concentrations are the key driver of other climate effects (which in turn act as drivers on the resource impacts discussed in Chapter 4), this leads to small differences in these effects.

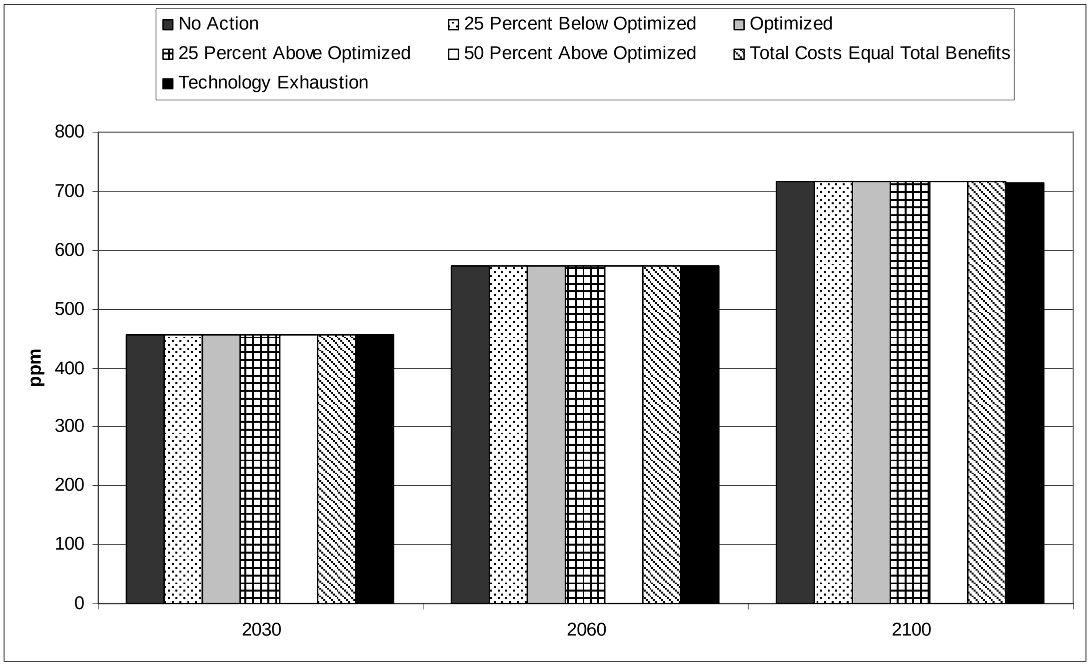
Table 3.4-6

Reference Case MY 2011-2015 Standards Impact on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC (A1B a/)

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
	2030	2060	2100	2030	2060	2100	2030	2060	2100
1 No Action (A1B-AIM)	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.5	573.4	716.7	0.873	1.943	2.957	7.99	19.29	37.08
3 Optimized	455.5	573.4	716.6	0.873	1.943	2.956	7.99	19.29	37.08
4 25 Percent Above Optimized	455.5	573.4	716.6	0.873	1.943	2.956	7.99	19.29	37.08
5 50 Percent Above Optimized	455.5	573.4	716.5	0.873	1.943	2.956	7.99	19.29	37.08
6 Total Costs Equal Total Benefits	455.4	573.3	716.4	0.873	1.943	2.956	7.99	19.28	37.07
7 Technology Exhaustion	455.3	572.5	714.6	0.872	1.938	2.946	7.99	19.25	36.99
Reductions Under Alternative CAFE Standards									
2 25 Percent Below Optimized	0.0	0.3	0.5	0.000	0.001	0.002	0.00	0.01	0.02
3 Optimized	0.0	0.3	0.6	0.000	0.001	0.002	0.00	0.01	0.02
4 25 Percent Above Optimized	0.0	0.3	0.6	0.000	0.001	0.003	0.00	0.01	0.02
5 50 Percent Above Optimized	0.0	0.3	0.7	0.000	0.001	0.003	0.00	0.01	0.02
6 Total Costs Equal Total Benefits	0.1	0.4	0.8	0.000	0.002	0.003	0.00	0.02	0.03
7 Technology Exhaustion	0.2	1.2	2.6	0.002	0.007	0.013	0.00	0.05	0.11

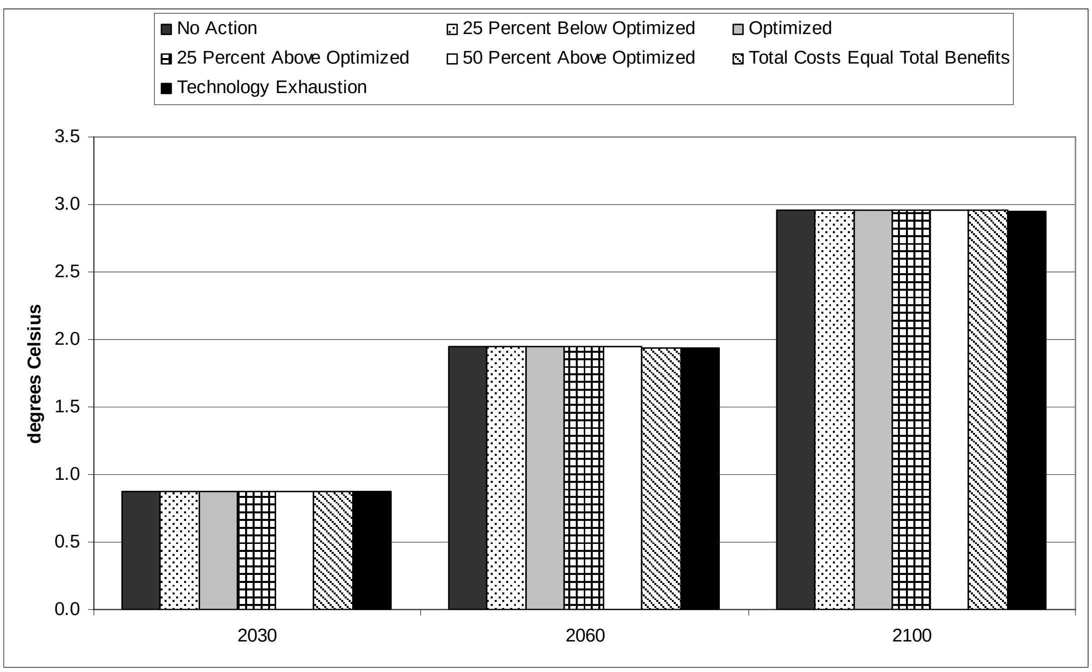
a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 3.4-10. Reference Case MY 2011-2015 Standards Impact on CO_2 Concentrations (ppm) Using MAGICC (A1B a/)



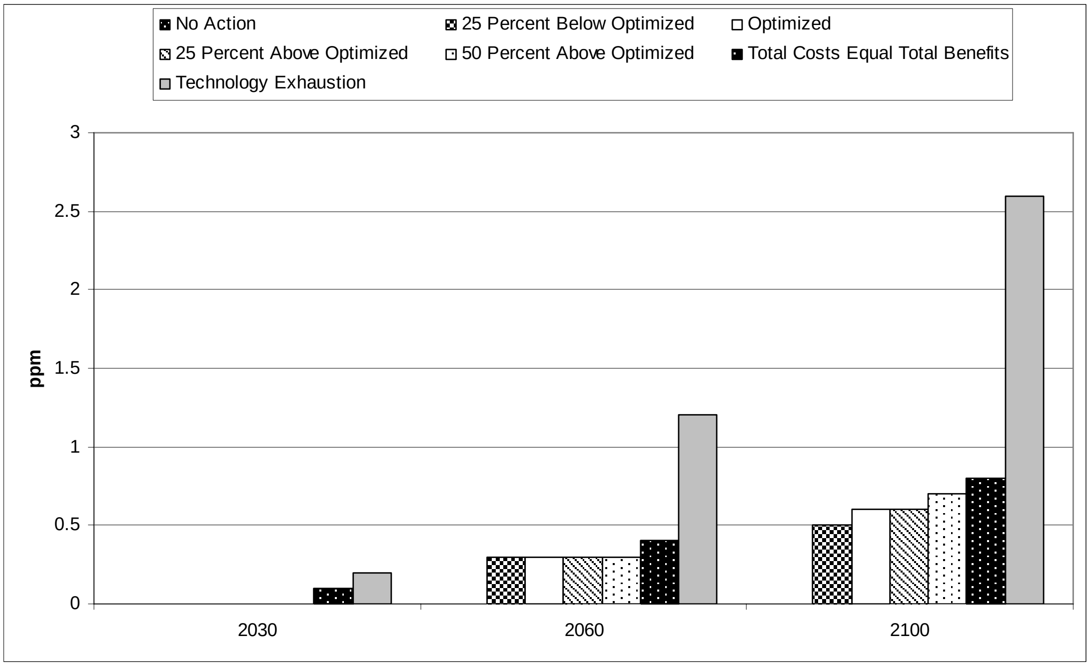
a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 3.4-11. Reference Case MY 2011-2015 Standards Impact on Global Mean Surface Temperature Increase (°C) Using MAGICC (A1B a/)



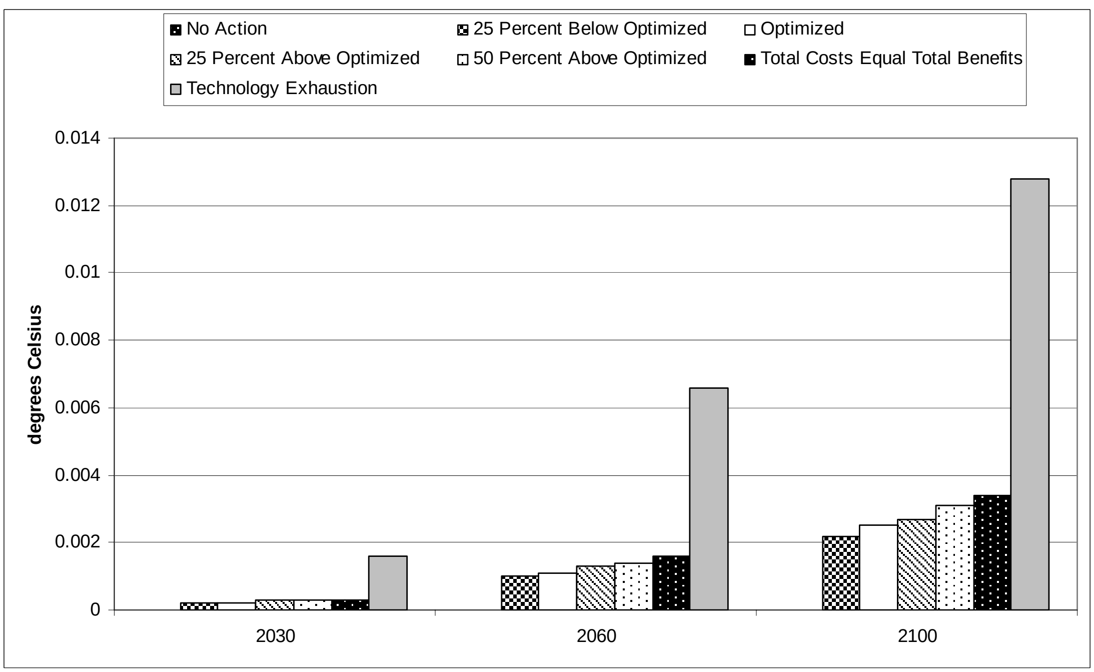
a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 3.4-12. Reference Case MY 2011-2015 Standards Impact on the Reduction in the Increase of CO_2 Concentrations (ppm) Using MAGICC (A1B a/)



a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 3.4-13. Reference Case MY 2011-2015 Standards Impact on the Reduction in the Increase of Global Mean Temperature Using MAGICC (A1B a/)



a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

3.4.4.4.2 Temperature

The MAGICC model simulations of mean global surface air temperature increases are shown in Table 3.4-6. For all alternatives, the temperature increase is about 0.87 °C for 2030, 1.94 °C for 2060, and 2.95 °C for 2100. The differences among alternatives are small. For 2100, the reduction in temperature increase, in relation to the No Action Alternative, ranges from 0.002 °C to 0.013 °C.

Table 3.4-7 summarizes the regional changes in warming and seasonal temperatures presented in the IPCC Fourth Assessment Report. At this time, quantifying the changes to regional climate from the CAFE alternatives is not possible, but the alternatives would be expected to reduce the impacts in proportion to the amount of reduction in global mean surface temperature.

Table 3.4-7

Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment Report (Christensen *et al.* 2007)

Land Area	Sub-region	Mean Warming	Maximum Summer Temperatures
Africa	Mediterranean area and northern Sahara	*Likely* larger than global mean throughout continent and in all seasons	
	Southern Africa and western margins		
	East Africa		
Mediterranean and Europe	Northern Europe	*Likely* to increase more than the global mean with largest warming in winter	Maximum summer temperatures *likely* to increase more than the average
	Southern and Central Europe		
	Mediterranean area		
Asia	Central Asia	*Likely* to be well above the global mean	
	Tibetan Plateau	*Likely* to be well above the global mean	
	Northern Asia	*Likely* to be well above the global mean	
	Eastern Asia	*Likely* to be above the global mean	*Very likely* that heat waves/hot spells in summer will be longer, more intense, and more frequent *Very likely* fewer very cold days
	South Asia	*Likely* to be above the global mean	*Very likely* fewer very cold days
	Southeast Asia	*Likely* to be similar to the global mean	
North America	Northern regions/Northern North America	*Likely* to exceed the global mean warming	Warming is *likely* to be greatest in winter. Minimum winter temperatures are *likely* to increase more than the average
	Southwest		Warming is *likely* to be greatest in summer Maximum summer temperatures are *likely* to increase more than the average
	Northeast USA		
	Southern Canada		
	Canada		

Table 3.4-7 (cont'd)

Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment Report (Christensen *et al.* 2007)

Land Area	Sub-region	Mean Warming	Maximum Summer Temperatures
	Northernmost part of Canada		
Central and South America	Southern South America	*Likely* to be similar to the global mean warming	
	Central America	*Likely* to be larger than global mean warming	
	Southern Andes		
	Tierra del Fuego		
	Southeastern South America		
	Northern South America		
Australia and New Zealand	Southern Australia	*Likely* comparable to the global mean but less than in the rest of Australia	Increased frequency of extreme high daily temperatures and decreased frequency of cold extremes are *very likely*
	Southwestern Australia	*Likely* comparable to the global mean	
	Rest of Australia	*Likely* comparable to the global mean	
	New Zealand, South Island	*Likely* less than the global mean	
	Rest of New Zealand	*Likely* comparable to the global mean	
Polar Regions	Arctic	*Very likely* to warm during this century more than the global mean	Warming greatest in winter and smallest in summer
	Antarctic	*Likely* to warm	
Small Islands		*Likely* to be smaller than the global annual mean	

MAGICC 5.3 estimates radiative forcing from black carbon, a primary aerosol emitted through the incomplete combustion of fossil fuel and biomass burning. However, emissions trends for black carbon are "hard-wired" in the model to follow emissions of SO_2 and cannot be specified as separate inputs to the model.[35] The radiative forcing of black carbon is difficult to accurately quantify because it is a function of microphysical properties of the geographic and vertical placement, and lifetime of the aerosol; however, that black carbon contributes substantially to global warming is clear (Jacobson 2001). Total global black carbon emissions are estimated to be approximately 8 teragrams of carbon per year (Tg C/yr) (Bond *et al.* 2004 as cited in Forster *et al.* 2007) with estimates of fossil fuel contributions

[35] Accurately determining the magnitude of mobile source emissions of black carbon is difficult because the emissions vary with fuel properties and fluctuations in the combustion environment. MOBILE6.2 outputs particulate matter mass that is then incorporated in the Volpe model. This particulate matter is based on tailpipe emissions and thus includes carbon emissions from the combustion process. Because the carbon emissions are included as part of the particular matter and are not treated independently, the Volpe model does not provide direct results of the impact of the carbon emissions.

ranging from 2.8 Tg C/yr (Ito and Penner 2005 as cited in Forster *et al.* 2007) to 8.0 Tg C/yr (Haywood and Boucher as cited in Forster *et al.* 2007). The United States contributes an estimated 6.1 percent of the global soot emissions, with major sources including off-road vehicles, on-road vehicles, stack emissions, and fugitive sources (Jacobson Testimony 2007). In summary, the climate modeling accounts for the effects of black carbon on climate variables.

3.4.4.4.3 Precipitation

According to IPCC (Meehl *et al.* 2007), global mean precipitation is expected to increase under all scenarios. Generally, precipitation increases occur in the tropical regions and high latitudes, with decreases in the sub-tropics. The results from the AOGCMs suggest considerable uncertainty in future precipitation for the five SRES scenarios.

Where information in the analysis included in this FEIS is incomplete or unavailable, NHTSA has relied on the CEQ regulations regarding incomplete or unavailable information. *See* 40 CFR § 1502.22(b). In this case, the IPCC (Meehl *et al.* 2007) summary of precipitation represents the most thoroughly reviewed, credible assessment of this highly uncertain factor. NHTSA expects that the alternative CAFE standards would reduce the changes in proportion to their effects on temperature.

The global mean change in precipitation provided by the IPCC for the A2 (high), A1B (medium), and B1 (low) scenarios (Meehl *et al.* 2007) is given as the scaled change in precipitation (as a percentage change from 1980 to 1999 averages) divided by the increase in global mean surface warming for the same period (per °C) as shown in Table 3.4-8. The IPCC provides scaling factors in the year ranges of 2011 to 2030, 2046 to 2065, 2080 to 2099, and 2180 to 2199. NHTSA used the scaling factors for the A1B (medium) scenario in our analysis because MAGICC does not directly estimate changes in global mean precipitation.

Table 3.4-8

Global Mean Precipitation Change (scaled, % per °C) (Meehl *et al.* 2007)

Scenario	2011-2030	2046-2065	2080-2099	2180-2199
A2 (high)	1.38	1.33	1.45	NA
A1B (medium	1.45	1.51	1.63	1.68
B1 (low)	1.62	1.65	1.88	1.89

Applying these scaling factors to the reductions in global mean surface warming provides estimates of changes in global mean precipitation. Given that the CAFE standards action alternatives reduce temperature increases slightly in relation to the No Action Alternative, they also slightly reduce predicted increases in precipitation, as shown in Table 3.4-9 (again based on the A1B [medium] scenario).

In addition to changes in mean annual precipitation, climate change is anticipated to affect the intensity of precipitation, as described below (Meehl *et al.* 2007):

> Intensity of precipitation events is projected to increase, particularly in tropical and high latitude areas that experience increases in mean precipitation. Even in areas where mean precipitation decreases (most subtropical and mid-latitude regions), precipitation intensity is projected to increase but there would be longer periods between rainfall events. There is a tendency for drying of the mid-continental areas during summer, indicating a greater risk of droughts in those regions. Precipitation extremes increase more than does the mean in most tropical and mid- and high-latitude areas.

Table 3.4-9

Reference Case MY 2011-2015 Alternative CAFE Standards: Impact on Reductions in Global Mean Precipitation Based on A1B a/ SRES Scenario (percent change), Using Increases in Global Mean Surface Temperature Simulated by MAGICC

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaled, % K-1)	1.45	1.51	1.63
Global Temperature Above Average 1980-1999 Levels (°K) for the A1B Scenario and Alternative CAFE Standards, Mid-level Results			
1 No Action	0.560	1.764	2.765
2 25 Percent Below Optimized	0.560	1.763	2.763
3 Optimized	0.560	1.763	2.763
4 25 Percent Above Optimized	0.560	1.763	2.762
5 50 Percent Above Optimized	0.560	1.763	2.762
6 Total Costs Equal Total Benefits	0.560	1.763	2.762
7 Technology Exhaustion	0.560	1.758	2.753
Reduction in Global Temperature (°K) for Alternative CAFE Standards, Mid-level Results (Compared to No Action Alternative)			
2 25 Percent Below Optimized	0.000	0.001	0.002
3 Optimized	0.000	0.001	0.002
4 25 Percent Above Optimized	0.000	0.001	0.002
5 50 Percent Above Optimized	0.000	0.001	0.003
6 Total Costs Equal Total Benefits	0.000	0.001	0.003
7 Technology Exhaustion	0.000	0.006	0.011
Mid-level Global Mean Precipitation Change (%)			
1 No Action	0.81	2.66	4.51
2 25 Percent Below Optimized	0.81	2.66	4.50
3 Optimized	0.81	2.66	4.50
4 25 Percent Above Optimized	0.81	2.66	4.50
5 50 Percent Above Optimized	0.81	2.66	4.50
6 Total Costs Equal Total Benefits	0.81	2.66	4.50
7 Technology Exhaustion	0.81	2.65	4.49
Reduction in Global Mean Precipitation Change for Alternative CAFE Standards (% Compared to No Action Alternative)			
2 25 Percent Below Optimized	0.00	0.00	0.00
3 Optimized	0.00	0.00	0.00
4 25 Percent Above Optimized	0.00	0.00	0.00
5 50 Percent Above Optimized	0.00	0.00	0.00
6 Total Costs Equal Total Benefits	0.00	0.00	0.00
7 Technology Exhaustion	0.00	0.01	0.02

a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Regional variations and changes in the intensity of precipitation events cannot be quantified further, primarily due to the unavailability of AOGCMs required to estimate these changes. These models are typically used to provide results among scenarios with very large changes in emissions such as the SRES B1 (low), A1B (medium), and A2 (high) scenarios; very small changes in emissions profiles would produce results that would be difficult to resolve among scenarios with small changes in emissions. Also, the multiple AOGCMs produce results that are regionally consistent in some cases but inconsistent for other areas.

Table 3.4-10 summarizes the regional changes in precipitation from the IPCC Fourth Assessment Report. Quantifying the changes in regional climate from the alternative CAFE standards is not possible at present, but they would be expected to reduce the changes in relation to the reduction in global mean surface temperature.

Table 3.4-10

Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment Report (Christensen *et al.* 2007)

Land Area	Sub-region	Precipitation	Snow Season and Snow Depth
Africa	Mediterranean area and northern Sahara	*Very likely* to decrease	
	Southern Africa and western margins	Winter rainfall *likely* to decrease in southern parts	
	East Africa	*Likely* to be an increase in annual mean rainfall	
Mediterranean and Europe	Northern Europe	*Very likely* to increase and extremes are *likely* to increase	*Likely* to decrease.
	Southern and Central Europe		
	Mediterranean area	*Very likely* to decrease and precipitation days are *very likely* to decrease	
Asia	Central Asia	Precipitation in summer is *likely* to decrease	
	Tibetan Plateau	Precipitation in boreal winter is *very likely* to increase	
	Northern Asia	Precipitation in boreal winter is *very likely* to increase Precipitation in summer is *likely* to increase	
	Eastern Asia	Precipitation in boreal winter is *likely* to increase Precipitation in summer is *likely* to increase *Very likely* to be an increase in the frequency of intense precipitation Extreme rainfall and winds associated with tropical cyclones are *likely* to increase	
	South Asia	Precipitation in summer is *likely* to increase *Very likely* to be an increase in the frequency of intense precipitation Extreme rainfall and winds associated with tropical cyclones are *likely* to increase	
	Southeast Asia	Precipitation in boreal winter is *likely* to increase in southern parts Precipitation in summer is *likely* to increase in most parts Extreme rainfall and winds associated with tropical cyclones are *likely* to increase	
North America	Northern regions/Northern North America		Snow season length and snow depth are *very likely* to decrease
	Southwest	Annual mean precipitation is *likely* to decrease	
	Northeast USA	Annual mean precipitation is *very likely* to increase	
	Southern Canada		
	Canada	Annual mean precipitation is *very likely* to increase	

Table 3.4-10 (cont'd)

Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment Report (Christensen *et al.* 2007)

Land Area	Sub-region	Precipitation	Snow Season and Snow Depth
North America (cont'd)	Northernmost part of Canada		Snow season length and snow depth are *likely* to increase
Central and South America	Southern South America		
	Central America	Annual precipitation is *likely* to decrease	
	Southern Andes	Annual precipitation is *likely* to decrease	
	Tierra del Fuego	Winter precipitation is *likely* to increase	
	Southeastern South America	Summer precipitation is *likely* to increase	
	Northern South America	Uncertain how rainfall would change	
Australia and New Zealand	Southern Australia	Precipitation is *likely* to decrease in winter and spring	
	Southwestern Australia	Precipitation is *very likely* to decrease in winter	
	Rest of Australia		
	New Zealand, South Island	Precipitation is *likely* to increase in the west	
	Rest of New Zealand		
Polar Regions	Arctic	Annual precipitation is *very likely* to increase. *Very likely* that the relative precipitation increase would be largest in winter and smallest in summer	
	Antarctic	Precipitation *likely* to increase	
Small Islands		Mixed, depending on the region	

3.4.4.4.4 Sea-level Rise

IPCC identifies four primary components to sea-level rise: (1) thermal expansion of ocean water, (2) melting of glaciers and ice caps, (3) loss of land-based ice in Antarctica, (4) and loss of land-based ice in Greenland (IPCC 2007c). Ice-sheet discharge is an additional factor that could influence sea level over the long term. MAGICC calculates the oceanic thermal expansion component of global-mean sea level rise using a nonlinear temperature- and pressure-dependent expansion coefficient (Wigley 2003 to 2008). It also addresses the other three primary components through ice-melt models for small glaciers and the Greenland and Antarctic ice sheets, and excludes non-melt sources, which the IPCC Fourth Assessment Report also excluded. Neither MAGICC 5.3 nor the IPCC Fourth Assessment Report includes more recent information, suggesting that ice flow from Greenland and Antarctica will be accelerated. The Fourth Assessment Report estimates the ice flow to be between 9 and 17 centimeters by 2100 (Wigley 2003 to 2008).

The state of the science reflected as of the publication of the IPCC Fourth Assessment Report projects a sea-level rise of 18 to 59 centimeters by 2090 to 2099 (Parry *et al.* 2007 as cited by National Science and Technology Council 2008). This projection does not include all changes in ice-sheet flow or the potential for rapid acceleration in ice loss (Alley *et al.* 2005, Gregory and Huybrechts 2006, and Hansen 2005, all as cited by Pew Center on Global Climate Change 2007). Several recent studies have found the IPCC estimates of potential sea-level rise might be underestimated regarding ice loss from the Greenland and Antarctic ice sheets (Shepherd and Wignham 2007, Csatho *et al.* 2008) and ice loss from mountain glaciers (Meier *et al.* 2007). Further, IPCC results for sea-level projections might underestimate sea level rise due to changes in global precipitation (Wentz *et al.* 2007 and Zhang *et al.* 2007). Rahmstorf (2007) used a semi-empirical approach to project future sea-level rise. The approach yielded a proportionality coefficient of 3.4 millimeters per year per degree Centigrade of warming, and a projected sea-level rise of 0.5 to 1.4 meters above 1990 levels in 2100 when applying IPCC Third Assessment Report warming scenarios. Rahmstorf (2007) concludes that "[a] rise over 1 meter by 2100 for strong warming scenarios cannot be ruled out." Section 3.5.5, Coastal Ecosystems, discusses sea-level rise in more detail.

Table 3.4-6 lists the impacts on sea-level rise under the scenarios and shows sea-level rise in 2100 ranging from 37.10 centimeters under the No Action Alternative to 36.99 centimeters under the Technology Exhaustion Alternative, for a maximum reduction of 0.11 centimeter by 2100 from the CAFE alternatives.

In summary, the impacts of the MY 2011-2015 alternative CAFE alternatives on global mean surface temperature, precipitation, or sea-level rise are small in relation to the expected changes associated with the emissions trajectories in the SRES scenarios. This is due primarily to the global and multi-sectoral nature of the climate problem.

3.4.5 Input Scenarios

In response to public comments, and to test how different economic assumptions might affect estimates of emissions reductions and resulting climate effects, NHTSA modeled three additional scenarios—High, Mid-1, and Mid-2—and compared the results to the results for the Reference Case described in Section 3.4.4. Variables NHTSA altered include fuel price, SCC, oil import externalities, and the discount rate for other benefits.

For the High Scenario, NHTSA used the AEO 2008 high fuel prices, an SCC of $33 per ton (2007 dollars), and a 3-percent discount rate for other benefits. Table 3.4-11 shows the emissions and emissions reductions resulting from the High Scenario.

Table 3.4-11

High Scenario Emissions and Emissions Reductions Due to the MY 2011-2015 CAFE Standards from 2010-2100 (MMTCO$_2$)

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	195,501	0
2 25 Percent Below Optimized	182,890	12,611
3 Optimized	180,591	14,910
4 25 Percent Above Optimized	179,079	16,422
5 50 Percent Above Optimized	177,669	17,832
6 Total Costs Equal Total Benefits	176,736	18,765
7 Technology Exhaustion	170,829	24,672

Compared to the Reference Case, total emissions under the High Scenario were lower for all alternatives (*see* Figure 3.4-13). The primary reason for this difference is the lower VMT forecast under the High Scenario. Emissions reductions for all alternatives compared to the No Action Alternative were higher under the High Scenario than under the Reference Case, except for the emissions reduction resulting from the Technology Exhaustion Alternative (*see* Figure 3.4-14). Emissions reductions would be greater for the Technology Exhaustion Alternative under the Reference Case than under the High Scenario.

Table 3.4-12 shows the resulting effects on CO_2 concentration, global mean surface temperature, and sea-level rise. Under the High Scenario, the resulting CO_2 concentration, global mean surface temperature, and sea-level rise were lower than under the Reference Case for all action alternatives except the Technology Exhaustion Alternative. Thus, the differences between the action alternatives and the No Action Alternative are greater under the High Scenario than under the Reference Case, except for the Technology Exhaustion Alternative.[36]

To further assess how different economic assumptions could affect estimates of fuel consumption, NHTSA ran two additional scenarios in the Volpe model: the Mid-1 Scenario and the Mid-2 Scenario. For the Mid-1 Scenario, NHTSA used the AEO 2008 high fuel prices, an SCC of $33 per ton (2007 dollars), and a 7-percent discount rate for other benefits. Compared to the Reference Case, total emissions under the Mid-1 Scenario were lower for all alternatives. Emissions reductions compared to the No Action Alternative were higher for all alternatives under the Mid-1 Scenario, except for the Technology Exhaustion Alternative. The primary reason for this difference is the lower VMT forecasted under the Mid-1 Scenario. The resulting CO_2 concentrations, global mean surface temperature, and sea-level rise were lower for all alternatives under the Mid-1 Scenario, except for the Technology Exhaustion Alternative. Thus, the differences between the action alternatives and the No Action Alternative are greater under the Mid-1 Scenario than under the Reference Case except for the Technology Exhaustion Alternative.

For the Mid-2 Scenario, NHTSA used the AEO 2008 high fuel prices, an SCC of $2 per ton (2007 dollars), and a 7-percent discount rate for other benefits. Compared to the Reference Case, total emissions under the Mid-2 Scenario were lower for all alternatives. Emissions reductions compared to the No Action Alternative were higher for all alternatives under the Mid-2 Scenario, except the Technology Exhaustion Alternative. The primary reason for this difference is the lower VMT forecast under the Mid-2 Scenario. The resulting CO_2 concentrations, global mean surface temperature, and sea-level rise were lower for all alternatives under the Mid-2 Scenario, except for the Technology Exhaustion Alternative. Thus, the differences between the action alternatives and the No Action Alternative are greater under the Mid-2 Scenario than under the Reference Case, except for the Technology Exhaustion Alternative.

Tables in Appendix B list the results for the Mid-1 and Mid-2 Scenarios.

[36] Note that in both the Reference Case and the High Scenario, the No Action Alternative is modeled to have the same emissions, *viz.* emissions set to the A1B scenario. This is the case even though, in absolute terms, U.S. passenger-vehicle and light-truck emissions are lower under the High Scenario than the Reference Case. In other words, the MAGICC model runs are intended to show relative differences in relation to a no action case; they are not intended to show absolute differences between Volpe model assumptions.

Figure 3.4-14. Comparison of Emissions under the Reference Case and High Scenario Due to the MY 2011-2015 CAFE Standards from 2010-2100 ($MMTCO_2$)

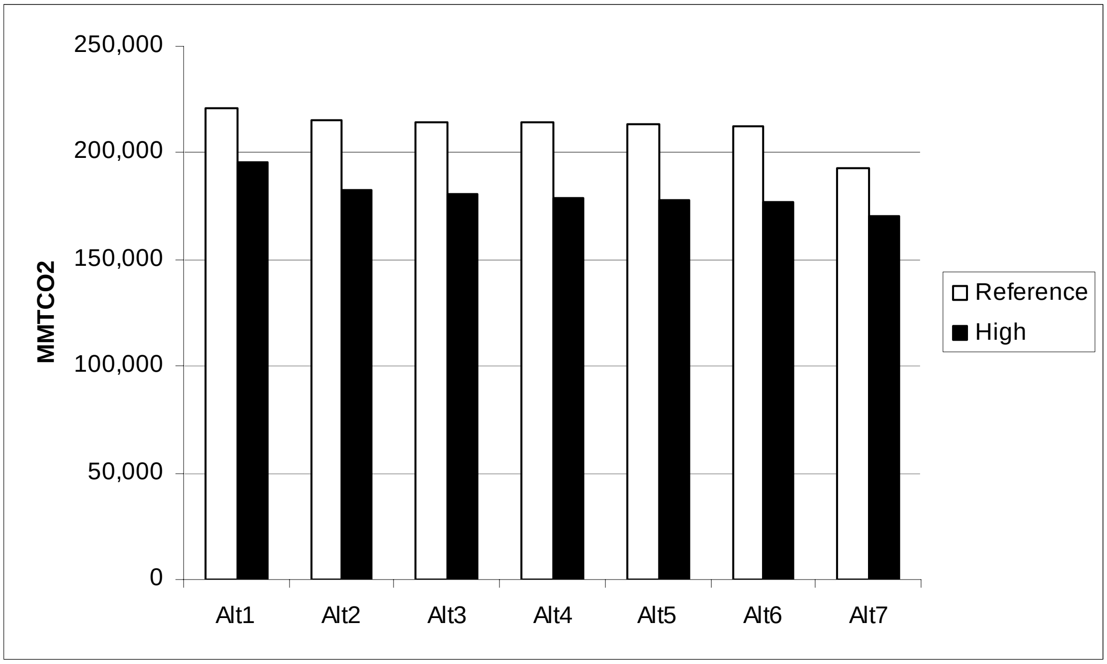


Figure 3.4-15. Comparison of Emissions Reductions under the Reference Case and High Scenario Due to the MY 2011-2015 CAFE Standards from 2010-2100 ($MMTCO_2$)

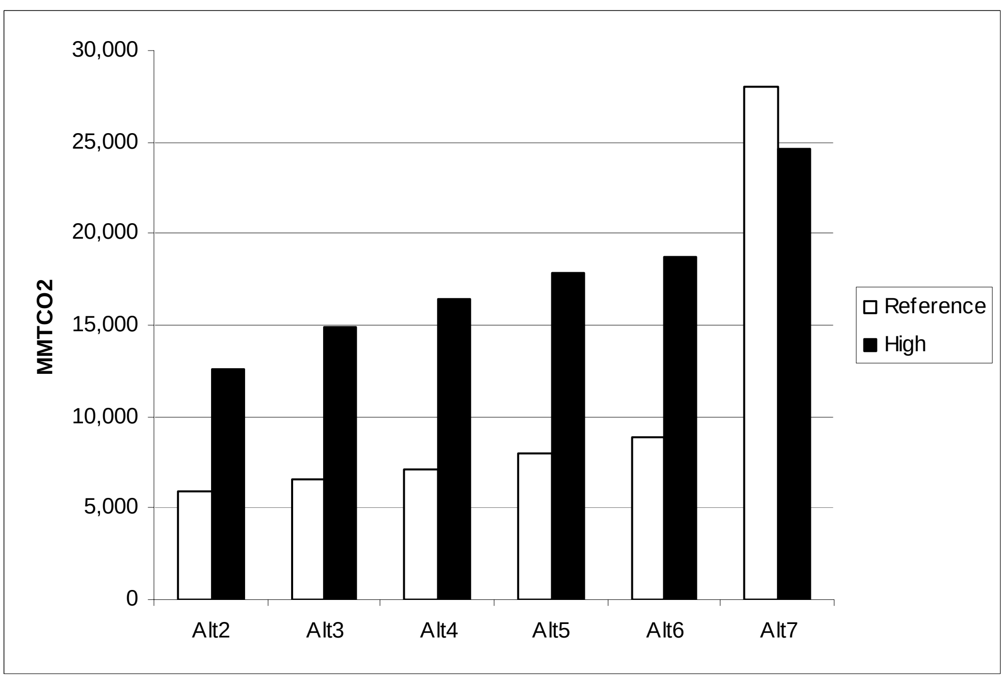


Table 3.4-12

High Scenario MY 2011-2015 Impacts of Alternative CAFE Standards on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC (A1B a/)

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (centimeters)		
	2030	2060	2100	2030	2060	2100	2030	2060	2100
1 No Action (A1B-AIM)	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.4	573.2	716.1	0.873	1.942	2.954	7.99	19.28	37.06
3 Optimized	455.4	573.1	715.8	0.873	1.942	2.953	7.99	19.28	37.05
4 25 Percent Above Optimized	455.4	573.0	715.7	0.873	1.941	2.953	7.99	19.28	37.04
5 50 Percent Above Optimized	455.4	572.9	715.6	0.873	1.941	2.952	7.99	19.27	37.04
6 Total Costs Equal Total Benefits	455.3	572.9	715.5	0.873	1.940	2.951	7.99	19.27	37.03
7 Technology Exhaustion	455.3	572.6	714.9	0.872	1.938	2.948	7.99	19.26	37.00
Reductions Compared to the No Action Alternative									
2 25 Percent Below Optimized	0.1	0.5	1.1	0.001	0.002	0.005	0.00	0.02	0.04
3 Optimized	0.1	0.6	1.4	0.001	0.003	0.006	0.00	0.02	0.05
4 25 Percent Above Optimized	0.1	0.7	1.5	0.001	0.003	0.006	0.00	0.02	0.06
5 50 Percent Above Optimized	0.1	0.8	1.6	0.001	0.004	0.007	0.00	0.03	0.06
6 Total Costs Equal Total Benefits	0.2	0.8	1.7	0.001	0.004	0.008	0.00	0.03	0.07
7 Technology Exhaustion	0.2	1.1	2.3	0.002	0.006	0.011	0.00	0.04	0.10

a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

3.5 OTHER POTENTIALLY AFFECTED RESOURCE AREAS

This section describes the affected environment and environmental consequences of the alternative CAFE standards on water resources (3.5.1), biological resources (3.5.2), land use and development (3.5.3), safety (3.5.4), hazardous materials and regulated wastes (3.5.5), land uses protected under Section 4(f) (3.5.6), historic and cultural resources (3.5.7), noise (3.5.8), and environmental justice (3.5.9). These sections describe the current and projected future threats to these resources from non-global climate change impacts relevant to the alternatives and provide primarily qualitative assessments of any potential consequences of the alternatives—either positive or negative—on these resources.

This section does not describe the affected environment in relation to, or address potential environmental consequences resulting from, global climate change. For a description of potential impacts of global climate change, *see* Chapter 4.

3.5.1 Water Resources

3.5.1.1 Affected Environment

Water resources include surface water and groundwater. Surface waters are water bodies open to the atmosphere, such as rivers, streams, lakes, oceans, and wetlands; surface waters can contain either fresh or salt water. Groundwater is found in natural reservoirs or aquifers below Earth's surface. Sources of groundwater include rainfall and surface water, which penetrate the ground and recharge the water table. Sections 3.5.1.1.1 through 3.5.1.1.3 describe the current and projected future threats to these resources from non-global climate change impacts related to the proposed action. The production and combustion of fossil fuels, the production of biofuels, and shifts in the location of mining activities are the identified relevant sources of impact. Section 3.5.2 describes relevant aspects of surface water resources from a habitat perspective. For a discussion of the effects of global climate change on freshwater and coastal systems, see Sections 4.5.3 and 4.5.5.

Impacts to water resources during recent decades have come from a number of different sources. These impacts include increased water demand for human and agricultural use, pollution from point and non-point sources, and climatic changes. One of the major human-caused impacts on water quality has been the extraction, refining, and combustion of petroleum products, or oil.

3.5.1.1.1 Oil Extraction and Refining

Oil refineries, which produce gasoline and diesel fuel, and the motor vehicles that combust petroleum-based fuels, are major sources of VOCs, SO_2, NO_x, CO, and other air pollutants (EPA 1995a, EPA 1997b). In the atmosphere, SO_2 and NO_x contribute to the formation of acid rain (the wet, dry, or fog deposition of SO_2 and NO_x), which enters water bodies either directly or as runoff from terrestrial systems (*see* Section 3.3 for more information on air quality). Once in surface waters, these pollutants can cause acidification of the water body, changing the acidity or alkalinity (commonly called pH) of the system and affecting the function of freshwater ecosystems (Van Dam 1996, Baum 2001, EPA 2007b). An EPA survey of sensitive freshwater lakes and streams (those with a low capacity to neutralize or buffer against decreases in pH) found that 75 percent of the lakes and 50 percent of the streams had experienced acidification as a result of acid rain (EPA 2007b). EPA has identified the areas of the United States most sensitive to acid rain as the Adirondacks and Catskill Mountains in New York State, the mid-Appalachian highlands along the east coast, the upper Midwest, and mountainous areas of the western United States (EPA 2007b).

Water quality might also be affected by petroleum products released during the refining and distribution process. Oil spills can lead to contamination of surface and groundwater and can result in impacts to drinking water and marine and freshwater ecosystems (*see* Section 3.5.2.1.1). EPA estimates that, of the volume of oil spilled in "harmful quantities," as defined under the Clean Water Act, 83.8 percent was deposited in internal/headland waters and within 3 miles of shore, with 17.5 percent spilled from pipelines, often in inland areas (EPA 2004a). The environmental impacts on and recovery time for individual waterbodies vary based on several factors (*e.g.*, salinity, water movement, wind, temperature), with faster-moving and warm water locations recovering more quickly (EPA 2008f).

During oil extraction, the primary waste product is highly saline liquid called "produced water," which can contain metals and other potentially toxic components (*see* Section 3.5.5.1.1 for more on produced water). Produced water and other oil extraction wastes are most commonly disposed of by reinjecting them to the well, which increases pressure and can force out more oil. Potential impacts from these wastes generally occur when large amounts are spilled and they enter surface waters, when decommissioned wells are improperly sealed, or when saline water from the wells intrudes into fresh surface water or groundwater (Kharaka and Otton 2005).

Water quality impacts also occur as a result of contamination by VOCs. A nationwide study of groundwater aquifers conducted by United States Geological Survey (USGS) found VOCs in 90 of 98 major aquifers sampled (Zogorski *et al.* 2006). The study concluded that "…[t]he widespread occurrence of VOCs indicates the ubiquitous nature of VOC sources and the vulnerability of many of the Nation's aquifers to low-level VOC contamination." Several of the most commonly identified VOCs were a gasoline additive (gasoline oxygenate – methyl tertiary butyl ether [MTBE]) and a gasoline hydrocarbon (toluene). USGS notes, however, that only 1 to 2 percent of the well samples had concentrations of VOCs at levels that would be of potential concern to human health; none of the VOCs found in potentially hazardous quantities were primarily used in the manufacture of fuels or as fuel additives (Zogorski *et al.* 2006). Section 3.5.5 describes toxic chemicals released during fuel production and combustion.

3.5.1.1.2 CO_2 Emissions

Oceanic concentrations of CO_2 from anthropogenic (human-made) sources, primarily the combustion of fossil fuels, have increased since the Industrial Revolution and likely will continue to increase. In addition to its role as a GHG, atmospheric CO_2 plays a key role in the biogeochemical cycle of carbon. Atmospheric CO_2 concentrations influence the chemistry of natural waters.

Atmospheric concentrations of CO_2 are in equilibrium with aqueous (dissolved in water) carbonic acid (H_2CO_3), which in turn influences the aqueous concentrations of bicarbonate ion (HCO_3^-) and carbonate ion (CO_3^{2}). In natural waters, the carbonate system controls pH, which in turn controls the availability of some nutrients and toxic materials in freshwater and marine systems.

One of the large-scale non-climatic effects of an increase in CO_2 emissions is the potential for ocean acidification. The ocean exchanges huge quantities of CO_2 with the atmosphere, and when atmospheric concentrations rise (due to anthropogenic emissions), there is a net flux from the atmosphere into the oceans. This decreases the pH of the oceans, reducing the availability of calcium. According to Richardson and Poloczanska (2008), "declines in ocean pH may impact calcifying organisms, from corals in the tropics to pteropods (winged snails) in polar ecosystems, and will take tens of thousands of years to reequilibrate to preindustrial conditions." Section 4.7 provides more information on the non-climate effects of CO_2 on plant and animal communities.

3.5.1.1.3 Biofuel Cultivation and Mining Activity

The need to supply agricultural products for a growing population will continue to affect water resources; future irrigation needs are likely to include increased production of both food and biofuel crops (Simpson 2008). Global demand for water is increasing as a result of population growth and economic development and irrigation currently accounts for around 70 percent of global water withdrawals (Shiklomanov and Rodda 2003 as cited in Kundzewicz *et al.* 2007). EPA states that "[d]emand for biofuels is also likely to have impacts on water including increasing land in agricultural production, resulting in increased risk of runoff of sediments, nutrients, and pesticides … [p]roduction of biofuels also uses significant amounts of water" (EPA 2008d). Runoff from agricultural sources often contains nitrogen, phosphorus, and other fertilizers and chemicals that harm water quality and can lead to euthrophication (the enrichment of a water body with plant-essential nutrients that can ultimately lead to oxygen depletion) (Vitousek *et al.* 1997, as cited in Fischlin *et al.* 2007). If biofuel production in the United States continues to be based on input-intensive crops like corn and soybeans, projected expansions to meet demand likely will result in significantly increased runoff of fertilizer and sediment (Simpson 2008).

Shifts toward fuel-saving lighter vehicles, either as a result of consumer preference for fuel-efficient vehicles or down-weighting design decisions by manufacturers, might result in changes in mining land use patterns with resulting impacts to water quality (*see* Section 3.5.3.1.1). Metal mining results in impacts to water resources via run-off sedimentation from cleared mining sites and degradation of groundwater quality or quantity due to excavation and extraction activities (EPA 1995a). Shifts in demand for lighter vehicles could mean that areas with iron deposits would experience less mining activity, while areas where commonly used light weight metals (such as aluminum or magnesium) might experience an increase in mining and related water impacts.

3.5.1.2 Environmental Consequences

As discussed in Section 3.3, each action alternative is generally expected to decrease the amount of VOCs, SO_2, NO_x, and other air pollutants in relation to No Action Alternative (Alternative 1) levels. Reductions in these pollutant levels would be the result of lower petroleum fuel consumption by cars and light trucks, and a potential for reduced extraction, transportation, and refining of crude oil. NHTSA expects that lower pollutant emissions would decrease the formation of acid rain in the atmosphere as compared to the No Action Alternative, which in turn would have a beneficial impact on the quality of freshwater standards by decreasing eutrophication and acidification. As discussed in Section 3.4, the impact of the alternative CAFE standards on CO_2 is relatively small compared to global emissions of CO_2. The U.S. car and light-truck fleet represents less than 4 percent of the global emissions of CO_2 from cars and light trucks, and this contribution is projected to decline in the future, due primarily to rapid growth of emissions from developing countries.

Each alternative could lead to an indirect increase in the production of biofuels and the use of more lightweight materials in vehicles, depending on the mix of tools manufacturers use to meet the increased CAFE standards, economic demand, and technological capabilities. If biofuel production were to increase, agricultural runoff could increase. If manufacturers opted for increased production of down-weighted vehicles, shifts in the location of metal extraction could alternatively benefit water quality in locations of decreased activity, while negatively affecting it in areas of increased activity. However, due to uncertainty about how manufacturers would meet the new requirements, and the fact that none of the alternative CAFE standards prescribe increased biofuel use or vehicle down-weighting, these potential impacts are not quantifiable. Section 3.5.4 provides additional information on vehicle down-weighting.

3.5.2 Biological Resources

3.5.2.1 Affected Environment

Biological resources include vegetation, wildlife, and special status species (those classified as "threatened" or "endangered" under the Endangered Species Act). The U.S. Fish and Wildlife Service has jurisdiction over terrestrial and freshwater special status species and the National Marine Fisheries Service has jurisdiction over marine special status species. States and other federal agencies, such as the Department of the Interior's Bureau of Land Management, also have species of concern to which they have assigned additional protections. Sections 3.5.2.1.1 through 3.5.2.1.3 describe the current and projected future threats to these biological resources from non-global climate change impacts related to the proposed action. As discussed below, the production and combustion of fossil fuels, the cultivation and production of biofuels from agricultural crops, and shifts in the location of mining activities are the identified relevant sources of impacts on biological resources. Section 4.5 describes the effects of global climate change on ecosystems.

3.5.2.1.1 Petroleum Extraction and Refining

Oil extraction activities could impact biological resources through habitat destruction and encroachment, raising concerns about their effects on the preservation of animal and plant populations and their habitats. Oil exploration and extraction result in intrusions into onshore and offshore natural habitats and can involve construction within natural habitats. "The general environmental effects of encroachment into natural habitats and the chronic effects of drilling and generating mud and discharge water on benthic (bottom-dwelling) populations, migratory bird populations, and marine mammals constitute serious environmental concerns for these ecosystems" (Borasin *et al.* 2002 as cited in O'Rourke and Connolly 2003).

Oil extraction and transportation can also result in spills of oil and hazardous materials. Oil contamination of aquatic and coastal habitats can directly smother small species and is dangerous to animals and fish if ingested or coated on their fur, skin, or scales. Oil refining and related activities result in chemical and thermal pollution of water, both of which can be harmful to animal and plant populations (Borasin *et al.* 2002). Offshore and onshore drilling and oil transport can lead to spills, vessel or pipeline breakage, and other accidents that release petroleum, toxic chemicals, and highly saline water into the environment and affect plant and animal communities.

Oil extraction, refining and transport activities, and the combustion of fuel during motor-vehicle operation, result in air emissions that affect air quality and can contribute to the production of acid rain; these effects can have negative impacts on plants and animals. Once present in surface waters, air pollutants can cause acidification of waterbodies, changing the pH of the system and affecting the function of freshwater ecosystems. EPA states:

> …plants and animals living within an ecosystem are highly interdependent…Because of the connections between the many fish, plants, and other organisms living in an aquatic ecosystem, changes in pH or aluminum levels affect biodiversity as well. Thus, as lakes and streams become more acidic, the numbers and types of fish and other aquatic plants and animals that live in these waters decrease (EPA 2008b).

Acid rain has also been shown to affect forest ecosystems negatively, both directly and indirectly. These impacts include stunted tree growth and increased mortality, primarily as a result of the leaching of calcium and other soil nutrients (Driscoll *et al.* 2001, DeHayes *et al.* 1999, Baum 2001). Declines in biodiversity of aquatic species and changes in terrestrial habitats likely have ripple effects on other wildlife that depend on these resources.

The combustion of fossil fuels and certain agricultural practices have lead to a disruption in the nitrogen cycle (the process by which gaseous nitrogen from the atmosphere is used and recycled by organisms) with serious repercussions for biological resources. Nitrogen-cycle disruption has occurred through the introduction of large amounts of anthropogenic nitrogen in the form of ammonium and nitrogen oxides to aquatic and terrestrial systems (Vitousek 1994). Increased availability of nitrogen in these systems is a major cause of eutrophication in freshwater and marine waterbodies. Eutrophic systems typically contain communities dominated by phytoplankton (free-floating microscopic plants). Eutrophication can ultimately result in fish and other aquatic animal kills and harmful algal blooms. Acid rain enhances eutrophication of aquatic systems through the deposition of additional nitrogen (Lindberg n.d.). Introduction of large quantities of nitrogen to certain terrestrial systems has also been predicted to lead to an increase in decomposing soil bacteria and subsequent increase in the release of CO_2 into the atmosphere as these bacteria consume organic matter (Black 2008).

3.5.2.1.2 CO_2 Emissions

Ocean acidification as a result of increasing concentrations of atmospheric CO_2, primarily from the combustion of fossil fuels, is expected to affect calciferous marine organisms. In conjunction with rapid climate change, ocean acidification could pose severe threats to coral reef ecosystems. Hoegh-Guldberg *et al.* (2007) state that "[u]nder conditions expected in the 21st century, global warming and ocean acidification will compromise carbonate accretion, with corals becoming increasingly rare on reef systems. The result will be less diverse reef communities and carbonate reef structures that fail to be maintained."

In contrast to its potential adverse effect on the productivity of marine ecosystems, higher CO_2 concentrations in the atmosphere could increase the productivity of terrestrial systems, because plants use CO_2 as an input to photosynthesis. The IPCC Fourth Assessment Report states that "[o]n physiological grounds, almost all models predict stimulation of carbon assimilation and sequestration in response to rising CO_2, called CO_2 fertilization" (Denman *et al.* 2007).

Under bench-scale and field-scale experimental conditions, several investigators have found that higher concentrations have a "fertilizer" effect on plant growth (*e.g.*, Long *et al.* 2006, Schimel *et al.* 2000). IPCC reviewed and synthesized field and chamber studies, finding that:

> There is a large range of responses, with woody plants consistently showing NPP [net primary productivity] increases of 23 to 25 percent (Norby *et al.*, 2005), but much smaller increases for grain crops (Ainsworth and Long 2005) … Overall, about two-thirds of the experiments show positive response to increased CO_2 (Ainsworth and Long 2005, Luo *et al.* 2005, as cited in Denman *et al.* 2007). Since saturation of CO_2 stimulation due to nutrient or other limitations is common (Dukes *et al.* 2005, Körner *et al.* 2005, both as cited in Denman *et al.* 2007), it is not yet clear how strong the CO_2 fertilization effect actually is.

The CO_2 fertilization effect could mitigate some of the increase in atmospheric CO_2 concentrations by resulting in more storage of carbon in vegetation.

Increased atmospheric CO_2, in conjunction with other environmental factors and changes in plant communities, could alter growth, abundance, and respiration rates of some soil microbes (Lipson *et al.* 2005, Chung *et al.* 2007, Lesaulnier *et al.* 2008).

3.5.2.1.3 Land Disturbances Due to Biofuel Production and Mining

Future demands for biofuel production are predicted to require increased commitments of land to agricultural production (EPA 2008d). Placing additional land into agricultural production or returning marginal agricultural land to production to grow perennial grass or trees for use in cellulosic ethanol production would decrease the area available as natural habitat. A decrease in habitat and potential habitat for plants and animal species would likely result in negative impacts to certain species. Increased agriculture production would also likely result in increased surface runoff of sediments and fertilizers. Additional fertilizer inputs to water could increase eutrophication and associated impacts. Sediment runoff can settle to the bottom of waterbodies and degrade essential habitat for some species of aquatic organisms, bury food sources and areas used for spawning, and kill benthic organisms (EPA 2000b).

As stated in section 3.5.1.1.3, a shift toward lighter vehicles would likely result in changes to mining land use patterns and impacts to water quality; such changes could affect aquatic and terrestrial ecosystems. EPA notes that mining activities could result in the destruction of terrestrial habitat, loss of fish populations due to water-quality impacts, and a loss of plants due to increased dust (EPA 1995a). As previously stated, such a shift would likely be beneficial in areas of decreased activity and detrimental in areas of increased activity.

3.5.2.1.4 Endangered Species

Off-shore drilling, on-shore oil and gas drilling, and roads created to access remote extraction sites through habitats used by threatened or endangered species might also affect these plants and animals both directly, through loss of individual animals or habitat, and indirectly, through water-quality degradation or cumulative impacts with other projects. Loss of potential habitat to the production of biofuels could also result in negative impacts to some species (*e.g.*, diminished potential for habitat expansion, increased runoff-related impacts).

Increased anthropogenic inputs of nitrogen to terrestrial, aquatic, and microbial communities containing rare plants and animals could also affect threatened and endangered species. In ecosystems with certain vegetation and soil types, this increased nitrogen availability can result in reduced biodiversity or the exclusion of certain endemic species in favor of those adapted to make use of these nutrients to their competitive advantage (Bobbink *et al.* 1998, Fenn *et al.* 2003, Weiss 1999). For example, the decline of certain nutrient-poor native grasslands in California, which serve as critical habitat for the Bay checkerspot butterfly, is likely partially due to an increase in invasive grass species made possible by such nutrient inputs (Weiss 1999).

3.5.2.2 Environmental Consequences

The decrease in overall fuel consumption by cars and light trucks, anticipated under all of the alternatives except the No Action Alternative, could lead to reductions in oil exploration, extraction, transportation, and refining. NHTSA expects that a reduction in these activities would result in decreased impacts to on- and off-shore habitat and plant and animal species. This decrease could have a small overall benefit to plants and animals primarily through decreased levels of direct ground disturbance and releases of oil and hazardous materials. Reductions in the rate of fuel consumption increase under all of the alternatives compared to the No Action Alternative would lead to overall decreases in the release of SO_2 and NOx. Reductions in acid rain and anthropogenic nutrient deposition could lower levels of eutrophication in surface waters and could slow direct impacts to ecosystems and to soil leaching.

Reductions in the rate of fuel consumption increase would also lead to a decrease in the release of CO_2 compared to the No Action Alternative. Lower levels of atmospheric CO_2 could slow projected effects to terrestrial plant growth, calciferous marine organisms, and microorganisms. However, as discussed in Section 3.5.1.2, the reduction in CO_2 as a result of the proposed action would be relatively small compared to current and projected global CO_2 releases (*see* Chapter 2 and Section 3.3).

The alternatives could lead to an increase in the production of biofuels and mining for lightweight raw materials, depending on the mix of tools manufacturers use to meet the new CAFE standards, economic demands from consumers and manufacturers, and technological developments. Depending on these factors, increased production of biofuels could result in the conversion of existing food-agricultural lands and non-agricultural areas to biofuel crop production. This change in land use would have implications for environmental issues associated with fertilizer runoff, water body eutrophication, and sediment runoff effects to aquatic organism food and spawning habitat. Similarly, increased mining land-disturbance activities could affect aquatic health due to increased sedimentation. However, due to the uncertainty surrounding how manufacturers would meet the new requirements and the fact that none of the analyzed standards prescribe increased biofuel use or vehicle downweighting, these potential effects are not quantifiable.

NHTSA has not been able to identify or quantify the impacts to endangered or threatened species or critical habitat as a result of this rulemaking. Therefore, NHTSA will not perform a Section 7 Consultation.

3.5.3 Land Use and Development

3.5.3.1 Affected Environment

Land use and development refers to human activities that alter land (*e.g.*, industrial and residential construction in urban and rural settings, clearing of natural habitat for agricultural or industrial use) and may affect the amount of carbon or biomass in existing forest or soil stocks in the affected areas. For the purposes of this analysis, shifts in agricultural and mining production and changes to manufacturing plants that produce cars and light trucks are the identified relevant sources of impact.

3.5.3.1.1 Changes in Agricultural Production and Mining

Biofuel production is predicted to require increased devotion of land to agricultural production (EPA 2008d, Keeney and Hertel 2008). Converting areas into cropland would decrease the overall land area kept in a natural state as well as the potential area available for other uses (such as commercial development or pastureland) (Keeney and Hertel 2008). Uncertainty exists regarding how much additional land could be required to meet projected biofuel needs in the United States, as well as how an increase in biofuel production could affect other land uses (Keeney and Hertel 2008).

Shifts toward fuel-saving lighter vehicles, either as a result of consumer preference for fuel-efficient vehicles or downweighting design decisions by manufacturers, might result in changes in mining land use patterns. Mining for the minerals needed to construct these lighter vehicles (primarily aluminum and magnesium) could shift some metal extraction activities to areas rich in these resources. Schexnayder *et al.* (2001) noted that such a shift in materials "could reduce mining for iron ore in the United States, but increase the mining of bauxite for aluminum, magnesium, titanium, and other materials in such major countries as Canada, China, and Russia and in many small, developing countries, such as Guinea, Jamaica, and Sierra Leone."

3.5.3.1.2 Manufacturing Changes

Recent shifts in consumer demand in the United States away from less fuel-efficient vehicles have begun to change the types of vehicles produced and the manufacturing plants where they are made. Sharp decreases in demand for trucks and SUVs have recently resulted in plant closures and production shifts to plants where small cars and gas-electric hybrid vehicles are made (WWJ News Radio 2008, Keenan and Mckenna 2008, Bunkley 2008).

3.5.3.2 Environmental Consequences

The alternatives could lead to an increase in the production of biofuels and the use of more lightweight materials in vehicles, depending on the mix of tools manufacturers use to meet the new CAFE standards, economic demands from consumers and manufacturers, and technological developments. Depending on these factors, increased production of biofuels could result in the conversion of existing food-agricultural lands and natural areas to the production of these fuel crops. Downweighted vehicles could result in shifts in mining from areas containing iron to those containing aluminum and magnesium. These changes would have implications for environmental issues associated with land use and development. However, due to the uncertainty surrounding how manufacturers would meet the new requirements and the fact that none of the analyzed standards prescribe increased biofuel use or vehicle downweighting, these potential impacts are not quantifiable. *See* Section 3.5.4 for more information on vehicle downweighting.

Major changes to manufacturing facilities, such as those occurring with the apparent shift in consumer demand toward more fuel-efficient vehicles, might have implications for environmental issues associated with land use and development. However, NHTSA's review of existing and available technologies and capabilities shows that the CAFE standards under all the alternatives can be met by existing and planned manufacturing facilities. Because of the availability of sufficient existing and planned capacity, and because none of the alternatives prescribe particular technologies for meeting these standards, the various alternatives are not projected to force changes in product mixes that would result in plant changes.

3.5.4 Safety and Other Impacts to Human Health

This section addresses how future improvements in fuel economy might affect human health and welfare through vehicle safety performance, particularly crashworthiness and the rate of traffic fatalities. It also addresses how the new standards might affect energy concerns, which could have ramifications for family health and welfare.

3.5.4.1 Affected Environment

Multiple factors influence traffic fatality rates, including driver demographics (age, gender, etc); driver behavior (*e.g.*, driving under the influence, seat belt use, observance of speed limits and other traffic laws, miles driven); and vehicle characteristics such as size, weight, and various technologies designed to increase vehicle safety performance (*e.g.*, air bags, anti-lock braking systems, structural reinforcement, impact crumple zones). Several studies have attempted to define the relationship between vehicle crashworthiness (specifically as it relates to traffic fatalities) and fuel economy standards; however, different methodologies have yielded different conclusions. Although much of the research identifies a link between vehicle downsizing and decreased crashworthiness, studies have reached various conclusions.

The 2002 National Academy of Sciences report (NAS 2002) made explicit links between weight and vehicle safety. The NAS study conclusions were divided, with 11 of 13 committee members representing the majority view and 2 of 13 the minority view. The findings of the majority state, "the majority of the committee finds that the downsizing and weight reduction that occurred in the late 1970s and early 1980s most likely produced between 1,300 and 2,600 crash fatalities and between 13,000 and 26,000 serious injuries in 1993. The proportion of these casualties attributable to CAFE standards is uncertain." Two members provided a minority view: "The relationships between vehicle weight and safety are complex and not measurable with any reasonable degree of certainty at present. The relationship of fuel economy to safety is even more tenuous. … it appears that in certain kinds of accidents, reducing weight will increase safety risk, while in others it may reduce it. Reducing the weights of light-duty vehicles will neither benefit nor harm all highway users, there will be winners and losers…"

The Kahane study (2003) estimates the effect of 100-pound reductions in heavy (more than 3,900 pounds curb weight) light trucks and vans (LTVs), light LTVs, heavy passenger cars, and light passenger cars. It compares the fatality rates of LTVs and cars to quantify differences among vehicle types, given drivers of the same age, gender, etc. The study found that annual fatalities increased with a reduction in weight in all groups of passenger vehicles except light trucks with a curb weight greater than 3,900 pounds. The net safety effect of removing 100 pounds from a light truck is close to zero for the group of all light trucks with a curb weight greater than 3,900 pounds.

Honda has cited several reports, which it asserts demonstrate that limited weight reductions would not reduce safety and could possibly decrease overall fatalities. Honda stated that the 2003 study by Dynamic Research Inc. (DRI) found that reducing weight without reducing size slightly decreased fatalities, and that this was confirmed in a 2004 study by DRI[37] that assessed new data and methodology changes in the 2003 Kahane study. DRI submitted an additional study, *Supplemental Results on the Independent Effects of Curb Weight, Wheelbase, and Track Width on Fatality Risk in 1985-1998 Model Year Passenger Cars and 1985-1997 Model Year LTVs* (van Auken and Zellner 2005). This DRI study concluded that reductions in "footprint" (the product of multiplying a vehicle's wheelbase by its track width) are harmful to safety, whereas reductions in mass while holding footprint constant would benefit safety.

NHTSA analyses of the relationships between fatality risk and mass, track width, and wheelbase in four-door 1991 to 1999 passenger cars (Docket No. 2003-16318-0016) found a strong relationship between track width and the rollover fatality rate, but only a modest (although substantial) relationship between track width and fatality rate in non-rollover crashes. Even controlling for track width and wheelbase – for example, by holding footprint constant – weight reduction in the lighter cars is strongly associated with higher non-rollover fatality rates in the NHTSA analysis.

While further scientific examination continues, EISA included an important reform that requires NHTSA to issue attribute-based standards, which eliminates or reduces the incentive to decrease the size (weight) of the vehicle to comply with the fuel economy standards because smaller-footprint (size) vehicles have to achieve higher fuel economy targets. The attribute-based approach was originally recommended by the NAS to remove the apparent incentive to reduce size and/or the weight of vehicles as a means of meeting the standards.

NHTSA adopted an attribute-based approach for light trucks in 2006. NHTSA continues to examine this important safety issue and has tentatively concluded in its current NPRM that use of the

[37] *See* Docket Nos. 2003-16318-2, 2003-16318-3, and 2003-16318-7.

footprint-attribute will achieve greater fuel economy/emissions reductions without creating an incentive to downsize vehicles.

Another way that the new standards could affect human health and welfare is by increasing the amount of VMT. NHTSA tracks very closely the rate of traffic fatalities as a function of VMT, even while recognizing that many other factors are critical in determining fatality risks. In February 2008, NHTSA reported that the fatality rate in 2006 was 1.41 per million VMT, a decline from 2005 rates (Subramanian 2008). These effects are not limited to vehicle occupants (bicyclists and pedestrians could also have an increased risk as a result of increased VMT). However, as with vehicle occupant fatalities, many other factors are important in determining the overall risk associated with vehicle, pedestrian, and bicycle fatalities.

Finally, there is scientific literature that posits a relationship between petroleum scarcity and human health. Frumkin *et al.* (2007) argues that increased oil prices could result in increased use of other fuels for power generation and increase costs to hospitals for providing back-up power via diesel generators. Petroleum scarcity could also result in more expensive food (due to transportation and agricultural costs), which could be intensified by several factors, including climate change, market demand for biofuels (which would inflate some food prices), and degradation of agricultural land. These effects could threaten the health of low-income people and others who do not have secure access to food. Other effects of peak petroleum prices on health are more speculative, but concerns remain for issues such as (1) higher petroleum prices triggering a persistent economic downturn, which could increase the ranks of the uninsured, (2) social disruptions that could create a substantial burden of anxiety, depression, and other psychological ailments, and (3) resource scarcity, including petroleum scarcity, that could trigger armed conflict, which poses multiple risks to public health. To the extent that the CAFE standards affect petroleum supply or price, they might have an effect on human welfare.

3.5.4.2 Environmental Consequences

Because of the attribute-based approach recommended by NAS and adopted by NHTSA, the incentive to meet the new standards by making more smaller vehicles and fewer larger vehicles should be reduced or eliminated. Further, NHTSA chose fuel-economy levels that could be achieved without reductions in weight for vehicles less than 5,000 pounds. Because the alternatives do not mandate the methods by which the CAFE standards are achieved, vehicle manufacturers could achieve increased fleet fuel economy by reducing vehicle weight. To the extent that manufacturers choose this approach, there could be some additional traffic fatalities and more serious injuries resulting from vehicle accidents. The extent of these effects cannot be estimated without knowing the extent to which manufacturers choose to meet the new CAFE standards by making lighter vehicles with similar footprints.

The PRIA for the CAFE standards of MY 2011-2015 passenger cars and light trucks concluded that increases in fleet fuel economy are likely to lead to more miles being driven by the U.S. population (NHTSA 2008a). Known as the rebound effect, higher CAFE standards would lead to the perception of a lower cost of driving, which is typically the largest component of the cost of operating a vehicle. In response to the perception of lowered costs, consumers would increase the number of miles they drive. By one estimate, a 10-percent increase in fuel economy would ultimately result in a 2.4-percent increase in total miles traveled (Small and Dender 2005a). The recent and unprecedented decline in miles driven – a 4.3 percent drop in the total miles driven in March of 2008 as compared to March of 2007, equating to a decrease of 11 billion miles (FHWA 2008) – in response to recent surges in the price of gasoline, underscores the relationship between the cost of operating a passenger vehicle and driver behavior as it relates to miles driven. Because increased average fuel economy would lead to vehicles that cost less to operate, it can be expected that individuals would drive more miles, and traffic accidents and fatalities of vehicle occupants, bicyclists, and pedestrians would increase on the whole. However, an estimate of increased fatalities based on miles driven is influenced, in part, by unpredictable market forces, and is uncertain to predict.

The alternatives would reduce petroleum use. To the extent that petroleum scarcity would be reduced by higher fuel economy standards, any adverse health impacts as described by Frumkin *et al.* (2007) would also be reduced.

3.5.5 Hazardous Materials and Regulated Wastes

3.5.5.1 Affected Environment

Hazardous wastes are defined here as solid wastes, which also include certain liquid or gaseous materials, that because of their quantity and concentration, or their physical, chemical, or infectious characteristics could cause or contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness or could pose a substantial hazard to human health or the environment when improperly treated, stored, used, transported, disposed of, or otherwise managed. Hazardous wastes are generally designated as such by individual states or EPA under the Resource Conservation and Recovery Act of 1976. Additional federal and state legislation and regulations, such as the Federal Insecticide, Fungicide, and Rodenticide Act, determine handling and notification standards for other potentially toxic substances. For the purposes of this analysis, hazardous materials and wastes generated during the oil extraction and refining processes and by agricultural production and mining activities are the identified relevant sources of impact.

3.5.5.1.1 Wastes Produced during the Extraction Phase of Oil Production

The primary waste created during the extraction of oil is “produced water,” highly saline water pumped from oil and gas wells during mining (American Petroleum Institute 2000, EPA 2000c). In 1995, the onshore oil and gas industry produced approximately 15 billion barrels of produced water (American Petroleum Institute 2000). Produced waters are generally “highly saline (total dissolved solids may exceed 350,000 milligrams per liter [mg/L]), may contain toxic metals, organic and inorganic components, and radium-226/228 and other naturally occurring radioactive materials” (Kharaka and Otton 2005). Drilling wastes, primarily mud and rock cuttings, account for 149 million barrels of extraction wastes. “Associated wastes,” generally the most hazardous wastes produced during extraction (often containing benzenes, arsenic, and toxic metals), account for another 22 million barrels (The American Petroleum Institute 2000, EPA 2000c).

Wastes produced during oil and gas extraction have been known to have serious environmental effects on soil, water, and ecosystems (Kharaka and Otton 2005, O’Rourke and Connolly 2003). Onshore environmental effects result “primarily from the improper disposal of large volumes of saline water produced with oil and gas, from accidental hydrocarbon and produced water releases, and from abandoned oil wells that were not correctly sealed” (Kharaka and Otton 2005). Offshore effects result from improperly treated produced water released into the waters surrounding the oil platform (EPA 2000c).

3.5.5.1.2 Wastes Produced during the Refining Phase of Oil Production

Wastes produced during the petroleum-refining process are primarily released to the air and water, accounting for 75 percent (air emissions) and 24 percent (wastewater discharges) of the total (EPA 1995a). EPA defines a release as the “on-site discharge of a toxic chemical to the environment…emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells” (EPA 1995a). EPA reports that 9 of the 10 most common toxic substances released by the petroleum-refining industry are volatile chemicals, highly reactive substances prone to state changes or combustion, that include benzene, toluene, ethylbenzene, xylene, cyclohexane, 1,2,4-trimethylbenzene and ethylbenze (EPA 1995a). These substances are present in crude oil and in finished petroleum products. Other potentially dangerous substances commonly released during the refining process include ammonia, asoline additives (methanol, ethanol, and MTBE), and chemical feedstocks (propylene, ethylene, and napthalene) (EPA 1995a). Spent sulfuric acid is by far the most commonly produced toxic substance; however, it is generally reclaimed instead of released or transferred for disposal (EPA 1995a).

Wastes released during the oil-refining process can cause environmental impacts to water quality, air quality, and human health. The volatile chemicals released during the refining process are known to react in the atmosphere and contribute to ground-level ozone and smog (EPA 1995a). Several of the produced volatile chemicals are also known or suspected carcinogens, and many others are known to cause respiratory problems and impair internal-organ functions, particularly in the liver and kidneys (EPA 1995a). Ammonia is a form of nitrogen and can contribute to eutrophication in surface waters.

3.5.5.1.3 Agricultural Materials

Agricultural production, especially of the type required to grow the corn and soy beans most commonly used to produce biofuels in the United States, also results in the release of potentially hazardous materials and wastes. Wastes from agricultural production can include pesticide (insecticides, rodenticides, fungicides, and herbicides) and fertilizer runoff and leaching, wastes used in the maintenance and operation of agricultural machinery (used oil, fuel spills, organic solvents, metal machining wastes, spent batteries), and other assorted process wastes (EPA 2000d).

Agricultural wastes in the form of runoff from agricultural fields can cause environmental impacts to water and human health. Fertilizers can run off into surface waters and cause eutrophication, while pesticides can directly affect beneficial insects and wildlife (EPA 2000d). A National Renewable Energy Lab report concludes that the negative environmental impacts on soil and water due to impacts of increased biofuel production are likely to occur disproportionately in the Midwest, where most of these crops are grown (Powers 2005). Human health can also be affected by improperly handled or applied pesticides, with potential effects ranging from minor respiratory or skin inflammation to death (EPA 2000d). Nitrogen fertilizer runoff to drinking-water sources can lead to methemogloanemia, the potentially fatal binding of a form of nitrogen to hemoglobin in infants (Powers 2005).

Ethanol, as a biofuel additive to gasoline, is suspected of enhancing the plume size after a gasoline-blended ethanol spill and might decrease degradation of the spilled hydrocarbon and related compounds, such as benzene (Powers *et al.* 2001, Deeb *et al.* 2002, Williams *et al.* 2003).

3.5.5.1.4 Automobile Production and Assembly

Hazardous materials and toxic substances are produced by motor vehicles and the motor vehicle equipment industry, businesses engaged in the manufacture and assembly of cars, trucks, and busses. EPA reports that solvents (xylene, methyl ethyl ketone, acetone, etc.) are the most commonly released toxic substances it tracks for this industry (EPA 1995a). These solvents are used to clean metal and in the vehicle-finishing process during assembly and painting (EPA 1995a). Other industry wastes include metal paint and component-part scrap.

In addition, studies have suggested that the substitution of lighter weight materials (such as aluminum, magnesium, titanium, or plastic) for steel and iron to increase fuel efficiency could increase the total waste stream resulting from automobile manufacturing (Schexnayder *et al.* 2001). Mining wastes generated during the extraction of these lighter raw materials would likely increase substantially, primarily due to aluminum mining, and other production wastes (e.g., from refining of aluminum and plastic manufacturing) could also increase (Schexnayder *et al.* 2001, Dhingra 1999). The extraction and processing of these metals and the production of manmade fibers and plastics also generate various hazardous wastes (EPA 1995b, EPA 1997c). An assessment of the solid and hazardous wastes generated during the production of three lightweight concept cars concluded the net generation of waste would increase versus conventional vehicles; however, the study also noted that the generation of most hazardous materials of particular concern to human health (*e.g.*, cadmium, chlorine, lead) emitted during the production of vehicles appeared to decrease in the vehicle models analyzed (Schexnayder *et al.* 2001). Recycling of vehicles at the end of the vehicle life could help to offset some of the projected net increase in waste production versus primarily steel/iron construction vehicles.

3.5.5.1.5 CO_2 Emissions

CO_2 is not currently classified as a hazardous material or regulated waste. For a discussion of the release of CO_2 relevant to the proposed action and its impacts on climate change, *see* Section 3.4. For a discussion of the impacts of CO_2 on water resources, *see* Section 3.5.1.1.2. For a discussion of the impacts of CO_2 on biological resources, *see* Section 3.5.2.1.2.

3.5.5.2 Environmental Consequences

The projected reduction in fuel production and consumption as a result of the proposed action could lead to a reduction in the amount of hazardous materials and wastes created by the oil extraction and refining industries. NHTSA expects corresponding decreases in the associated environmental and health impacts of these substances. However, these effects would likely be small if they occurred because of the limited overall effect of the proposed action on these areas.

All of the alternatives could lead to an increase in the production of biofuels and the use of more lightweight materials in vehicles, depending on the mix of tools manufacturers use to meet the new CAFE standards, economic demands from consumers and manufacturers, and technological developments. If biofuel production increased, these could be additional runoff of agricultural fertilizers and pesticides; if manufacturers pursued vehicle downweighting, these could be a net increase in the waste stream. However, due to the uncertainty surrounding how manufacturers would meet the new requirements and the fact that none of the analyzed standards prescribes increased biofuel use or vehicle downweighting, these potential impacts are not quantifiable. *See* Section 3.5.4 for additional information on vehicle downweighting.

3.5.6 Land Uses Protected under Section 4(f)

3.5.6.1 Affected Environment

Section 4(f) resources are publicly owned parks, recreational areas, wildlife and waterfowl refuges, or public and private historical sites, which are given special consideration by the DOT. Originally included as part of the Department of Transportation Act of 1966, Section 4(f) stipulates that DOT agencies cannot approve the use of land from publicly owned parks, recreational areas, wildlife and waterfowl refuges, or public and private historical sites unless: "(1) there is no feasible and prudent alternative to the use of such land, and (2) such program includes all possible planning to minimize harm to such park, recreational area, wildlife and waterfowl refuge, or historic site resulting from such use" (49 U.S.C. 303).

3.5.6.2 Environmental Consequences

"Section 4(f) only applies where land is permanently incorporated into a transportation facility and when the primary purpose of the activity on the 4(f) resource is for transportation" (FHWA 2005). Therefore, these resources are not affected by the types of environmental issues under consideration as part of the proposed action.

3.5.7 Historic and Cultural Resources

3.5.7.1 Affected Environment

The National Historic Preservation Act of 1966, Section 106 states that agencies of the Federal Government must take into account the impacts of their action to historic properties; the regulations to meet this requirement can be found at 36 CFR Part 800. This process, known as the "Section 106 process," is intended to support historic preservation and mitigate impacts to significant historical or archeological properties through the coordination of federal agencies, states, and other affected parties. Historic properties are generally identified through the *National Register of Historic Places*, which lists properties of significance to the United States or a particular locale because of their setting or location, contribution to or association with history, or unique craftsmanship or materials. National Register-eligible properties must also be sites: "A. That are associated with events that have made a significant contribution to the broad patterns of our history; or B. That are associated with the lives of persons significant in our past; or C. That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or D. That have yielded, or may be likely to yield, information important in prehistory or history" (NPS n.d.). Acid rain as a result of the processing of petroleum products and the combustion of petroleum-based fuels is the identified relevant source of impact to historic and cultural resources for this analysis.

Acid rain, the primary source of which is the combustion of fossil fuels, is one cause of degradation to exposed cultural resources and historic sites. EPA states that "[a]cid rain and the dry deposition of acidic particles contribute to the corrosion of metals (such as bronze) and the deterioration of paint and stone (such as marble and limestone). These effects substantially reduce the societal value of buildings, bridges, cultural objects (such as statues, monuments, and tombstones), and cars" (EPA 2007b).

3.5.7.2 Environmental Consequences

The projected reduction in fuel production and combustion as a result of the proposed action could lead to a minor reduction in the amount of pollutants that cause acid rain. A decrease in the production of such pollutants could result in a corresponding decrease in the amount of damage to historic and other structures caused by acid rain. However, such effects are not quantifiable.

3.5.8 Noise

3.5.8.1 Affected Environment

Excessive amounts of noise, which is measured in decibels, can present a disturbance and a hazard to human health at certain levels. Potential health hazards from noise range from annoyance (sleep disturbance, lack of concentration, and stress) to hearing loss at high levels (Delucchi and Hsu 1998, Geary 1998, Fleming *et al.* 2005). Motor-vehicle noise also affects property value. A study of the impacts of roadway noise on property value estimated this cost to be roughly 3 billion dollars in 1991 dollars (Delucchi and Hsu 1998). The noise from motor vehicles has been shown to be one of the primary causes of noise disturbance in homes (OECD 1988, as cited in Delucchi and Hsu 1998 and Geary 1998). Noise generated by vehicles causes inconvenience, irritation, and potentially even discomfort to occupants of other vehicles, to pedestrians and other bystanders, and to residents or occupants of surrounding property.

3.5.8.2 Environmental Consequences

As a result of the rebound effect (the increase in VMT as the cost per mile for fuel decreases), NHTSA predicts that there will be increased vehicle use under all of the alternatives; higher overall VMTs would result in increases in vehicle road noise. However, determining if there will be noise impacts is not possible based on the available data. Noise levels are location specific, meaning factors such as the time of day at which increases in traffic occur, existing ambient noise levels, the presence or absence of noise abatement structures, and the location of school, residences, and other sensitive noise receptors all influence whether there will be noise impacts.

All of the alternatives could lead to an increase in use of hybrid vehicles, depending on the mix of tools manufacturers use to meet the new CAFE standards, economic demands from consumers and manufacturers, and technological developments. An increased percentage of hybrid vehicles could result in reduced road noise, potentially offsetting some of the increase in road noise predicted to result from increased VMT. However, due to the uncertainty surrounding how manufacturers would meet the new requirements, the fact that none of the alternatives prescribes increased production of hybrid vehicles, and the location-specific nature of noise impacts, these potential impacts are not quantifiable.

3.5.9 Environmental Justice

3.5.9.1 Affected Environment

Federal agencies must identify and address disproportionably high and adverse impacts to minority and low-income populations in the United States (Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*). DOT Order 5610.2 establishes the process the Department uses to “incorporate environmental justice principles (as embodied in the Executive Order) into existing programs, policies, and activities.” The production and use of fossil fuels and the production of biofuels are the identified relevant sources of impact to environmental populations for this analysis. For a discussion of the effects of changes in climate on environmental justice populations, *see* Section 4.6.

Numerous studies have noted that there appears to be a historic and ongoing relationship between the environmental impacts of petroleum extraction, processing, and use and environmental justice populations (Pastor *et al.* 2001, O’Rourke and Connolly 2003, Lynch *et al.* 2004, Hymel 2007, Srinivasan *et al.* 2003).

Potential impacts of the oil exploration and extraction process on environmental justice communities include “human health and safety risks for neighboring communities and oil industry workers, and displacement of indigenous communities” (O’Rourke and Connolly 2003). Subsistence-use activities (collecting plants or animals to fulfill basic needs for food, clothing, or shelter) can also be affected by extraction and exploration through the direct loss of subsistence-use areas or impacts to culturally/economically important plants and animals as a result of a spill or hazardous material release (O’Rourke and Connolly 2003, Kharaka and Otton 2005).

It has been shown that minority and low income populations often disproportionately reside near high-risk polluting facilities, such as oil refineries (Pastor *et al.* 2001, Graham *et al.* 1999, O'Rourke and Connolly 2003), and "mobile" sources of air toxins and pollutants, such as highways (Morello-Frosch 2002, Jerrett *et al.* 2001, O'Neill *et al.* 2003c). Populations near refineries could be disproportionately affected by exposure to potentially dangerous petroleum and by-products of the refining process, such as benzene (Borasin et. al 2002). Exposure to the toxic chemicals associated with refineries, primarily by refinery workers, has been shown to be related to increases in certain diseases and types of cancer (Pukkala 1998, Chan *et al.* 2005); the precise nature and severity of these health impacts are still under debate. Pollutants from transportation sources, such as NO_2 and CO from roadway traffic, are often unevenly distributed and tend to remain near their release locations (O'Neill *et al.* 2003c). A correlation between this uneven distribution of some pollutants and minority and low income populations has been documented, demonstrating the potential for a disproportionate allocation of the health impacts of these air pollutants to environmental justice populations (Jerret *et al.* 2001, Morello-Frosch 2002). Recent reviews by health and medical researchers indicate a general consensus that proximity to high-traffic roadways could result in health effects in the areas of cardiovascular health (Adar and Kaufman 2007), and asthma and respiratory health (Heinrich and Wichmann 2004, Salam *et al.* 2008). The exact nature of the relationship between these health impacts, traffic-related emissions, and the influence of confounding factors such as traffic noise are not known at this time (Samet 2007).

The production of biofuels could, depending on the mix of agricultural crops or crop residues used in its production, affect food prices. The International Food Policy Research Institute states, "An aggressive biofuel scenario that assumes that current plans for expansion of the sector in Africa, Asia, Europe, and North and South America are actually realized could lead to substantial price increases for some food crops by 2020 – about 80 percent for oilseeds and about 40 percent for maize – unless new technologies are developed that increase efficiency and productivity in both crop production and biofuel processing" (von Braun and Pachauri 2006). Such an increase in food prices would disproportionately affect low income and minority populations, because these groups are less likely to be capable of absorbing the impacts of higher prices.

3.5.9.2 Environmental Consequences

The projected reduction in fuel production and consumption as a result of the action alternatives could lead to a minor reduction in the amount of direct land disturbance as a result of oil exploration and extraction, and the amount of air pollution produced by the oil refineries. There could be corresponding decreases in impacts on environmental justice populations as a result of the alternatives, but the effects of any such decreases are not quantifiable and would likely be minor, if they occurred.

As discussed in Section 3.3, the overall decrease in emissions predicted to occur as a result of the new CAFE standards is not evenly distributed due to the increase in VMT from the rebound effect and regional changes in upstream emissions. As a result, some criteria and toxic air pollutants are predicted to increase in some air quality nonattainment areas. The large size of each nonattainment area, the uniform distribution of increases in VMT, and the minor emissions increases in affected nonattainment and other areas make it unlikely that there would be disproportionate effects to environmental justice populations.

All of the alternatives could lead to an increase in the production of biofuels, depending on the mix of tools manufacturers use to meet the increased CAFE standards, economic demands from consumers and manufacturers, and technological developments. If grain-based biofuel production increases, there could be effects on food prices. However, because of the uncertainty surrounding how manufacturers would meet the new requirements, and the fact that none of the alternatives prescribes increased biofuel use, these potential impacts are not quantifiable.

4 Cumulative Impacts

4.1 INTRODUCTION

The Council on Environmental Quality (CEQ) identifies the impacts that must be addressed and considered by federal agencies in satisfying the requirements of the National Environmental Policy Act (NEPA). This includes permanent, temporary, indirect, and cumulative impacts.

CEQ NEPA implementing regulations define “cumulative impact” as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions.” 40 Code of Federal Regulations (CFR) § 1508.7. Cumulative impacts should be evaluated along with the overall impacts analysis of each alternative. The range of alternatives considered should include a No Action Alternative as a baseline against which to evaluate cumulative effects. The range of actions to be considered includes not only the proposed action but all connected and similar actions that could contribute to cumulative effects. Related actions should be addressed in the same analysis. CEQ recommends that an agency’s analysis accomplish the following:

- Focus on the effects and resources within the context of the proposed action.
- Present a concise list of issues that have relevance to the anticipated effects of the proposed action or eventual decision.
- Reach conclusions based on the best available data at the time of the analysis.
- Rely on information from other agencies and organizations on reasonably foreseeable projects or activities that are beyond the scope of the analyzing agency’s purview.
- Relate to the geographic scope of the proposed project.
- Relate to the temporal period of the proposed project.

A cumulative impacts analysis involves assumptions and uncertainties. Monitoring programs and research can be identified to supplement the available information and thus, enhance analyses for the future. The absence of an ideal database should not prevent the completion of a cumulative effects analysis.

This section addresses areas of the quantitative analyses presented in Chapter 3, with particular attention to energy, air, and climate. Chapter 4 describes the indirect cumulative effects of climate change on a global scale. This chapter is organized according to the conventions of the climate change literature rather than the conventions of an Environmental Impact Statement (EIS) format. To assist the reader, the chart on the following page maps topics found in U.S. Department of Transportation (DOT) NEPA documents (DOT Order 5610.1C) to the sections in this Final Environmental Impact Statement (FEIS).

4.1.1 Approach to Scientific Uncertainty and Incomplete Information

4.1.1.1 CEQ Regulations

CEQ regulations recognize that many federal agencies confront limited information and substantial uncertainties when analyzing the potential environmental impacts of their actions under NEPA

Typical NEPA Topics	EIS Subsections
Water	4.4 Climate; 4.5.3 Freshwater Resources; 4.5.5 Coastal Systems and Low-lying Areas
Ecosystems	4.5.3 Freshwater Resources; 4.5.4 Terrestrial Ecosystems; 4.5.5 Coastal Systems and Low-lying Areas; 4.5.6 Food, Fiber, and Forest Products; 4.7 Non-climate Cumulative Impacts of CO_2
Threatened and endangered species	4.5.4 Terrestrial Ecosystems; 4.5.5 Coastal Systems and Low-lying Areas; 4.7 Non-climate Cumulative Impacts of CO_2
Publicly owned parklands, recreational areas, wildlife and waterfowl refuges, and historic sites, Section 4(f) related issues	4.5.3 Freshwater Resources; 4.5.4 Terrestrial Ecosystems; 4.5.5 Coastal Systems and Low-lying Areas; 4.5.7 Industries, Settlements, and Society
Properties and sites of historic and cultural significance	4.5.7 Industries, Settlements, and Society
Considerations relating to pedestrians and bicyclists	4.5.7 Industries, Settlements, and Society
Social impacts	4.5.7 Industries, Settlements, and Society; 4.6 Environmental Justice
Noise	4.5.7 Industries, Settlements, and Society
Air	4.3 Air Quality
Energy supply and natural resource development	4.2 Energy; 4.5.4 Terrestrial Ecosystems; 4.5.6 Food, Fiber, and Forest Products; 4.5.7 Industries, Settlements, and Society
Floodplain management evaluation	4.5.3 Freshwater Resources; 4.5.5 Coastal Systems and Low-lying Areas
Wetlands or coastal zones	4.5.3 Freshwater Resources; 4.5.5 Coastal Systems and Low-lying Areas
Construction impacts	4.3 Air Quality; 4.4 Climate; 4.5.7 Industries, Settlements, and Society; 4.5.8 Human Health
Land use and urban growth	4.4 Climate; 4.5.6 Food, Fiber, and Forest Products; 4.5.7 Industries, Settlements, and Society
Human environment involving community disruption and relocation	4.3 Air Quality; 4.4 Climate; 4.5.5 Coastal Systems and Low-lying Areas; 4.6 Environmental Justice; 4.5.7 Industries, Settlements, and Society; 4.5.8 Human Health

(40 CFR § 1502.22). Accordingly, the regulations provide agencies with a means to formally acknowledge incomplete or unavailable information in NEPA documents. Where “information relevant to reasonably foreseeable significant adverse impacts cannot be obtained because the overall costs of obtaining it are exorbitant or the means to obtain it are not known,” the regulations require an agency to include in its NEPA document:

1. A statement that such information is incomplete or unavailable;

2. A statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment;

3. A summary of existing credible scientific evidence that is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment; and

4. The agency’s evaluation of such impacts based on theoretical approaches or research methods generally accepted in the scientific community.

Relying on these provisions is appropriate where an agency is performing a NEPA analysis that involves potential environmental impacts resulting from carbon dioxide (CO_2) emissions (***e.g., Mayo Found. v. Surface Transp. Bd.***, 472 F.3d 545, 555, 8th Cir. 2006). CEQ regulations also authorize agencies to incorporate material into a NEPA document by reference in order to “cut down on bulk without impeding agency and public review of the action” (40 CFR § 1502.21).

Throughout this EIS, the National Highway Transportation Safety Administration (NHTSA) uses these two mechanisms – acknowledging incomplete or unavailable information and incorporation by reference – to address areas where the agency cannot develop a credible estimate of the potential environmental impacts of the standards or reasonable alternatives. In particular, NHTSA recognizes that information about the potential environmental impacts of changes in emissions of CO_2 and other greenhouse gases (GHG) and associated changes in temperature, including those expected to result from the proposed rule, is incomplete. In this EIS, NHTSA often relies on the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007) as a recent “summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment” (40 CFR § 1502.22(b)(3)).

4.1.1.2 Uncertainty within the IPCC Framework

The IPCC Reports communicate uncertainty and confidence bounds using descriptive words in italics, such as *likely* and *very likely*, to represent levels of confidence in conclusions. This is briefly explained in the IPCC Fourth Assessment Synthesis Report and the IPCC Fourth Assessment Report Summary for Policy Makers (IPCC 2007d, IPCC 2007c). A more detailed discussion of the IPCC’s treatment of uncertainty can be found in the Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties (IPCC 2005).

This FEIS uses the IPCC uncertainty language (always noted in italics) throughout Chapters 3 and 4 when discussing qualitative environmental impacts on certain resources. The reader should refer to the documents referenced above to gain a full understanding of the meaning of those uncertainty terms, because they might be different from the meaning of language describing uncertainty in this FEIS as required by the CEQ regulations discussed above.

4.1.2 Temporal and Geographic Boundaries

When evaluating cumulative effects, the analyst must consider expanding the geographic study area beyond that of the proposed action, as well as expanding the temporal (time) limits to consider past, present, and reasonably foreseeable future actions that might affect the environmental resources of concern. The timeframe for this cumulative impacts analysis extends through year 2100 and considers potential cumulative impacts on a national, as well as global, basis.

4.2 ENERGY

A NEPA analysis must consider the cumulative impacts of the proposed action. For this EIS, such considerations involve evaluating the cumulative fuel consumption of the vehicle fleet from the onset of the new standards.

4.2.1 Affected Environment

According to the Energy Information Administration (EIA), net imports of total liquid fuels, including crude oil and refined products, will fall to 51 percent in 2022 and then increase to 54 percent in 2030. This change is attributed to changes in the Corporate Average Fuel Economy (CAFE) standards and in the increased use of biofuels. These imports will replace declining production in meeting the increasing demand for liquid fuels in the United States. The large volume of crude oil imports has a number of impacts on the domestic economy. Further decreases or increases in imports, likely under some of the CAFE alternatives, could affect the world price of crude oil. However, over time the U.S. share of global demand for liquid fuels will decline due to rapid increases in demand in developing economies, including China and India, reducing the relative impact of the CAFE standards on global markets.

Over time a larger share of liquid fuels is expected to be produced from unconventional sources such as biofuels, shale oil, coal-to-liquids, and gas-to-liquids. These alternate sources would affect CO_2 and other emission reductions from the CAFE alternatives. This shift would be driven by changes to the Renewable Fuels Standard (RFS) in the Energy Independence and Security Act (EISA), which forecasts that 36 billion gallons of renewable fuels will be required by 2022 for use primarily in the transportation sector. The EIA Annual Energy Outlook (AEO) 2008 forecasts that domestic production of non-hydro renewable energy will increase from less than 4 quadrillion British thermal units (BTUs) in 2006 to more than 10 quadrillion BTUs in 2030 (EIA 2008a). In the United States, liquid fuels from gas, coal, and biomass are projected to increase from 0.00 quadrillion BTUs in 2006 to 0.54 quadrillion BTUs. Overall, NHTSA expects in the short-term, the impact from these changes would net out. Over the long-term, the impact of these changes remains uncertain.

Changes to the CAFE standards are unlikely to affect domestic production, given the level of crude oil imports. The domestic environmental impacts over the life of the model year (MY) 2011-2020 vehicles are unlikely to change, regardless of the alternative elected. Impacts on production would occur outside of the United States, and would be determined by the balance between the decline in U.S. imports and the increase in demand from developing countries. Impacts on petroleum products would be mixed. U.S. imports of petroleum products are often targeted for specific product requirements, for logistical reasons, or to optimize the inputs and outputs from refineries. Petroleum imports depend on specific product demands and the mix of crudes processed in the refineries, which are projected to change considerably over time. Consequently, any decline in demand for petroleum products is likely to have some effect on both overseas and domestic refineries.

4.2.2 Environmental Consequences

Implementing alternative CAFE standards would result in different future levels of fuel use, total energy, and petroleum consumption, which in turn would have an impact on emissions of GHGs and criteria air pollutants. An important measure of the impact of alternative CAFE standards is the impact on the cumulative fuel consumption of the vehicle fleet from the onset of the new standards. Passenger cars and light trucks are considered separately; total fuel consumption encompasses gasoline and diesel. CAFE standards for MY 2011-2020 are assumed to apply to all subsequent additions to the vehicle fleet. The impact of alternative CAFE standards, by affecting petroleum consumption, total energy consumption, and emissions, would ultimately determine many of the indirect environmental impacts of adopting higher CAFE standards.

Table 4.2-1 shows the cumulative fuel consumption of passenger cars under the No Action Alternative (Alternative 1) and the six action alternative CAFE standards with the Reference Case inputs, as described in Table 2.2-1 (*see* Section 2.2 of this FEIS). By 2060, when MY 2011 or later cars are likely to comprise the entire fleet, cumulative fuel consumption (from 2010) reaches 4.43 trillion gallons under the No Action Alternative. Cumulative consumption falls across the alternatives, from 4.03 trillion gallons under the Optimized Alternative (Alternative 3) to 3.47 trillion gallons under the Technology Exhaustion Alternative (Alternative 7).

Table 4.2-2 shows the cumulative fuel consumption of light trucks/sport utility vehicles (SUVs) under the CAFE alternatives examined. Cumulative fuel consumption by 2060 reaches 5.31 trillion gallons under the No Action Alternative. Cumulative consumption declines across the alternatives, from 4.73 trillion gallons under the Optimized Alternative to 3.93 trillion gallons under the Technology Exhaustion Alternative, which represent a cumulative savings of 1.38 trillion gallons relative to the No Action Alternative.

4.2.3 Input Scenarios

In response to public comments, and to test how different economic assumptions might affect estimates of fuel consumption, NHTSA ran a scenario using high cost assumptions and compared the results to the Reference Case. Tables 4.2-3 and 4.2-4 list the results for the High Scenario. The High Scenario assumes higher fuel prices than are assumed in the Reference Case, which results in lower fuel consumption across all of the CAFE alternatives examined. This is true even for the No Action Alternative, because higher fuel prices in the High Scenario would reduce fuel consumption (relative to the Reference Case) even in the absence of any change in CAFE standards.

Table 4.2-3 shows the cumulative fuel consumption of passenger cars under the No Action Alternative and the six action alternative CAFE standards in the High Scenario. By 2060, when MY 2011 or later cars are likely to comprise the entire fleet, cumulative fuel consumption (from 2010) reaches 3.97 trillion gallons under the No Action Alternative. Cumulative consumption declines across the alternatives, from 3.32 trillion gallons under the Optimized Alternative to 3.12 trillion gallons under the Technology Exhaustion Alternative, which represents cumulative savings of 851.1 billion gallons relative to the No Action Alternative.

Table 4.2-4 shows the cumulative fuel consumption of light trucks/SUVs under the various CAFE alternatives in the High Scenario. Cumulative fuel consumption by 2060 reaches 4.76 trillion gallons under the No Action Alternative. Cumulative consumption falls across the alternatives, from 3.87 trillion gallons under the Optimized Alternative to 3.54 trillion gallons under the Technology Exhaustion Alternative, which represents cumulative savings of 1.22 trillion gallons relative to the No Action Alternative.

To further assess how different economic assumptions might affect estimates of fuel consumption, NHTSA ran two additional scenarios in the Volpe model: the Mid-1 Scenario and the Mid-2 Scenario. As the names of the scenarios suggest, results from the two additional scenarios fall between those of the Reference Case and the High Scenario. For a summary of Mid-1 and Mid-2 scenario results, *see* tables in Appendix B.

Table 4.2-1

Reference Case Passenger Car Cumulative Annual Fuel Consumption and Cumulative Fuel Savings (billion gallons)

Calendar Year Range	Alternative CAFE Standards for MY 2011-2020						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Cumulative Fuel Consumption							
2010-2020	697.6	688.3	688.0	687.7	687.3	686.5	653.0
2010-2030	1,437.7	1,372.3	1,370.3	1,369.1	1,366.5	1,364.1	1,239.9
2010-2040	2,292.6	2,136.1	2,131.3	2,129.0	2,122.9	2,119.0	1,880.2
2010-2050	3,282.8	3,017.5	3,009.6	3,005.9	2,995.6	2,989.9	2,618.3
2010-2060	4,427.9	4,036.9	4,025.2	4,020.0	4,004.9	3,997.1	3,471.9
Cumulative Fuel Savings Compared the No Action Alternative							
2010-2020	--	9.3	9.6	9.9	10.3	11.1	44.6
2010-2030	--	65.4	67.4	68.6	71.2	73.6	197.8
2010-2040	--	156.5	161.3	163.6	169.7	173.7	412.4
2010-2050	--	265.2	273.2	276.8	287.1	292.9	664.5
2010-2060	--	391.0	402.7	407.9	423.0	430.9	956.0

Table 4.2-2

Reference Case Light Truck Cumulative Annual Fuel Consumption and Cumulative Fuel Savings (billion gallons)

Calendar Year Range	Alternative CAFE Standards for MY 2011-2020						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Cumulative Fuel Consumption							
2010-2020	903.7	894.9	893.8	891.8	890.4	888.0	858.0
2010-2030	1,791.9	1,711.4	1,705.7	1,694.0	1,685.5	1,674.4	1,546.5
2010-2040	2,800.0	2,595.3	2,582.7	2,555.4	2,535.7	2,511.4	2,245.6
2010-2050	3,962.4	3,602.6	3,581.5	3,535.1	3,501.5	3,461.2	3,029.6
2010-2060	5,305.3	4,763.2	4,732.3	4,663.5	4,613.7	4,554.6	3,929.6
Cumulative Fuel Savings Compared to the No Action Alternative							
2010-2020	--	8.7	9.8	11.9	13.2	15.6	45.7
2010-2030	--	80.6	86.2	98.0	106.5	117.6	245.4
2010-2040	--	204.7	217.3	244.5	264.3	288.6	554.3
2010-2050	--	359.8	380.9	427.3	460.9	501.2	932.8
2010-2060	--	542.1	573.0	641.8	691.7	750.8	1,375.7

Table 4.2-3

High Scenario Passenger Car Cumulative Fuel Consumption and Cumulative Fuel Savings (billion gallons)

Calendar Year Range	Alternative CAFE Standards for MY 2011-2020						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Cumulative Fuel Consumption							
2010-2020	652.7	636.7	633.7	630.4	627.9	624.8	611.5
2010-2030	1,322.1	1,219.6	1,205.4	1,193.1	1,183.2	1,169.3	1,142.4
2010-2040	2,088.5	1,850.8	1,820.5	1,796.1	1,776.1	1,746.7	1,716.4
2010-2050	2,966.7	2,570.0	2,521.0	2,482.6	2,450.8	2,403.4	2,371.1
2010-2060	3,970.2	3,391.6	3,321.2	3,266.8	3,221.7	3,153.7	3,119.1
Cumulative Fuel Savings Compared to the No Action Alternative							
2010-2020	--	16.0	19.1	22.3	24.8	27.9	41.2
2010-2030	--	102.5	116.7	129.0	138.9	152.8	179.7
2010-2040	--	237.7	268.0	292.4	312.4	341.8	372.1
2010-2050	--	396.8	445.8	484.2	515.9	563.3	595.6
2010-2060	--	578.6	649.0	703.4	748.5	816.5	851.1

Table 4.2-4

High Scenario Light Truck Cumulative Fuel Consumption and Cumulative Fuel Savings (billion gallons)

Calendar Year Range	Alternative CAFE Standards for MY 2011-2020						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Cumulative Fuel Consumption							
2010-2020	845.9	828.1	825.1	822.2	819.9	818.2	803.9
2010-2030	1,649.4	1,518.7	1,504.1	1,490.4	1,476.9	1,474.5	1,426.6
2010-2040	2,553.1	2,236.1	2,204.0	2,174.3	2,143.3	2,141.7	2,053.5
2010-2050	3,584.1	3,038.3	2,985.0	2,936.0	2,883.8	2,883.7	2,748.8
2010-2060	4,760.9	3,949.8	3,872.1	3,800.8	3,723.9	3,725.6	3,537.4
Cumulative Fuel Savings Compared to the No Action Alternative							
2010-2020	--	17.9	20.8	23.7	26.1	27.7	42.1
2010-2030	--	130.7	145.3	159.0	172.5	174.9	222.7
2010-2040	--	317.0	349.1	378.8	409.8	411.4	499.6
2010-2050	--	545.8	599.1	648.1	700.3	700.4	835.3
2010-2060	--	811.1	888.8	960.1	1,037.0	1,035.3	1,223.4

4.3 AIR QUALITY

4.3.1 Affected Environment

Section 3.3.1 describes the air quality affected environment.

4.3.2 Methodology

4.3.2.1 Overview

The analysis methodology for air quality cumulative impacts and consequent health outcomes is the same as described in Section 3.3.2, except that NHTSA added the potential CAFE standards for MY 2016-2020 because the EISA requires that passenger cars and light trucks achieve an average of at least 35 miles per gallon (mpg) by 2020. The MY 2016-2020 standards are thus a reasonably foreseeable future action that must be considered.

NHTSA analyzed the cumulative air quality impacts of the action alternatives by calculating the emissions from passenger cars and light trucks that would occur under each alternative and including the potential CAFE standards for MY 2016-2020, and assessing the changes in emissions in relation to the No Action Alternative. Many of the factors that affect air quality at any given location, such as meteorology and atmospheric processes, cannot be accounted for when evaluating human health and environmental impacts because this analysis cannot be done without a full-scale photochemical air quality modeling analysis. Full-scale photochemical air quality modeling was not conducted for this cumulative analysis; therefore, the ambient air quality impacts associated with each alternative cannot be analyzed for this FEIS. Full-scale photochemical air quality modeling is necessary to accurately project levels of particulate matter 2.5 microns in diameter or less ($PM_{2.5}$), ozone, and air toxics. A national-scale air quality modeling analysis would analyze the combined impacts of each alternative on $PM_{2.5}$, ozone, and MSATs. The atmospheric chemistry related to ambient concentrations of $PM_{2.5}$, ozone, and air toxics is very complex, and making predictions based solely on emissions changes is extremely difficult. The analysis of the alternatives is predicated on the common sense proposition that assessing emissions is a valid approach to assessing air quality impacts because emissions, ambient concentrations, and health effects are connected. Lower emissions should result in lower ambient concentrations of pollutants on an overall average basis, which should lead to decreased health effects of those pollutants.

The cumulative impacts analysis consists of three components analyzed together:

- CAFE implementation through MY 2010
- The MY 2011-2015 CAFE standard rules
- Assumed MY 2016-2020 rules based on EISA requirements for at least 35 mpg by 2020

For comparison, the non-cumulative impacts analysis (Section 3.3.2) consists of only two components:

- CAFE implementation through MY 2010
- The MY 2011-2015 CAFE standard rules

Because EISA directs NHTSA to increase CAFE standards to reach a combined fleet average CAFE level of at least 35 mpg by model year 2020, MY 2016-2020 CAFE standards are reasonably foreseeable and must be accounted for when analyzing the cumulative impacts of the MY 2011-2015 CAFE standards. For each alternative, NHTSA assumed that passenger-car and light-truck CAFE standards would continue to increase over MY 2016-2020 at their average annual rate of increase over

MY 2011-2015. This assumption results in passenger-car and light-truck CAFE standards under each action alternative that meet or exceed the EISA requirement of a combined fleet average of at least 35 mpg by model year 2020. NHTSA assumed further that the fuel economy standards for model year 2020 would remain in effect through the end of the analysis period. Because the CAFE standards apply to new vehicles, this assumption results in emissions reductions and fuel savings that continue to grow as new vehicles meeting the CAFE standards for MY 2020 and beyond are added to the fleet in each subsequent year, reaching their maximum values when all passenger cars and light trucks in the U.S. fleet meet these standards. For calendar years 2016-2020, the non-cumulative impacts analysis (Section 3.3.2) assumes that MY 2016-2020 and later passenger cars and light trucks would continue to meet the MY 2015 standards. By contrast, the cumulative impacts analysis assumes that MY 2016-2020 passenger cars and light trucks would meet the potential MY 2016-2020 standards and that MY 2021 and later passenger cars and light trucks would meet the potential MY 2020 standard.

The results presented in Section 4.3.3, Environmental Consequences, are for the Reference Case inputs as shown in Table 2.2-1 (*see* Section 2.2). Section 4.3.4, Input Scenarios, discusses the alternatives with three other input scenarios – High, Mid-1, and Mid-2.

4.3.2.2 Treatment of Incomplete or Unavailable Information

As noted in Section 3.3.2, the estimates of emissions rely on models and forecasts that contain numerous assumptions and data that are uncertain. Examples of areas in which information is incomplete or unavailable include future emission rates, vehicle manufacturers' decisions on vehicle technology and design, the mix of vehicle types and model years, emissions from fuel refining and distribution, and economic factors. Where information in the analysis included in the FEIS is incomplete or unavailable, the agency has relied on CEQ regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). NHTSA used the best available models and supporting data in preparing this FEIS. The models used have been scientifically reviewed and have been approved by the agencies that sponsored their development. NHTSA believes that the assumptions made in the FEIS regarding uncertain conditions reflect the best available information and are valid and sufficient for this analysis.

4.3.3 Environmental Consequences

4.3.3.1 Results of Emissions Analysis – Reference Case

The Clean Air Act (CAA) has been successful in reducing emissions from on-road mobile sources. As discussed in Section 3.3.1, pollutant emissions from vehicles have been declining since 1970, and the U.S. Environmental Protection Agency (EPA) projects the decline will continue. However, as future trends show, vehicle travel is having increasingly less impact on emissions as a result of stricter EPA standards for vehicle emissions and the chemical composition of fuels, even with additional increases in vehicle miles traveled (VMT) (Smith 2002). This general trend would continue, more or less, with implementation of any alternative CAFE standard. The cumulative impacts analysis shows that some of the alternative CAFE standards would lead to reductions and some would lead to increases in emissions from passenger cars and light trucks, compared to current trends without the alternative CAFE standards. The amounts of the reductions and increases would vary by pollutant, calendar year, and alternative. The more restrictive alternatives generally would result in greater emission reductions compared to the No Action Alternative. This trend is shown in the analysis of the MY 2011-2015 CAFE standards in Section 3.3.3.

This section analyzes the cumulative impacts of the standards and the assumed MY 2016-2020 standards. The analysis shows that the CAFE standards would lead to further reductions in emissions from passenger cars and light trucks, although the amount of the reductions would vary by the alternative

CAFE standards. Some exceptions, however, are: carbon monoxide (CO) emissions would increase with Alternative 2 (25 Percent Below Optimized), Alternative 3 (Optimized), and (in 2025 and 2035) Alternative 4 (25 Percent Above Optimized). VOC emissions would increase with Alternatives 2 and 3 in 2015. The more restrictive alternatives would result in greater emission reductions compared to Alternative 1 (No Action).

4.3.3.2 Alternative 1: No Action

4.3.3.2.1 Criteria Pollutants

With the No Action Alternative, the CAFE standards would remain at the MY 2010 level in future years. Emissions for this alternative would follow the same trends as shown in the environmental consequences analysis (*see* Section 3.3.3.2). Nationwide emissions changes would be uneven with respect to pollutant and alternative, reflecting projected changes in VMT, emission factors, and diesel share of the vehicle fleet. Cumulative emissions would be less than non-cumulative emissions for the same combination of pollutant, year, and alternative, with the exception of CO.

Table 4.3-1 summarizes the total national cumulative emissions from passenger cars and light trucks for Alternative 1 (No Action) for each criteria pollutant and analysis year. Alternatives 2 through 7 are presented from left to right in the table in order of increasing fuel economy requirements. Alternative 1 would generally have the highest emissions for all criteria pollutants. Emissions of CO under Alternatives 2 and 3 are exceptions, showing increases compared to the No Action Alternative. Appendix B-1 presents the cumulative emissions of criteria pollutants for each nonattainment area.

Table 4.3-1

Reference Case Alternative CAFE Standards
Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

Pollutant and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
CO							
2015	20,241,797	20,253,445	20,257,987	20,228,139	20,224,744	20,189,464	19,529,680
2020	18,133,965	18,186,406	18,206,784	18,075,188	18,060,051	17,968,700	15,338,352
2025	18,103,174	18,247,050	18,288,999	18,023,431	17,994,420	17,842,582	12,918,978
2035	19,745,847	20,068,580	20,145,455	19,664,457	19,615,715	19,406,046	11,524,825
NO_x							
2015	2,305,222	2,303,582	2,303,373	2,303,034	2,302,869	2,301,994	2,287,081
2020	1,670,131	1,659,367	1,658,963	1,656,253	1,655,168	1,651,757	1,587,272
2025	1,426,220	1,403,976	1,403,684	1,396,298	1,394,058	1,387,882	1,248,660
2035	1,369,135	1,335,125	1,335,545	1,318,678	1,314,728	1,305,570	1,048,518
$PM_{2.5}$							
2015	80,400	80,254	80,242	80,153	80,124	80,062	78,981
2020	82,456	81,374	81,331	81,026	80,910	80,859	78,190
2025	87,471	85,076	84,999	84,469	84,265	84,228	80,710
2035	99,707	95,588	95,468	94,650	94,333	94,305	89,788
SO_x							
2015	208,833	207,880	207,784	207,448	207,302	206,804	196,728
2020	217,490	210,826	210,470	209,405	208,750	207,666	182,940
2025	232,179	217,440	216,796	214,942	213,736	212,094	175,787
2035	265,792	240,446	239,437	236,567	234,662	232,370	183,541

Table 4.3-1 (cont'd)

Reference Case Alternative CAFE Standards
Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

Pollutant and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
VOCs							
2015	2,261,550	2,259,712	2,259,680	2,257,453	2,256,856	2,253,598	2,185,838
2020	1,896,683	1,882,585	1,882,513	1,875,117	1,872,667	1,864,598	1,666,245
2025	1,817,495	1,787,653	1,787,778	1,773,541	1,769,015	1,755,492	1,407,415
2035	1,906,119	1,861,129	1,862,621	1,832,904	1,825,138	1,803,935	1,196,950

Table 4.3-2 lists the net changes in nationwide cumulative emissions from passenger cars and light trucks for the No Action Alternative for each criteria pollutant and analysis year. Alternatives 2 through 7 are presented in the table from left to right in order of increasing fuel economy requirements. The reductions in nationwide cumulative emissions generally increase from left to right, except as noted above for CO emissions. This reflects the increasing fuel economy requirements that are assumed under successive alternatives.

Table 4.3-2

Reference Case Alternative CAFE Standards
Nationwide Criteria Pollutant Emission Changes from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards a/

Pollutant and Year	Alt. 1 No Action b/	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
CO							
2015	0	11,649	16,190	-13,658	-17,053	-52,332	-712,117
2020	0	52,441	72,819	-58,778	-73,914	-165,265	-2,795,614
2025	0	143,876	185,825	-79,743	-108,754	-260,592	-5,184,196
2035	0	322,733	399,608	-81,390	-130,132	-339,801	-8,221,022
NO_x							
2015	0	-1,640	-1,849	-2,188	-2,353	-3,228	-18,141
2020	0	-10,764	-11,168	-13,878	-14,963	-18,374	-82,859
2025	0	-22,244	-22,536	-29,922	-32,162	-38,338	-177,560
2035	0	-34,010	-33,590	-50,457	-54,407	-63,566	-320,618
$PM_{2.5}$							
2015	0	-147	-158	-247	-276	-338	-1,419
2020	0	-1,083	-1,126	-1,431	-1,546	-1,597	-4,266
2025	0	-2,395	-2,472	-3,002	-3,206	-3,243	-6,761
2035	0	-4,119	-4,239	-5,057	-5,374	-5,402	-9,919
SO_x							
2015	0	-952	-1,049	-1,385	-1,530	-2,029	-12,105
2020	0	-6,664	-7,020	-8,085	-8,740	-9,824	-34,550
2025	0	-14,740	-15,383	-17,237	-18,443	-20,085	-56,393
2035	0	-25,346	-26,356	-29,225	-31,131	-33,422	-82,252
VOCs							
2015	0	-1,838	-1,870	-4,097	-4,694	-7,952	-75,712
2020	0	-14,098	-14,170	-21,566	-24,016	-32,085	-230,438
2025	0	-29,842	-29,717	-43,954	-48,480	-62,003	-410,080
2035	0	-44,990	-43,498	-73,215	-80,981	-102,184	-709,169

a/ Negative emissions changes indicate reductions; positive emissions changes are increases.
b/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

4.3.3.2.2 Air Toxics

As with the criteria pollutants, current trends in the levels of air toxics emissions from vehicles would continue, with emissions of most air toxics continuing to decline, despite a growth in total VMT, as a result of the EPA emission standards. Exceptions to this trend are emissions of benzene and formaldehyde, which increase in 2035 over 2025 levels with the No Action Alternative. Further, with current trends, emissions of diesel particulate matter (DPM) increase in every analysis year with the No Action Alternative. Alternative 1 (No Action) would result in no other increase or decrease in toxic air pollutant emissions in nonattainment and maintenance areas throughout the United States.

Table 4.3-3 summarizes the cumulative national toxic air pollutant emissions from passenger cars and light trucks for Alternative 1 (No Action) for each toxic air pollutant and analysis year. Alternatives 2 through 7 are presented in order of increasing fuel economy requirements from left to right. Unlike criteria pollutants, emissions of many toxic air pollutants would increase in several alternatives. The changes in air toxic emissions, whether positive or negative, would generally be small relative to Alternative 1 emissions levels. An exception is Alternative 7, which would result in changes in emissions of some toxic air pollutants that would be large relative to Alternative 1 emissions levels.

Changes in cumulative emissions for toxic air pollutants reflect decreases with reductions in upstream emissions, and increases due to the rebound effect and changes in the proportion of diesel vehicles. Cumulative emissions of acetaldehyde would increase under Alternatives 4 and 5 for all analysis years, and under Alternatives 2, 3, 6, and 7 for some analysis years. Cumulative emissions of acrolein would increase with all the action alternatives because data on upstream emissions reductions were not available. Cumulative emissions of benzene would decrease under all the action alternatives compared to the No Action Alternative. Cumulative emissions of 1,3-butadiene would generally decrease slightly from Alternative 1 under successive alternatives. Cumulative emissions of DPM would decline under all alternatives relative to the No Action Alternative. Cumulative emissions of formaldehyde would decrease with Alternatives 2 and 3 but increase with Alternative 7; changes in formaldehyde emissions under Alternatives 4, 5, and 6 vary depending on analysis year.

Cumulative emissions would generally be less than non-cumulative emissions for the same combination of pollutant, year, and alternative, for acetaldehyde (except in 2035 and with Alternative 7 in all years), benzene (except Alternative 7 in 2035), DPM, and formaldehyde (except Alternative 7). Cumulative emissions would generally be greater than non-cumulative emissions for the same combination of pollutant, year, and alternative, for acrolein and 1,3-butadiene (in 2020-2035). Appendix B-1 presents the cumulative emissions of toxic air pollutants for each nonattainment area for the No Action Alternative.

Table 4.3-4 lists the net changes in nationwide cumulative emissions from passenger cars and light trucks compared to Alternative 1 (No Action) for each air toxic and analysis year. Alternatives 2 through 7 are presented from left to right in order of increasing fuel economy requirements. In Table 4.3-4 the nationwide emissions changes are uneven with respect to pollutant and alternative, reflecting the changes in VMT and emissions by cars versus trucks and gasoline versus diesel engines that are projected to occur with the increasing fuel economy requirements assumed under successive alternatives.

Table 4.3-3

Reference Case Alternative CAFE Standards
Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Acetaldehyde							
2015	11,982	11,978	11,976	11,985	11,987	11,991	12,093
2020	9,420	9,408	9,406	9,425	9,428	9,420	9,610
2025	8,401	8,390	8,389	8,402	8,406	8,386	8,468
2035	8,209	8,224	8,229	8,211	8,214	8,183	7,974
Acrolein a/							
2015	569	569	569	571	571	574	626
2020	429	431	430	438	439	444	602
2025	371	376	375	386	389	396	652
2035	351	362	361	377	381	392	758
Benzene							
2015	64,524	64,510	64,514	64,458	64,447	64,374	62,953
2020	51,781	51,645	51,664	51,431	51,385	51,200	46,206
2025	47,378	47,125	47,171	46,690	46,602	46,291	36,932
2035	47,515	47,256	47,364	46,405	46,251	45,791	29,613
1,3-butadiene							
2015	6,134	6,133	6,133	6,133	6,134	6,133	6,141
2020	4,698	4,688	4,687	4,686	4,685	4,680	4,625
2025	4,092	4,071	4,071	4,065	4,064	4,050	3,850
2035	3,885	3,852	3,854	3,839	3,839	3,803	3,331
Diesel particulate matter (DPM)							
2015	94,873	94,356	94,292	94,197	94,130	94,033	92,005
2020	98,292	94,693	94,463	94,189	93,880	93,678	89,049
2025	104,603	96,630	96,218	95,732	95,157	94,850	88,442
2035	119,499	105,773	105,131	104,372	103,457	102,999	94,643
Formaldehyde							
2015	17,382	17,358	17,351	17,388	17,393	17,421	18,018
2020	14,106	13,998	13,977	14,092	14,103	14,129	15,995
2025	12,930	12,719	12,688	12,859	12,876	12,906	15,817
2035	13,035	12,717	12,677	12,899	12,924	12,961	17,034

a/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

Table 4.3-4

Reference Case Alternative CAFE Standards
Nationwide Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards a/

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action b/**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Acetaldehyde							
2015	0	-4	-6	3	5	9	111
2020	0	-12	-15	4	7	-1	189
2025	0	-11	-12	1	4	-16	66
2035	0	15	20	3	5	-26	-235
Acrolein c/							
2015	0	0	0	2	2	5	57
2020	0	2	1	8	10	14	173
2025	0	5	4	15	18	25	281
2035	0	11	10	26	30	40	407
Benzene							
2015	0	-14	-10	-66	-77	-150	-1,570
2020	0	-137	-117	-350	-396	-582	-5,576
2025	0	-253	-207	-688	-776	-1,087	-10,446
2035	0	-259	-151	-1,110	-1,264	-1,724	-17,902
1,3-butadiene							
2015	0	-1	-1	-1	-1	-1	7
2020	0	-10	-11	-12	-13	-18	-73
2025	0	-22	-21	-27	-28	-43	-242
2035	0	-33	-31	-46	-46	-82	-555
Diesel particulate matter (DPM)							
2015	0	-517	-581	-676	-743	-840	-2,868
2020	0	-3,599	-3,828	-4,103	-4,412	-4,613	-9,243
2025	0	-7,973	-8,384	-8,870	-9,446	-9,753	-16,160
2035	0	-13,726	-14,368	-15,127	-16,042	-16,500	-24,857
Formaldehyde							
2015	0	-24	-32	6	11	39	636
2020	0	-108	-129	-14	-2	24	1,890
2025	0	-211	-242	-71	-54	-24	2,887
2035	0	-319	-358	-136	-111	-74	3,999

a/ Negative emissions changes indicate reductions; positive emissions changes are increases.

b/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

c/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

4.3.3.2.3 Health Outcomes and Costs

With Alternative 1 (No Action), the CAFE standards would remain at the MY 2010 level in future years. Emissions of criteria pollutants and air toxics would change as described above. Human health effects of emissions are tied to specific pollutants, and will vary as emissions of these pollutants vary. The No Action Alternative would result in no other increase or decrease in human health effects throughout the United States, compared to current trends.

Table 4.3-5 lists the net changes in health outcomes due to nationwide cumulative emissions in each analysis year. Alternatives 1 through 7 are presented from left to right in order of increasing fuel economy requirements. The health impacts of vehicle emissions decrease for all alternatives compared to the No Action Alternative, and decrease successively in each analysis year.

Table 4.3-5

Reference Case Alternative CAFE Standards
Nationwide Changes in Health Outcomes from Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks (cases/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards a/

Health Outcome and Year	Alt. 1 No Action b/	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Mortality (ages 30 and older)							
2015	0	-11	-12	-19	-21	-26	-109
2020	0	-83	-86	-110	-119	-122	-327
2025	0	-184	-190	-230	-246	-249	-518
2035	0	-316	-325	-388	-412	-414	-760
Chronic bronchitis							
2015	0	-10	-11	-16	-18	-23	-95
2020	0	-72	-75	-95	-103	-106	-284
2025	0	-160	-165	-200	-214	-216	-451
2035	0	-275	-283	-337	-358	-360	-661
Emergency room visits for asthma							
2015	0	-2	-3	-4	-4	-5	-23
2020	0	-17	-18	-23	-25	-26	-68
2025	0	-38	-40	-48	-51	-52	-108
2035	0	-66	-68	-81	-86	-86	-159
Work-loss days							
2015	0	-2,006	-2,162	-3,377	-3,772	-4,619	-19,392
2020	0	-14,796	-15,383	-19,552	-21,126	-21,824	-58,309
2025	0	-32,732	-33,787	-41,024	-43,814	-44,325	-92,403
2035	0	-56,293	-57,939	-69,110	-73,443	-73,833	-135,560

a/ Negative changes indicate reductions; positive emissions changes are increases.
b/ Changes in health outcomes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

The economic value of health impacts would vary proportionately with changes in health outcomes, under the methodology defined in Section 3.3.2.4.2. The economic impacts analyzed here are the result of changes in ambient particulate matter (PM) and ozone concentrations as caused by changes in precursor criteria pollutants NO_x, VOCs, SO_2 and $PM_{2.5}$. Alternative 1 (No Action) would result in no other change in health-related costs throughout the United States, compared to current trends.

Table 4.3-6 lists the nationwide changes in health costs from cumulative emissions from passenger cars and light trucks. Results for each analysis year are shown for the No Action Alternative in the left column, and for other alternatives from left to right in order of increasing fuel economy requirements. As with health outcomes, the economic impacts of each alternative decrease across successive alternatives and years compared to the health costs of emissions under the No Action Alternative.

Table 4.3-6

Reference Case Alternative CAFE Standards
Nationwide Changes in Health Costs from Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks (U.S. million dollars/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards a/

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Year	No Action b/	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
2015	0	-20	-23	-29	-32	-42	-240
2020	0	-192	-201	-241	-260	-302	-1,177
2025	0	-414	-426	-515	-552	-622	-2,228
2035	0	-680	-694	-871	-933	-1,034	-3,703

a/ Negative changes indicate economic benefit; positive emissions changes are economic costs.
b/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

4.3.3.3 Alternative 2: 25 Percent Below Optimized

4.3.3.3.1 Criteria Pollutants

CAFE standards under the 25 Percent Below Optimized Alternative (Alternative 2) would require increased fuel economy compared to the No Action Alternative (Alternative 1). Alternative 2 would increase fuel economy less than would Alternatives 3 through 7. Under Alternative 2, cumulative emissions are generally less than Alternative 1, but greater than all other alternatives. However, Alternative 2 would have greater cumulative emissions of CO than the No Action Alternative.

Emissions in individual nonattainment areas might follow different patterns than nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel. Compared to Alternative 1, cumulative emissions of NO_x, SO_x, and VOCs under Alternative 2 decrease in all nonattainment areas. In contrast, CO emissions increase in almost all nonattainment areas, while PM emissions vary. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

Cumulative fuel economy standards would lead to lower emissions of most pollutants compared to non-cumulative standards, due to the impact of more stringent standards in the cumulative case. In

Alternative 2, cumulative emissions of all pollutants are lower than non-cumulative emissions. However, emissions of CO are higher under the cumulative case than the non-cumulative case.

4.3.3.3.2 Air Toxics

Under Alternative 2, cumulative emissions would generally be less than non-cumulative emissions for the same combinations of pollutant and year.

There would be reductions in cumulative nationwide emissions of all toxic air pollutants (except acrolein and acetaldehyde in 2035) under Alternative 2 compared to the No Action Alternative. Compared to Alternative 3, Alternative 2 would have higher emissions of DPM and formaldehyde but lower emissions of benzene. Compared to Alternatives 4 through 7, Alternative 2 would generally have higher emissions of benzene, 1,3-butadiene, and DPM, but lower emissions of acrolein and formaldehyde, and mixed results for acetaldehyde depending on the year and alternative.

At the nationwide level, the reduction in upstream emissions of toxic air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, as noted above, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Net emission reductions can occur if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect. Under Alternative 2, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix B-2). However, the emission increases would be quite small, as shown in Appendix B-2, and emissions increases would be distributed throughout each nonattainment area.

4.3.3.3.3 Health Outcomes and Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 2 would result in 316 fewer mortalities and 56,293 fewer work-loss days in 2035. Cumulative health benefits would exceed non-cumulative benefits, reducing mortalities by an additional 238 cases and lost-work days by an additional 42,415 cases in 2035. In that same year, Alternative 2 would reduce health costs by $680 million, an additional $507 million over non-cumulative benefits.

4.3.3.4 Alternative 3: Optimized

4.3.3.4.1 Criteria Pollutants

CAFE standards under the Optimized Alternative (Alternative 3) would require increased fuel economy compared to Alternatives 1 and 2, but less than Alternatives 4 through 7. Under Alternative 3, cumulative emissions are generally less than Alternative 1, but greater than all other alternatives. However, Alternative 3 would have greater cumulative emissions of CO than any other alternative. Alternative 3 would also have slightly greater cumulative emissions of NO_x and VOCs than Alternative 2.

Emissions in individual nonattainment areas could follow different patterns than nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel. Compared to Alternative 1, cumulative emissions of NO_x, SO_x, and VOCs under Alternative 3 decrease in almost all nonattainment areas. In contrast, CO emissions increase in almost all nonattainment areas, while PM emissions vary. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

As with previously discussed alternatives, cumulative fuel economy standards would lead to lower emissions of most pollutants compared to non-cumulative standards. In Alternative 3, cumulative emissions of all pollutants are lower than non-cumulative emissions.

4.3.3.4.2 Air Toxics

Under Alternative 3, cumulative emissions would generally be less than non-cumulative emissions for the same combinations of pollutant and year.

Alternative 3 would reduce air toxics emissions compared to the No Action Alternative for all air toxics (except acetaldehyde in 2035, and acrolein). Alternative 3 would have higher emissions of benzene, 1,3-butadiene (2015 and 2020), and DPM compared to Alternatives 4 through 7. Alternative 3 would have lower emissions of acrolein and formaldehyde compared to Alternatives 4 through 7, and mixed results for acetaldehyde depending on the year and alternative.

Nationwide, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 3, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix B-2). However, the emission increases would be quite small, as shown in Appendix B-2, and emission increases would be distributed throughout each nonattainment area.

4.3.3.4.3 Health Outcomes and Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 3 would result in 325 fewer mortalities and 57,939 fewer work-loss days in 2035. Cumulative health benefits would exceed non-cumulative benefits, reducing mortalities by an additional 242 cases and lost-work days by an additional 43,150 cases in 2035. In that same year, Alternative 3 would reduce health costs by $694 million, an additional $515 million over non-cumulative benefits.

4.3.3.5 Alternative 4: 25 Percent Above Optimized

4.3.3.5.1 Criteria Pollutants

CAFE standards under the 25 Percent Above Optimized Alternative (Alternative 4) would require increased fuel economy compared to Alternatives 1 through 3, but less than Alternatives 5 through 7. Under Alternative 4, cumulative emissions would be less than under Alternatives 1, 2, and 3, but greater than all other alternatives.

Emissions in individual nonattainment areas could follow different patterns than nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel. Compared to Alternative 1, cumulative emissions of CO, NO_x, SO_x, VOCs, and PM under Alternative 4 decrease in almost all nonattainment areas. However, PM emissions could increase or decrease depending on nonattainment area. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

As with previously discussed alternatives, cumulative fuel economy standards would lead to lower emissions of most pollutants compared to non-cumulative standards. In Alternative 4, cumulative emissions of all pollutants are lower than non-cumulative emissions.

4.3.3.5.2 Air Toxics

Under Alternative 4, cumulative emissions would generally be less than non-cumulative emissions for the same combinations of pollutant and year.

Alternative 4 would reduce air toxics emissions compared to the No Action Alternative for all air toxics except acetaldehyde, acrolein, and formaldehyde in 2015. Compared to Alternatives 5 through 7, Alternative 4 would have higher emissions of benzene, 1,3-butadiene (except in 2015), and DPM. Alternative 4 would have lower emissions of acrolein and formaldehyde compared to Alternatives 5 through 7, and mixed results for acetaldehyde depending on the year and alternative.

At the nationwide level, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 4, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix B-2). However, the emission increases would be quite small, as shown in Appendix B-2, and emission increases would be distributed throughout each nonattainment area.

4.3.3.5.3 Health Outcomes and Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 4 would result in 388 fewer mortalities and 69,110 fewer work-loss days in 2035. Cumulative health benefits would exceed non-cumulative benefits, reducing mortalities by an additional 262 cases and lost-work days by an additional 46,654 cases in 2035. In that same year, Alternative 4 would reduce health costs by $871 million, an additional $564 million over non-cumulative benefits.

4.3.3.6 Alternative 5: 50 Percent Above Optimized

4.3.3.6.1 Criteria Pollutants

CAFE standards under the 50 Percent Above Optimized Alternative (Alternative 5) would require increased fuel economy compared to Alternatives 1 through 4, but less than Alternatives 6 and 7. Under Alternative 5, cumulative emissions would be less than Alternatives 1 through 4, but greater than all other alternatives.

Emissions in individual nonattainment areas could follow different patterns than nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel. Compared to Alternative 1, cumulative emissions of CO, NO_x, SO_x, and VOCs under Alternative 5 decrease in all nonattainment areas. PM emissions increase or decrease depending on nonattainment area. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

As with previously discussed alternatives, cumulative fuel economy standards would lead to lower emissions of most pollutants compared to non-cumulative standards. In Alternative 5, cumulative emissions of all pollutants are lower than non-cumulative emissions.

4.3.3.6.2 Air Toxics

Under Alternative 5, cumulative emissions would generally be less than non-cumulative emissions for the same combinations of pollutant and year, with the exception of acrolein, butadiene, and acetaldehyde in 2035.

Alternative 5 would reduce air toxics emissions of benzene, 1,3-butadiene, formaldehyde (except in 2015), and DPM compared to the No Action Alternative, but would increase emissions of acetaldehyde and acrolein compared to the No Action Alternative. Alternative 5 would have higher emissions of benzene, 1,3-butadiene (except for Alternative 7 in 2015), and DPM compared to Alternatives 6 and 7. Alternative 5 would have lower emissions of acrolein and formaldehyde compared to Alternatives 6 and 7, and mixed results for acetaldehyde depending on year and alternative.

At the nationwide level, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 5, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix B-2). However, the emission increases would be quite small, as shown in Appendix B-2, and emission increases would be distributed throughout each nonattainment area.

4.3.3.6.3 Health Outcomes and Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 5 would result in 412 fewer mortalities and 73,443 fewer work-loss days in 2035. Cumulative health benefits would exceed non-cumulative benefits, reducing mortalities by an additional 270 cases and lost-work days by an additional 48,104 cases in 2035. In that same year, Alternative 5 would reduce health costs by $993 million, an additional $584 million over non-cumulative benefits.

4.3.3.7 Alternative 6: Total Costs Equal Total Benefits

4.3.3.7.1 Criteria Pollutants

CAFE standards under the Total Costs Equal Total Benefits Alternative (Alternative 6) would require increased fuel economy compared to Alternatives 1 through 5, but less than Alternative 7. Under Alternative 6, cumulative emissions would be less than Alternatives 1 through 5, but greater than Alternative 7.

Emissions in individual nonattainment areas could follow different patterns than nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel. Compared to Alternative 1, cumulative emissions of CO, NO_x, SO_x, and VOCs under Alternative 6 decrease in all nonattainment areas. PM emissions increase or decrease depending on nonattainment area. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

As with previously discussed alternatives, cumulative fuel economy standards would lead to lower emissions of most pollutants compared to non-cumulative standards. In Alternative 6, cumulative emissions of all pollutants are lower than non-cumulative emissions.

4.3.3.7.2 Air Toxics

Under Alternative 6, cumulative emissions would generally be less than non-cumulative emissions for the same combinations of pollutant and year, with the exception of acrolein, 1,3-butadiene, and acetaldehyde in 2035.

Alternative 6 would reduce air toxics emissions of acetaldehyde (in 2025-2035), benzene, 1,3-butadiene, and DPM compared to the No Action Alternative, but would increase emissions of acetaldehyde (in 2015), acrolein, and formaldehyde compared to the No Action Alternative. Alternative 6 would have higher emissions of acetaldehyde (in 2035), benzene, 1,3-butadiene (except in 2015), and DPM compared to Alternative 7. Alternative 6 would have lower emissions of acetaldehyde (in 2015-2025), acrolein, 1,3-butadiene (in 2015), and formaldehyde compared to Alternative 7.

At the nationwide level, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 6, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix B-2). However, the emission increases would be quite small, as shown in Appendix B-2, and emission increases would be distributed throughout each nonattainment area.

4.3.3.7.3 Health Outcomes and Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 6 would result in 414 fewer mortalities and 73,833 fewer work-loss days in 2035. Cumulative health benefits would exceed non-cumulative benefits, reducing mortalities by an additional 272 cases and lost-work days by an additional 48,600 cases in 2035. In that same year, Alternative 6 would reduce health costs by $1.034 billion, an additional $599 million over non-cumulative benefits.

4.3.3.8 Alternative 7: Technology Exhaustion

4.3.3.8.1 Criteria Pollutants

Of all the alternatives analyzed, the Technology Exhaustion Alternative (Alternative 7) would increase fuel economy the most. In this alternative, the cumulative fuel economy standard has more impact than in any other alternative. Cumulative standards would lead to greater reductions in emissions of all criteria pollutants. The greatest impact would be on SO_x emissions, which in 2035 would be reduced by an additional 12.4 percent to a 25.8 percent reduction in cumulative emissions below No Action Alternative levels, compared to a 13.4 percent reduction in non-cumulative emissions below No Action Alternative levels. Also in 2035, NO_x, PM, and VOC emissions would be reduced by an additional 4.9 percent, 4.3 percent, and 5.6 percent, respectively, in cumulative emissions compared to the non-cumulative emissions reductions. Alternative 7 is the only alternative in which CO emissions would decrease under cumulative standards, by an additional 3.7 percent.

Emissions in individual nonattainment areas might follow different patterns than nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel. Compared to Alternative 1, cumulative emissions of CO, NO_x, SO_x, and VOCs under Alternative 6 decrease in all nonattainment areas. PM emissions increase or decrease depending on nonattainment area. Tables in Appendix B-2 list the emissions reductions for each nonattainment area.

As with previously discussed alternatives, cumulative fuel economy standards would lead to lower emissions of most pollutants compared to non-cumulative standards. Unlike the prior alternatives, most (but not all) cumulative emissions in Alternative 7 are less than non-cumulative emissions. The exceptions are CO and VOCs, which are slightly higher for the cumulative standards in 2035.

4.3.3.8.2 Air Toxics

Under Alternative 7, cumulative emissions would generally be greater than non-cumulative emissions for the same combinations of pollutant and year, with the exception of benzene in 2020 and 2025 and DPM in all analysis years.

Alternative 7 would reduce air toxics emissions of acetaldehyde (in 2035 only), benzene, 1,3-butadiene (2020-2035), and DPM compared to the No Action Alternative, but would increase emissions of acetaldehyde (in 2015-2025), acrolein, and formaldehyde compared to the No Action Alternative.

At the nationwide level, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 7, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (see Appendix B-2). However, the emission increases would be quite small, as shown in Appendix B-2, and emission increases would be distributed throughout each nonattainment area.

4.3.3.8.3 Health Outcomes and Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 7 would result in 760 fewer mortalities and 135,560 fewer work-loss days in 2035. Cumulative health benefits would exceed non-cumulative benefits, reducing mortalities by an additional 100 cases and lost-work days by an additional 17,943 cases in 2035. In that same year, Alternative 7 would reduce health costs by $3.703 billion, an additional $374 million over non-cumulative benefits.

4.3.4 Input Scenarios

4.3.4.1 Results of the Emissions Analysis

The High Scenario analysis in this section shows that the alternatives would lead to further reductions in cumulative emissions from passenger cars and light trucks. The amount of the reductions would vary by alternative. The more restrictive High Scenario alternatives would result in greater cumulative emission reductions compared to the No Action Alternative.

4.3.4.2 Alternative 1: No Action

4.3.4.2.1 Criteria Pollutants

For the High Scenario analysis of the No Action Alternative, the CAFE standards would remain at the MY 2010 level in future years. Current trends in the levels of emissions from vehicles would continue, with emissions continuing to decline due to the EPA emission standards despite a growth in total VMT. Therefore, there would be no cumulative impacts due to future actions.

Table 4.3-7 summarizes the cumulative national criteria pollutant emissions from passenger cars and light trucks for the High Scenario No Action Alternative for each of the criteria pollutants and analysis years. The table presents the other High Scenario alternatives (Alternatives 2 through 7) left to right in order of increasing fuel economy requirements. The No Action Alternative has the highest cumulative emissions of all the High Scenario alternatives for all criteria pollutants. Also, the High Scenario cumulative emissions are lower than the Reference Case cumulative emissions for all criteria pollutants.

Table 4.3-7

High Scenario Alternative CAFE Standards
Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

Pollutant and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
CO							
2015	18,861,709	18,819,939	18,808,141	18,754,373	18,733,183	18,676,707	18,198,144
2020	16,619,854	16,415,502	16,425,986	16,213,912	16,097,921	15,910,952	14,057,662
2025	16,403,499	16,020,001	16,080,959	15,651,538	15,408,409	15,050,866	11,706,038
2035	17,713,991	17,102,067	17,249,166	16,551,203	16,107,699	15,482,276	10,338,916
NO_x							
2015	2,148,052	2,144,324	2,143,260	2,141,447	2,140,565	2,139,441	2,131,148
2020	1,530,682	1,508,585	1,505,911	1,498,908	1,495,495	1,491,055	1,454,741
2025	1,292,315	1,245,534	1,242,387	1,227,626	1,219,549	1,209,840	1,131,426
2035	1,228,251	1,147,887	1,145,748	1,120,053	1,102,988	1,082,932	940,625
$PM_{2.5}$							
2015	74,919	74,510	74,386	74,356	74,275	74,100	73,596
2020	75,571	73,546	73,270	73,293	72,959	72,684	71,661
2025	79,258	75,295	74,870	74,948	74,361	74,025	73,132
2035	89,447	83,017	82,423	82,542	81,642	81,247	80,549
SO_x							
2015	194,594	192,140	191,511	190,550	189,957	189,131	183,315
2020	199,331	186,854	185,311	183,031	181,350	179,659	167,666
2025	210,380	185,622	183,100	179,565	176,762	174,331	159,282
2035	238,442	198,158	194,471	189,553	185,397	182,149	164,654
VOCs							
2015	2,107,357	2,098,520	2,096,656	2,089,966	2,087,196	2,082,243	2,036,807
2020	1,738,318	1,697,234	1,694,410	1,675,994	1,667,362	1,653,626	1,527,120
2025	1,646,853	1,567,100	1,564,214	1,531,051	1,514,867	1,490,440	1,275,275
2035	1,709,979	1,575,147	1,574,616	1,518,089	1,486,823	1,440,609	1,073,784

Table 4.3-8 lists the net change in nationwide cumulative emissions from passenger cars and light trucks for each alternative and analysis year for the High Scenario. The table presents Alternatives 1 through 7 left to right in order of increasing fuel economy requirements. In Table 4.3-8, the nationwide cumulative emissions reductions tend to increase from left to right, reflecting the increasing fuel economy requirements that are assumed for the High Scenario.

Table 4.3-8

High Scenario Alternative CAFE Standards
Nationwide Criteria Pollutant Emission Changes from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards a/

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	No Action b/	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
CO							
2015	0	-41,769	-53,567	-107,336	-128,526	-185,002	-663,565
2020	0	-204,352	-193,867	-405,942	-521,932	-708,902	-2,562,191
2025	0	-383,498	-322,540	-751,962	-995,090	-1,352,633	-4,697,461
2035	0	-611,923	-464,825	-1,162,788	-1,606,291	-2,231,714	-7,375,075
NO_x							
2015	0	-3,727	-4,792	-6,605	-7,487	-8,610	-16,904
2020	0	-22,097	-24,771	-31,774	-35,187	-39,627	-75,941
2025	0	-46,781	-49,927	-64,688	-72,766	-82,475	-160,889
2035	0	-80,363	-82,503	-108,198	-125,262	-145,319	-287,626
$PM_{2.5}$							
2015	0	-408	-532	-562	-643	-819	-1,322
2020	0	-2,026	-2,302	-2,278	-2,612	-2,888	-3,910
2025	0	-3,964	-4,389	-4,311	-4,898	-5,234	-6,126
2035	0	-6,430	-7,024	-6,905	-7,805	-8,200	-8,898
SO_x							
2015	0	-2,455	-3,084	-4,045	-4,637	-5,463	-11,280
2020	0	-12,477	-14,020	-16,300	-17,980	-19,671	-31,665
2025	0	-24,758	-27,281	-30,816	-33,619	-36,050	-51,098
2035	0	-40,284	-43,971	-48,889	-53,046	-56,294	-73,788
VOCs							
2015	0	-8,838	-10,701	-17,391	-20,161	-25,115	-70,550
2020	0	-41,083	-43,908	-62,324	-70,955	-84,691	-211,198
2025	0	-79,753	-82,639	-115,802	-131,986	-156,414	-371,578
2035	0	-134,832	-135,363	-191,890	-223,156	-269,370	-636,195

a/ Negative emissions changes indicate reductions; positive emissions changes are increases.
b/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

4.3.4.2.2 Air Toxics

With the No Action Alternative, the CAFE standards would remain at the MY 2010 level in future years. As with the criteria pollutants, the High Scenario analysis indicates that current trends in the levels of air toxics emissions from vehicles would continue, with emissions continuing to decline due to the EPA emission standards despite a growth in total VMT. Exceptions to this trend are emissions of benzene and formaldehyde, which increase in 2035 over 2025 levels with the No Action Alternative. Further, with current trends, emissions of diesel particulate matter (DPM) increase in every analysis year with the No Action Alternative. The High Scenario analysis of Alternative 1 (No Action) would result in no other increase or decrease in cumulative toxic air pollutant emissions in nonattainment and maintenance areas throughout the United States.

Table 4.3-9 summarizes the High Scenario total national cumulative emissions of air toxics from passenger cars and light trucks with the No Action Alternative for each pollutant and analysis year.

Unlike with the criteria pollutants, the No Action Alternative does not have the highest cumulative emissions of all the alternatives for all toxic air pollutants. Table 4.3-9 shows increases for acrolein with Alternatives 2 through 7 because data on upstream emissions reductions were not available. The cumulative emissions for acrolein in Table 4.3-9 reflect only the increases due to the rebound effect and technology changes that manufacturers would introduce in response to CAFE standards. Because the upstream emissions reductions result from the decline in the amount of fuel processed, it is reasonable that upstream acrolein emissions should decrease as the upstream emissions for other pollutants do. Thus, the cumulative acrolein emissions given in Table 4.3.9 are an upper bound estimate.

Table 4.3-9

High Scenario Alternative CAFE Standards
Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

Pollutant and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Acetaldehyde							
2015	11,165	11,174	11,177	11,176	11,180	11,194	11,268
2020	8,634	8,649	8,648	8,631	8,648	8,666	8,808
2025	7,613	7,619	7,623	7,576	7,593	7,603	7,673
2035	7,364	7,351	7,372	7,282	7,278	7,255	7,153
Acrolein a/							
2015	530	535	536	540	542	546	583
2020	393	413	414	425	433	444	552
2025	336	373	372	393	406	424	591
2035	315	374	374	406	424	450	680
Benzene							
2015	60,125	59,974	59,937	59,809	59,755	59,640	58,661
2020	47,458	46,725	46,690	46,274	46,045	45,686	42,348
2025	42,930	41,487	41,498	40,686	40,211	39,533	33,465
2035	42,626	40,169	40,301	38,917	37,990	36,721	26,566
1,3-butadiene							
2015	6,134	6,134	6,133	6,133	6,134	6,134	6,141
2020	4,698	4,689	4,687	4,683	4,679	4,672	4,625
2025	4,092	4,067	4,069	4,053	4,037	4,016	3,850
2035	3,885	3,833	3,846	3,810	3,766	3,713	3,331
Diesel particulate matter (DPM)							
2015	88,405	87,306	86,998	86,858	86,658	86,379	85,732
2020	90,085	84,216	83,324	83,159	82,584	82,197	81,614
2025	94,782	82,884	81,373	81,199	80,232	79,801	80,139
2035	107,203	87,624	85,380	85,166	83,729	83,295	84,904
Formaldehyde							
2015	16,197	16,228	16,236	16,264	16,282	16,345	16,789
2020	12,928	12,999	12,980	13,047	13,146	13,291	14,660
2025	11,716	11,792	11,753	11,866	12,031	12,252	14,332
2035	11,694	11,783	11,730	11,897	12,127	12,433	15,281

a/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

High Scenario cumulative emissions of formaldehyde are lowest under the No Action Alternative. In contrast, cumulative emissions of benzene, DPM, and 1,3-butadiene are highest in the No Action Alternative, and are generally higher for the less restrictive alternatives than the more restrictive alternatives. An exception is 1,3-butadiene in 2015 under Alternative 7. Cumulative emissions of acetaldehyde are highest for Alternative 7 except in 2035.

Table 4.3-10 lists the net change in High Scenario cumulative nationwide emissions from passenger cars and light trucks in relation to the No Action Alternative for each air toxic pollutant and analysis year. The High Scenario results for Alternatives 2 through 7 are presented from left to right in order of increasing fuel economy requirements. In Table 4.3-10, the nationwide emissions reductions or increases tend to become greater from left to right, reflecting the increasing fuel economy requirements that are assumed under successive alternatives, except for the cases noted above.

Table 4.3-10

High Scenario Alternative CAFE Standards
Nationwide Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards a/

Pollutant and Year	Alt. 1 No Action b/	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Acetaldehyde							
2015	0	9	11	11	15	29	103
2020	0	16	15	-3	14	33	174
2025	0	6	11	-37	-20	-10	60
2035	0	-13	8	-82	-86	-109	-211
Acrolein c/							
2015	0	5	6	10	12	16	53
2020	0	20	20	32	39	50	158
2025	0	37	36	57	70	88	255
2035	0	59	58	90	109	135	365
Benzene							
2015	0	-150	-187	-316	-369	-485	-1,463
2020	0	-733	-767	-1,184	-1,413	-1,771	-5,110
2025	0	-1,443	-1,432	-2,244	-2,719	-3,397	-9,465
2035	0	-2,456	-2,324	-3,709	-4,636	-5,905	-16,060
1,3-butadiene							
2015	0	0	-1	-1	0	-1	7
2020	0	-10	-11	-16	-19	-26	-73
2025	0	-26	-24	-40	-55	-76	-242
2035	0	-52	-39	-75	-120	-172	-555
Diesel particulate matter (DPM)							
2015	0	-1,099	-1,407	-1,547	-1,747	-2,025	-2,673
2020	0	-5,868	-6,761	-6,926	-7,500	-7,888	-8,471
2025	0	-11,898	-13,408	-13,583	-14,550	-14,981	-14,643
2035	0	-19,579	-21,823	-22,036	-23,474	-23,908	-22,299
Formaldehyde							
2015	0	31	39	66	85	148	592
2020	0	72	52	119	218	363	1,732
2025	0	76	37	150	315	536	2,616
2035	0	89	36	203	433	739	3,587

a/ Negative emissions changes indicate reductions; positive emissions changes are increases.
b/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.
c/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

4.3.4.2.3 Health Outcomes and Costs

With the No Action Alternative (Alternative 1), the CAFE standards would remain at the MY 2010 level in future years. Current trends in the levels of criteria pollutants and air toxics emissions from vehicles would continue, with emissions continuing to decline due to the EPA emission standards despite an increase in total VMT. The human health effects and health-related costs that occur under current trends would continue, and are expected to decline in the future as a result of declines in pollutant emissions. The No Action Alternative under the High Scenario would result in no other increase or decrease in human health effects and health-related costs.

Table 4.3-11 list the net changes in health outcomes due to High Scenario analysis of cumulative emissions in each analysis year. Alternatives 1 through 7 are presented from left to right in order of increasing fuel economy requirements. The health impacts of vehicle emissions decrease for nearly all alternatives compared to the No Action Alternative and decrease successively in each analysis year.

Table 4.3-11

High Scenario Alternative CAFE Standards
Nationwide Changes in Health Outcomes from Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks (cases/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards a/

Health Outcome and Year	Alt. 1 No Action b/	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Mortality (ages 30 and older)							
2015	0	-31	-41	-43	-49	-63	-101
2020	0	-155	-176	-175	-200	-221	-300
2025	0	-304	-336	-330	-375	-401	-470
2035	0	-493	-539	-529	-598	-629	-682
Chronic bronchitis							
2015	0	-27	-35	-37	-43	-55	-88
2020	0	-135	-153	-152	-174	-193	-261
2025	0	-264	-293	-287	-327	-349	-408
2035							
Emergency room visits for asthma							
2015	0	-7	-9	-9	-10	-13	-21
2020	0	-32	-37	-36	-42	-46	-63
2025	0	-63	-70	-69	-78	-84	-98
2035	0	-103	-112	-110	-125	-131	-142
Work-loss days							
2015	0	-5,582	-7,277	-7,686	-8,790	-11,191	-18,070
2020	0	-27,684	-31,458	-31,134	-35,698	-39,466	-53,440
2025	0	-54,173	-59,978	-58,915	-66,935	-71,529	-83,728
2035	0	-87,883	-96,001	-94,366	-106,665	-112,073	-121,611

a/ Negative changes indicate reductions; positive emissions changes are increases.
b/ Changes in health outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

The economic value of health impacts would vary proportionately with changes in health outcomes under the methodology defined in Section 3.3.2.4.2. The economic impacts analyzed here are the result of changes in ambient particulate matter (PM) and ozone concentrations as caused by changes in precursor criteria pollutants NO_x, VOCs, SO_2, and $PM_{2.5}$. Alternative 1 (No Action) would result in no other change in health-related costs throughout the United States, as compared to current trends.

Table 4.3-12 lists the nationwide changes in health costs in the High Scenario analysis of cumulative emissions from passenger cars and light trucks. Results for each analysis year are shown for the No Action Alternative in the left column, and for other alternatives from left to right in order of increasing fuel economy requirements. As with health outcomes, the economic impacts of each alternative decrease across nearly all successive alternatives and all successive years, compared to the health costs of emissions with the No Action Alternative.

Table 4.3-12

High Scenario Alternative CAFE Standards
Nationwide Changes in Health Costs from Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks (U.S. million dollars/year)
Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards a/

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Year	No Action b/	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
2015	0	-50	-64	-84	-96	-112	-223
2020	0	-374	-420	-505	-559	-621	-1,079
2025	0	-763	-829	-988	-1,097	-1,209	-2,019
2035	0	-1,273	-1,351	-1,610	-1,809	-2,010	-3,322

a/ Negative changes indicate economic benefit; positive emissions changes are economic costs.
b/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

4.3.4.3 Alternative 2: 25 Percent Below Optimized

4.3.4.3.1 Criteria Pollutants

With the High Scenario analysis for the 25 Percent Below Optimized Alternative (Alternative 2), the CAFE standards would require increased fuel economy compared to the No Action Alternative. The 25 Percent Below Optimized Alternative would increase fuel economy less than would Alternatives 3 through 7. Cumulative nationwide emissions of all criteria pollutants would be reduced compared to the Reference Case; the magnitude of the reductions increase with analysis year. Reductions in cumulative emissions under Alternative 2 are less than reductions under successive alternatives, except for CO and $PM_{2.5}$ for which the reductions are slightly less for Alternative 3.

Cumulative emissions in individual nonattainment areas could follow different patterns than nationwide emissions. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. While cumulative emissions of CO, NO_x, SO_x, and VOCs decrease in each nonattainment area for all years, emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas. Appendix B-2 contains tables that list the emission reductions for each nonattainment area.

In Alternative 2, the reduction in cumulative emissions under the High Scenario is greater than that under the Reference Case, for each criteria pollutant and year.

4.3.4.3.2 Air Toxics

With the High Scenario analysis of the 25 Percent Below Optimized Alternative (Alternative 2), cumulative nationwide air toxics emissions would increase for some pollutants and decrease for others, as compared to the No Action Alternative. Benzene, 1,3-butadiene, and DPM cumulative emissions would decline, with reductions increasing with analysis year. Compared to the No Action Alternative, cumulative emissions would increase for acetaldehyde (except in 2035), acrolein, and formaldehyde.

High Scenario Alternative 2 would have generally higher cumulative emissions of benzene, 1,3-butadiene, and DPM compared to Alternatives 3 through 7. High Scenario Alternative 2 would have generally lower cumulative emissions of acrolein and formaldehyde compared to Alternatives 3 through 7. Results for acetaldehyde would be mixed depending on alternative and year. Cumulative emissions with High Scenario Alternative 2 would be less than with Reference Case Alternative 2 except for acrolein in 2035 and 1,3-butadiene in 2015 and 2020.

Under High Scenario Alternative 2, many nonattainment areas would experience net increases, and some would experience net decreases, in cumulative emissions of one or more toxic air pollutants in at least one analysis year (Appendix B-2). The cumulative emission increases are quite small, as shown in Appendix B-2. Air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each nonattainment area.

4.3.4.3.3 Health Outcomes and Costs

The High Scenario analysis shows a decrease in cumulative adverse health effects nationwide for the Alternative 2 compared to Alternative 1 (No Action). These reductions primarily reflect the projected $PM_{2.5}$ reductions, as $PM_{2.5}$ tends to be the largest contributor to adverse health effects. Compared to Alternative 1 (No Action), the cumulative impact of Alternative 2 would result in 493 fewer mortalities and 87,883 fewer work-loss days in 2035. Cumulative health benefits are greater under the High Scenario than under the Reference Case, reducing mortalities by an additional 177 cases and lost-work days by an additional 31,590 cases in 2035. In that same year, Alternative 2 would reduce health costs by $1.273 billion, an additional $593 million compared to Reference Case benefits.

4.3.4.4 Alternative 3: Optimized

4.3.4.4.1 Criteria Pollutants

With the High Scenario analysis of Optimized Alternative (Alternative 3), the CAFE standards would require increased fuel economy compared to Alternatives 1 and 2, but less than Alternative 4 through 7. Reductions in cumulative nationwide emissions are similar to reductions under Alternative 2. Cumulative emissions reductions of CO and $PM_{2.5}$ are slightly less than under Alternative 2. In other cases, the cumulative emissions reductions are greater than under Alternative 2.

Cumulative emissions in individual nonattainment areas could follow different patterns than nationwide emissions. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. While cumulative emissions of CO, NO_x, SO_x, and VOCs decrease in each nonattainment area for all years, emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas. Appendix B-2 contains tables that list the emission reductions for each nonattainment area.

In Alternative 3, the reduction in cumulative emissions under the High Scenario is greater than that under the Reference Case, for each criteria pollutant and year.

4.3.4.4.2 Air Toxics

Under High Scenario Alternative 3, nationwide cumulative emissions of benzene, 1,3-butadiene, and DPM would be lower compared to the High Scenario No Action Alternative. Nationwide cumulative emissions would be higher for acetaldehyde, acrolein, and formaldehyde compared to the High Scenario No Action Alternative.

High Scenario Alternative 3 would have generally higher emissions than would High Scenario Alternatives 4 through 7 for benzene, butadiene, and DPM. High Scenario Alternative 3 would have generally lower emissions than would High Scenario Alternatives 4-7 for acrolein and formaldehyde, and mixed results for acetaldehyde depending on alternative and year. Cumulative emissions under the High Scenario are lower than those under the Reference Case for Alternative 3 (except for acrolein in 2035).

Under High Scenario Alternative 3, many nonattainment areas would experience net increases, and some would experience net decreases, in cumulative emissions of one or more toxic air pollutants in at least one analysis year (Appendix B-2). The cumulative emission increases are quite small, as shown in Appendix B-2. Air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each nonattainment area.

4.3.4.4.3 Health Outcomes and Costs

The High Scenario analysis shows a decrease in cumulative adverse health effects nationwide for Alternative 3 compared to Alternative 1 (No Action). These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. Compared to Alternative 1 (No Action), the cumulative impact of Alternative 3 would result in 539 fewer mortalities and 96,001 fewer work-loss days in 2035. Cumulative health benefits are greater under the High Scenario than under the Reference Case, reducing mortalities by an additional 214 cases and lost-work days by an additional 38,062 cases in 2035. In that same year, Alternative 3 would reduce health costs by $1.351 billion, an additional $657 million compared to Reference Case benefits.

4.3.4.5 Alternative 4: 25 Percent Above Optimized

4.3.4.5.1 Criteria Pollutants

For the High Scenario analysis of the 25 Percent Above Optimized Alternative (Alternative 4), the CAFE standards would require increased fuel economy compared to Alternatives 1 through 3, but less than Alternatives 5 through 7. Cumulative nationwide emissions of all criteria pollutants for Alternative 4 would be reduced compared to Alternative 3. Compared to the No Action Alternative, the reductions increase for all analysis years.

Cumulative emissions in individual nonattainment areas could follow different patterns than nationwide emissions. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. While cumulative emissions of CO, NO_x, SO_x, and VOCs decrease in each nonattainment area for all years, emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas Appendix B-2 contains tables that list the emission reductions for each nonattainment area.

In Alternative 4, the reduction in cumulative emissions under the High Scenario is greater than that under the Reference Case, for each criteria pollutant and year.

4.3.4.5.2 Air Toxics

Under High Scenario Alternative 4, nationwide cumulative emissions of acetaldehyde (except in 2015), benzene, 1,3-butadiene, and DPM would be lower compared to the High Scenario No Action Alternative. Nationwide cumulative emissions would be higher for acetaldehyde (in 2015), acrolein, and formaldehyde compared to the High Scenario No Action Alternative.

High Scenario Alternative 4 would have generally higher emissions than would High Scenario Alternatives 5 through 7 for acetaldehyde (in 2035), benzene, 1,3-butadiene, and DPM. High Scenario Alternative 3 would have generally lower emissions than would High Scenario Alternatives 5 through 7 for acetaldehyde (except in 2035), acrolein, and formaldehyde. Cumulative emissions under the High Scenario are lower than those under the Reference Case for Alternative 4 (except for acrolein in 2025 and 2035 and 1,3-butadiene in 2015).

Under High Scenario Alternative 4, many nonattainment areas would experience net increases, and some would experience net decreases, in cumulative emissions of one or more toxic air pollutants in at least one analysis year (Appendix B-2). The cumulative emission increases are quite small, as shown in Appendix B-2. Air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each nonattainment area.

4.3.4.5.3 Health Outcomes and Costs

The High Scenario analysis shows a decrease in cumulative adverse health effects nationwide for Alternative 4 compared to Alternative 1 (No Action). These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. Compared to Alternative 1 (No Action), the cumulative impact of Alternative 4 would result in 529 fewer mortalities and 94,366 fewer work-loss days in 2035. Cumulative health benefits are greater under the High Scenario than under the Reference Case, reducing mortalities by an additional 141 cases and lost-work days by an additional 25,256 cases in 2035. In that same year, Alternative 4 would reduce health costs by $1.610 billion, an additional $739 million compared to Reference Case benefits.

4.3.4.6 Alternative 5: 50 Percent Above Optimized

4.3.4.6.1 Criteria Pollutants

For the High Scenario analysis of the 50 Percent Above Optimized Alternative (Alternative 5), the CAFE standards would require increased fuel economy compared to Alternatives 1 through 4, but less than Alternatives 6 and 7. Cumulative nationwide emissions of all criteria pollutants for Alternative 5 would be reduced compared to Alternative 4. Compared to the No Action Alternative, the percent reductions increase for all analysis years.

Cumulative emissions in individual nonattainment areas could follow different patterns than nationwide emissions. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. While cumulative emissions of CO, NO_x, SO_x, and VOCs decrease in each nonattainment area for all years, emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas. Appendix B-2 contains tables that list the emission reductions for each nonattainment area.

In Alternative 5, the reduction in cumulative emissions under the High Scenario is greater than that under the Reference Case, for each criteria pollutant and year.

4.3.4.6.2 Air Toxics

Under High Scenario Alternative 5, nationwide cumulative emissions of acetaldehyde (in 2025 and 2035), benzene, 1,3-butadiene, and DPM would be lower compared to the High Scenario No Action Alternative. Nationwide cumulative emissions would be higher for acetaldehyde (in 2015 and 2020), acrolein, and formaldehyde compared to the High Scenario No Action Alternative.

High Scenario Alternative 5 would have higher emissions than would High Scenario Alternatives 6 and 7 for acetaldehyde (in 2035), benzene, 1,3-butadiene (except Alternative 7 in 2015), and DPM (except Alternative 7 in 2035). High Scenario Alternative 5 would have lower emissions than would High Scenario Alternatives 6 and 7 for acetaldehyde (except in 2035), acrolein, 1,3-butadiene (Alternative 7 in 2015 only), and DPM (Alternative 7 in 2035 only), and formaldehyde. Cumulative emissions under the High Scenario are lower than cumulative emissions under the Reference Case for Alternative 5 (except for acrolein in 2025 and 2035, and 1,3-butadiene in 2015).

Under High Scenario Alternative 5, many nonattainment areas would experience net increases, and some would experience net decreases, in cumulative emissions of one or more toxic air pollutants in at least one analysis year (Appendix B-2). The cumulative emission increases are quite small, as shown in Appendix B-2. Air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each nonattainment area.

4.3.4.6.3 Health Outcomes and Costs

The High Scenario analysis shows a decrease in cumulative adverse health effects nationwide for the Alternative 5 compared to Alternative 1 (No Action). These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. Compared to Alternative 1 (No Action), the cumulative impact of Alternative 5 would result in 598 fewer mortalities and 106,665 fewer work-loss days in 2035. Cumulative health benefits are greater under the High Scenario than under the Reference Case, reducing mortalities by an additional 315 cases and lost-work days by an additional 56,220 cases in 2035. In that same year, Alternative 5 would reduce health costs by $1.809 billion, an additional $782 million compared to Reference Case benefits.

4.3.4.7 Alternative 6: Total Costs Equal Total Benefits

4.3.4.7.1 Criteria Pollutants

For the High Scenario analysis of the Total Costs Equal Total Benefits Alternative (Alternative 6), the CAFE standards would require increased fuel economy compared to Alternatives 1 through 5, but less than Alternative 7. Cumulative nationwide emissions of all criteria pollutants for Alternative 6 would be reduced compared to Alternative 5. Compared to the No Action Alternative, the percent reductions increase for all analysis years.

Cumulative emissions in individual nonattainment areas might follow different patterns than nationwide emissions. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. While cumulative emissions of CO, NO_x, SO_x, and VOCs decrease in each nonattainment area for all years, emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas. Appendix B-2 contains tables that list the emission reductions for each nonattainment area.

In Alternative 6, the reduction in cumulative emissions under the High Scenario is greater than that under the Reference Case, for each criteria pollutant and year.

4.3.4.7.2 Air Toxics

Under High Scenario Alternative 6, nationwide cumulative emissions of acetaldehyde (in 2025 and 2035), benzene, 1,3-butadiene, and DPM would be lower compared to the High Scenario No Action Alternative. Nationwide cumulative emissions with High Scenario Alternative 6 would be higher for acetaldehyde (in 2015 and 2020), acrolein, and formaldehyde compared to the High Scenario No Action Alternative.

High Scenario Alternative 6 would have higher emissions than would High Scenario Alternative 7 for acetaldehyde (in 2035), benzene, 1,3-butadiene (except in 2015), and DPM (except in 2025 and 2035). High Scenario Alternative 6 would have lower emissions than would High Scenario Alternative 7 for acetaldehyde (except in 2035), acrolein, 1,3-butadiene (in 2015 only), and DPM (in 2025 and 2035), and formaldehyde. Cumulative emissions under the High Scenario are lower than cumulative emissions under the Reference Case for Alternative 6 (except for acrolein in 2020-2035 and 1,3-butadiene in 2015).

Under High Scenario Alternative 6, many nonattainment areas would experience net increases, and some would experience net decreases, in cumulative emissions of one or more toxic air pollutants in at least one analysis year (Appendix B-2). The cumulative emission increases are quite small, as shown in Appendix B-2. Air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each nonattainment area.

4.3.4.7.3 Health Outcomes and Costs

The High Scenario analysis shows a decrease in cumulative adverse health effects nationwide for Alternative 6 compared to Alternative 1 (No Action). These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. Compared to Alternative 1 (No Action), the cumulative impact of Alternative 6 would result in 629 fewer mortalities and 112,073 fewer work-loss days in 2035. Cumulative health benefits are greater under the High Scenario than under the Reference Case, reducing mortalities by an additional 215 cases and lost-work days by an additional 38,340 cases in 2035. In that same year, Alternative 6 would reduce health costs by $2.010 billion, an additional $976 million compared to Reference Case benefits.

4.3.4.8 Alternative 7: Technology Exhaustion

4.3.4.8.1 Criteria Pollutants

For the High Scenario analysis of the Technology Exhaustion Alternative (Alternative 7), the CAFE standards would require higher fuel economy than for all other alternatives. Cumulative nationwide emissions of all criteria pollutants for Alternative 7 would be reduced compared to Alternative 6. Compared to the No Action Alternative, the percent reductions increase for all analysis years. Cumulative emissions reductions would be greater in Alternative 7 than in any other alternative.

Cumulative emissions in individual nonattainment areas could follow different patterns than nationwide emissions. Emissions of criteria pollutants decrease in part because the reduction in upstream emissions, among other effects related to technology changes introduced by manufacturers in response to CAFE standards, more than offsets the increase in VMT and emissions due to the rebound effect in every nonattainment area. While cumulative emissions of CO, NO_x, SO_x, and VOCs decrease in each nonattainment area for all years, emissions of $PM_{2.5}$ are projected to increase in some nonattainment areas. Appendix B-2 contains tables that list the emission reductions for each nonattainment area.

In Alternative 7, the reduction in cumulative emissions under the High Scenario is greater than or equal to that under the Reference Case, for each criteria pollutant and year.

4.3.4.8.2 Air Toxics

Under High Scenario Alternative 7, nationwide cumulative emissions of benzene, 1,3-butadiene (except in 2015), and DPM would be lower compared to the High Scenario No Action Alternative. Nationwide cumulative emissions with High Scenario Alternative 7 would be higher for acetaldehyde (except in 2035), acrolein, and formaldehyde compared to the High Scenario No Action Alternative.

All cumulative air toxics emissions under the High Scenario are lower than or equivalent to cumulative emissions under the Reference Case for Alternative 7.

Under High Scenario Alternative 7, some nonattainment areas would experience net increases, and some would experience net decreases, in emissions of one or more toxic air pollutants in at least one analysis year (Appendix B-2). The emission increases are quite small, as shown in Appendix B-2. Potential air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each nonattainment area.

4.3.4.8.3 Health Outcomes and Costs

The High Scenario analysis shows a decrease in cumulative adverse health effects nationwide for Alternative 7 compared to Alternative 1 (No Action). These reductions primarily reflect the projected $PM_{2.5}$ reductions, because $PM_{2.5}$ tends to be the largest contributor to adverse health effects. Compared to Alternative 1 (No Action), the cumulative impact of Alternative 7 would result in 682 fewer mortalities and 121,611 fewer work-loss days in 2035. In that same year, Alternative 7 would reduce health costs by $3.320 billion.

Unlike other Alternatives, cumulative health benefits are less under the High Scenario than under the Reference Case, increasing mortalities by 78 cases and lost-work days by 13,949 cases in 2035. Similarly, health costs would be $381 million greater under the High Scenario than under the Reference Case.

4.3.4.9 Mid-1 and Mid-2 Scenarios

Compared to the Reference Case, total cumulative emissions of criteria pollutants under the Mid-1 Scenario were lower for all alternatives. For toxic air pollutants, compared to the Reference Case, total cumulative emissions under the Mid-1 Scenario were lower except for emissions of acrolein and 1,3-butadiene for some alternatives and years. The cumulative emissions differences between the Reference Case and the Mid-1 Scenario reflect the differences in the forecasted levels of fuel economy, VMT, and diesel vehicle share of the vehicle fleet.

Compared to the Reference Case, total cumulative emissions of criteria pollutants under the Mid-2 Scenario were lower for all alternatives. For toxic air pollutants, compared to the Reference Case, total cumulative emissions under the Mid-2 Scenario were lower except for emissions of acrolein with Alternative 6 in 2035. The cumulative emissions differences between the Reference Case and the Mid-2 Scenario reflect the differences in the forecasted levels of fuel economy, VMT, and diesel vehicle share of the vehicle fleet.

Cumulative emissions of criteria pollutants would be generally higher with the Mid-2 Scenario than with the Mid-1 Scenario for Alternatives 2 through 6, and equivalent for Alternative 7. Cumulative emissions of toxic air pollutants would be generally higher with the Mid-2 Scenario than with the Mid-1 Scenario for benzene, 1,3-butadiene, and DPM for Alternatives 2 through 6. Cumulative emissions of toxic air pollutants would be generally lower with the Mid-2 Scenario than with the Mid-1 Scenario for acetaldehyde, acrolein, and formaldehyde. Cumulative emissions of toxic air pollutants with the Mid-1 and Mid-2 Scenarios would be equivalent for Alternative 7.

Appendix B presents the full results from analysis of the Mid-1 and Mid-2 Scenarios.

4.4 CLIMATE

Although the proposed rule covers model years only up to 2015, the Energy Policy and Conservation Act (EPCA) has directed the Secretary, after consultation with the Secretary of the U.S. Department of Energy (DOE) and the Administrator of EPA, to establish separate average fuel economy standards for passenger cars and for light trucks manufactured in each model year beginning with model 2011 "to achieve a combined fuel economy average for model year 2020 of at least 35 mpg for the total fleet of passenger and non-passenger automobiles manufactured for sale in the United States for that model year" (49 United States Code [U.S.C.] § 32902(b)(2)(A)).

In April 2008, NHTSA issued a supplemental notice of public scoping providing additional guidance for participating in the scoping process and additional information about the standards and the alternatives NHTSA expected to consider in its NEPA analysis. In that notice, NHTSA stated that it would consider the cumulative impacts of the standards for MY 2011-2015 automobiles together with estimated impacts of NHTSA's historic implementation of the CAFE Program through MY 2010 and NHTSA's future CAFE rulemaking for MY 2016-2020, as prescribed by EPCA, as amended by EISA.

Again, a cumulative impact is defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency … or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR § 1508.70).

This section on the cumulative impacts of the CAFE alternatives on climate covers many of the same topics as Section 3.4. However, Chapter 4 is broader than Chapter 3 because it compares foreseeable effects of both the MY 2011-2015 and future MY 2016-2020 CAFE standards to the MY 2020 levels affecting all passenger cars and light trucks built from 2020 through 2100 (Chapter 3 covers only the effects of the MY 2011-2015 standards).[1] Chapter 4 also addresses the consequences of emissions and effects on the climate system (both Section 4.4 and Section 3.4 address these topics), and the impacts of climate change on key resources (*e.g.*, freshwater resources, terrestrial ecosystems, and coastal ecosystems).

Understanding that many users of EIS documents do not read through in linear fashion, but instead focus on the sections of most interest, this section repeats some of the information in Section 3.4 with only minor modifications reflecting the slightly different scope (cumulative impacts versus the direct and indirect effects of the alternatives).

[1] Because EISA directs NHTSA to increase CAFE standards to reach a combined fleet average CAFE level of at least 35 mpg by model year 2020, MY 2016-2020 CAFE standards are reasonably foreseeable and must be accounted for when analyzing the cumulative impacts of the MY 2011-2015 CAFE standards. For each alternative, NHTSA assumed that passenger-car and light-truck CAFE standards would continue to increase over MY 2016-2020 at their average annual rate of increase over MY 2011-2015. This assumption results in passenger-car and light-truck CAFE standards under each action alternative that meet or exceed the EISA requirement of a combined fleet average of at least 35 mpg by model year 2020. NHTSA assumed further that the fuel economy standards for model year 2020 would remain in effect through the end of the analysis period. Because the CAFE standards apply to new vehicles, this assumption results in emissions reductions and fuel savings that continue to grow as new vehicles meeting the CAFE standards for MY 2020 and beyond are added to the fleet in each subsequent year, reaching their maximum values when all passenger cars and light trucks in the U.S. fleet meet these standards.

4.4.1 Introduction – Greenhouse Gases and Climate Change

A series of intensive and extensive analyses has been conducted by the IPCC, the scientific body tasked by the United Nations to evaluate the risk of human-induced climate change), the United States Climate Change Science Program (USCCSP), and many other programs sponsored by government, non-governmental organizations (NGO), and industry. Our discussion relies heavily on the most recent, thoroughly peer-reviewed, and credible assessments of global and U.S. climate change: the IPCC Fourth Assessment Report (*Climate Change 2007*), and reports by the USCCSP that include the *Scientific Assessment of the Effects of Global Change on the United States* and Synthesis and Assessment Products (SAPs). These sources and the studies they review are frequently quoted throughout this FEIS. Because new evidence is continuously emerging on the subject of climate change impacts, the discussions on climate impacts in this FEIS also draw on more recent studies, where possible.

Global climate change refers to long-term fluctuations in global surface temperatures, precipitation, ice cover, sea levels, cloud cover, ocean temperatures and currents, and other climatic conditions. Scientific research has shown that, in the past century, Earth's surface temperature and sea levels have risen, and most scientists attribute this to GHGs released by human activities, primarily the combustion of fossil fuels. The IPCC recently asserted that, "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations" (IPCC 2007c).

The primary GHGs – CO_2, methane (CH_4), and nitrous oxide (N_2O) – are created by both natural and human activities. Human activities that emit GHGs to the atmosphere include the combustion of fossil fuels, industrial processes, solvent use, land use change and forestry, agricultural production, and waste management. These gases trap heat in Earth's atmosphere, changing the climate, which then impacts resources such as ecosystems, water resources, agriculture, forests, and human health. As the world population grows and developing countries industrialize, fossil fuel use and resulting GHG emissions and their concentrations in the atmosphere are expected to grow substantially over the next century. For a more in-depth discussion of the science of climate change, *see* Section 3.4.1.

4.4.2 Affected Environment

The affected environment can be characterized in terms of GHG emissions and climate. Section 3.4.2 provides a discussion of both topics, including a description of conditions in both the United States and the global environment. Because there is no distinction between the affected environment for purposes of the direct/indirect effects analysis and the cumulative impacts analysis, the reader is referred to Section 3.4.1.

4.4.3 Methodology

The methodology used to characterize the effects of the alternative CAFE standards on climate has two key elements:

1. Analyzing the effects of the alternatives on GHG emissions, and
2. Analyzing how the GHG emissions affect the climate system (climate effects).

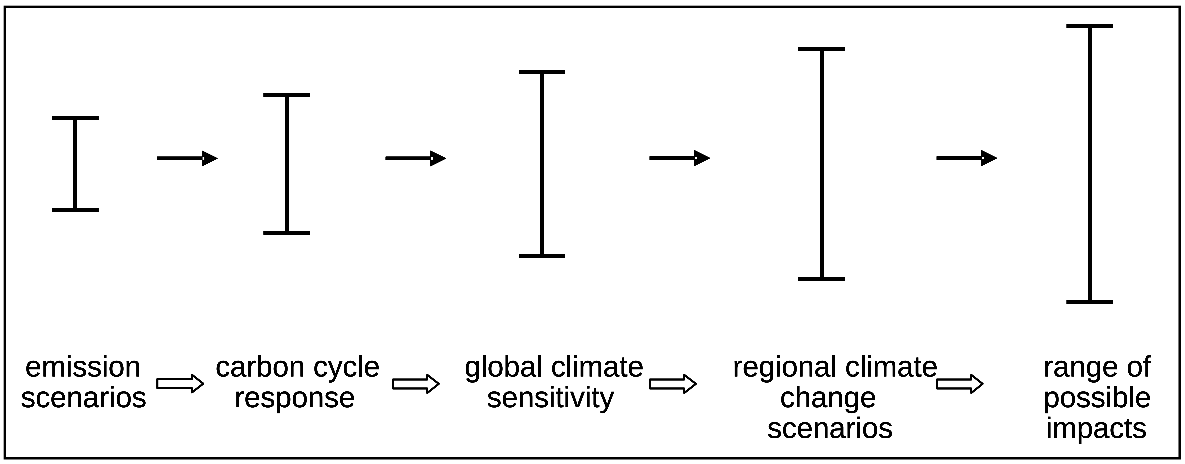
Each element is discussed below.

This FEIS expresses results for each alternative in terms of the environmental attribute being characterized (emissions, CO_2 concentrations, temperature, precipitation, sea level). It also presents the change between the No Action Alternative and each of the other six alternatives to illustrate the differences in environmental impacts across the CAFE alternatives.

The methods used to characterize emissions and climate change impacts involve considerable uncertainty. Sources of uncertainty include the pace and effects of technology change in both the transportation sector and other sectors that emit GHGs; changes in the future fuel supply that could affect emissions; the sensitivity of climate to increased GHG concentrations; the rate of change in the climate system in response to changing GHG concentrations; the potential existence of thresholds in the climate system (which could be difficult to predict and simulate); regional differences in the magnitude and rate of climate changes; and many other factors.

Moss and Schneider (2000) characterize the "cascade of uncertainty" in climate change simulations (Figure 4.4-1). As indicated in the figure, the emissions estimates used in this FEIS are less uncertain than the global climate effects (as illustrated by the heights of the bars), which in turn are less uncertain than the regional climate change effects. The effects on climate are in turn less uncertain than the impacts of climate changes on affected resources (terrestrial and coastal ecosystems, human health, and other resources discussed in Section 4.5).

Figure 4.4-1. Cascade of Uncertainty in Climate Change Simulations a/



a/ Source: Moss and Schneider (2000) – "Cascade of uncertainties typical in impact assessments showing the 'uncertainty explosion' as these ranges are multiplied to encompass a comprehensive range of future consequences, including physical, economic, social, and political impacts and policy responses."

Where information in the analysis included in this FEIS is incomplete or unavailable, NHTSA has relied on CEQ regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). The understanding of the climate system is incomplete; like any analysis of complex, long-term changes to support decisionmaking, the analysis described below involves many assumptions and uncertainties in the course of evaluating reasonably foreseeable significant adverse impacts on the human environment. This FEIS uses methods and data that represent the best available information on this topic, and which have been subject to peer review and scrutiny. In fact, the information cited throughout this section that is extracted from the IPCC and USCCSP has endured a more thorough and systematic review process than information on virtually any other topic in environmental science and policy. The Model for Assessment of Greenhouse Gas-induced Climate Change (MAGICC) and the IPCC emissions scenarios described below are generally accepted in the scientific community.

NHTSA notes that the USCCSP recently released for comment a draft SAP 3.1 regarding the strengths and limitations of climate models (CCSP 2008a). The reader might find the discussions in this draft SAP useful in understanding the methodological limitations regarding modeling the environmental impacts of the proposed action and the range of alternatives on climate change.

4.4.3.1 Methodology for Greenhouse Gas Emissions Modeling

GHG emissions were estimated using the Volpe model, described in Section 3.1.4. These emissions estimates include CO_2, CH_4, and N_2O emissions from both direct fuel consumption and upstream sources. The following non-GHGs were also estimated by the Volpe model and taken into account in the climate modeling: SO_2, NO_x, CO, and VOCs.

The Volpe model assumes that major manufacturers will exhaust all available technology before paying noncompliance civil penalties. In the more stringent alternatives, the Volpe model predicts that increasing numbers of manufacturers will run out of technology to apply and, theoretically, resort to penalty payment. Setting standards this high might not be technologically feasible, nor might it serve the need of the Nation to conserve fuel and reduce emissions.

Fuel savings from stricter CAFE standards also result in lower emissions of CO_2, the main GHG emitted as a result of refining, distribution, and use of transportation fuels.[2] Lower fuel consumption reduces carbon dioxide emissions directly, because the primary source of transportation-related CO_2 emissions is fuel combustion in internal combustion engines. NHTSA estimates reductions in CO_2 emissions resulting from fuel savings by assuming that the entire carbon content of gasoline, diesel, and other fuels is converted to CO_2 during the combustion process (*See* 73 *FR* 24352, 24412-24413, May 2, 2008). Reduced fuel consumption also reduces CO_2 emissions that result from the use of carbon-based energy sources during fuel production and distribution. NHTSA currently estimates the reductions in CO_2 emissions during each phase of fuel production and distribution using CO_2 emissions rates obtained from the Greenhouse Gases Regulated Emissions and Energy Use in Transportation (GREET) model. The previous assumptions about how fuel savings are reflected in reductions in each phase. The total reduction in CO_2 emissions from the improvement in fuel economy under each alternative CAFE standard is the sum of the reductions in emissions from reduced fuel use and reductions in emissions from lower fuel production and distribution.

4.4.3.2 Methodology for Estimating Climate Effects

This FEIS estimates and reports on four direct and indirect effects of climate change, driven by alternative scenarios of GHG emissions, including:

- Changes in CO_2 concentrations,
- Changes in global temperature,
- Changes in regional temperature and precipitation, and
- Changes in sea level.

The change in CO_2 concentration is a direct effect of the changes in GHG emissions, and influences each of the other factors.

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[2] For purposes of this rulemaking, NHTSA estimated emissions of vehicular CO_2, CH_4, and N_2O emissions, but did not estimate vehicular emissions of hydrofluorocarbons (HFCs). Methane and nitrous oxide account for less than 3 percent of the tailpipe GHG emissions from passenger cars and light trucks, and CO_2 emissions account for the remaining 97 percent. Of the total (including non-tailpipe) GHG emissions from passenger cars and light trucks, tailpipe CO_2 represents about 93.1 percent, tailpipe methane and nitrous oxide represent about 2.4 percent, and hydrofluorocarbons (from air conditioner leaks) represent about 4.5 percent. Calculated from *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006* (EPA 2008a).

This FEIS uses a climate model to estimate the key direct and indirect effects of the alternative CAFE standards. NHTSA chose to employ MAGICC Version 5.3 (Wigley 2008) to estimate changes in key direct and indirect effects. The application of MAGICC Version 5.3 uses the emissions estimates for CO_2, CH_4, and N_2O from the Volpe model. Sensitivity analyses examined the relationship among various CAFE alternatives, climate sensitivities, and scenarios of global emissions paths and the associated direct and indirect effects for each combination. These relationships can be used to infer the effect of the emissions associated with the regulatory alternatives on direct and indirect climate effects.

MAGICC , the modeling runs and sensitivity analyses, and the emissions scenarios used in the analysis are described in the three sections below.

4.4.3.3 MAGICC Version 5.3

The selection of MAGICC for this analysis was driven by a number of factors:

- MAGICC has been used in the peer-reviewed literature to evaluate changes in global mean surface temperature and sea-level rise. In the IPCC Fourth Assessment Report for Working Group I (WGI) (IPCC 2007a), it was used to scale the results from the atmospheric-ocean general circulation models (AOGCMs)[3] to estimate the global mean surface temperature and the sea-level rise for global emissions scenarios that the AOGCMs did not run.
- MAGICC is publicly available and is already populated with the Special Report on Emission Scenarios (SRES). The SRES scenarios are long-term emissions scenarios representing different assumptions about key drivers of GHG emissions. They are described in more detail below.
- MAGICC was designed for the type of analysis performed in this FEIS.
- More complex AOGCMs are not designed for the type of sensitivity analysis performed here and are best used to provide results for groups of scenarios with much greater differences in emissions such as the B1 (low), A1B (medium), and A2 (high) scenarios.[4]
- MAGICC has been updated to version 5.3 to incorporate the science from the IPCC Fourth Assessment Report (Wigley 2008).

For the primary analysis using MAGICC, NHTSA assumed that global emissions consistent with the No Action Alternative would follow the trajectory provided by the SRES A1B (medium) scenario.

4.4.3.4 Modeling Runs and Input Scenarios

The modeling runs and input scenarios are designed to use information on the alternatives, climate sensitivities, and SRES emissions scenarios provided by the IPCC WGI (IPCC 2007a)[5] to model relative changes in atmospheric concentrations, global mean surface temperature, precipitation, and sea-level rise.

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[3] For a discussion of AOGCMs, *see* Chapter 8 in IPCC (2007a).

[4] The IPCC SRES scenarios were developed in the late 1990s and published in 2000 (Nakicenovic et al. 2000). The SRES scenarios were developed around four storylines. The A1 storyline included a strong commitment to market-based solutions, high savings, high economic growth, and globalization. The A2 storyline differs from A1 with lower trade flows and slower rates of technological improvement. The B1 storyline includes a global integrated approach to sustainable development. The B2 storyline includes increased local awareness of environmental issues with strong efforts at the local level and less reliance on international institutions.

[5] The use of three emission scenarios provides insight into the impact of alternative global emission scenarios on the effect of the action alternatives.

The primary modeling runs are based on the results provided for the seven alternatives using the Reference Case Volpe model assumptions, a climate sensitivity of 3 °C for a doubling of CO_2 concentrations in the atmosphere, and the SRES A1B (medium) scenario. These are referred to as the Reference Case results below, in contrast with various sensitivity runs that test high and low values of the key parameters.

The approach uses the following steps to estimate these changes for the Reference Case and an analysis that examined the alternatives using the high-level Volpe assumptions (*e.g.*, higher fuel prices and a higher social cost of carbon) referred to as the "High Scenario":

1. NHTSA assumed that global emissions consistent with the No Action Alternative (Alternative 1) follow the trajectories provided by the SRES A1B (A1B) scenario, providing results illustrating the uncertainty due to factors influencing future global emissions of GHGs.

2. NHTSA assumed that global emissions for the action alternatives (Alternatives 2 through 7) are equal to the global emissions from the No Action Alternative minus the emissions reductions from the Volpe model for CO_2, CH_4, N_2O, SO_2, NO_x, CO, and VOCs. All SO_2 reductions were applied to Aerosol Region 1 of MAGICC, which includes North America.

3. MAGICC 5.3 was used to estimate the changes in CO_2 concentrations, global mean surface temperature, and sea-level rise through 2100 using the No Action Alternative and the action alternatives developed in steps 1 and 2 above.

4. For the Reference Case results, the increase in global mean surface temperature was used along with factors that relate increase in global average precipitation to this increase in global mean surface temperature to estimate the increase in global averaged precipitation for each alternative for the A1B (medium) scenario.

The approach uses the following steps to estimate the sensitivity of the results to the selection of the SRES global emissions scenario:

1. NHTSA assumed that global emissions consistent with the No Action Alternative (Alternative 1) follow four potential trajectories represented by the SRES A2, B1, B2, and A1FI scenarios. The results of these simulations illustrate the uncertainty due to factors influencing future global emissions of GHGs (factors other than the CAFE rulemaking).

2. For each SRES scenario from step 1, NHTSA assumed that global emissions for the action alternatives are equal to the global emissions from the No Action Alternative minus the emissions reductions from the Volpe model for CO_2, CH_4, N_2O, SO_2, NO_x, CO, and VOCs. All SO_2 reductions were applied to Aerosol Region 1 of MAGICC, which includes North America.

3. MAGICC 5.3 was used to estimate the changes in CO_2 concentrations, global mean surface temperature, and sea-level rise through 2100 using the No Action Alternative (Alternative 1) and action alternatives developed in steps 1 and 2 above.

Section 3.4.4 reports the results of the primary modeling runs. Section 3.4.5 reports the results from similar runs in which the alternatives use the high-level Volpe assumptions (*e.g.*, higher fuel prices and a higher social cost of carbon), in effect providing a "CAFE assumption sensitivity analysis."

4.4.3.5 Emissions Scenarios

As described above, MAGICC uses long-term emissions scenarios representing different assumptions about key drivers of GHG emissions. All scenarios used are based on the IPCC effort to develop a set of long-term (1990-2100) emissions scenarios to provide some standardization in climate change modeling. The most widely used scenarios are those from SRES (Nakicenovic *et al.* 2000).

Both the Reference Case and the Input Scenarios analyses rely primarily on the SRES scenario referred to as "A1B" to represent a baseline emissions scenario, that is, emissions for the No Action Alternative. NHTSA selected this scenario because it is regarded as a moderate emissions case and has been widely used in AOGCMs, including several AOGCM runs developed for the IPCC WGI Fourth Assessment Report (IPCC 2007a).

NHTSA's choice of the A1B scenario is based on the following factors:

- IPCC WGI evaluated the climate effects from A1B extensively in the Fourth Assessment Report (IPCC 2007a), which provides a basis for comparing the results from the analysis using MAGICC to the IPCC Fourth Assessment Report.

- The A1B and B2 scenarios are "middle-of-the road" scenarios and provide the best comparison (see below) to the EIA AEO 2008 and International Energy Outlook (IEO) 2008 forecast of liquid energy use. The AEO-2008/IEO-2008 provide the base assumptions for key parameters in the Volpe model scenarios.

The A1B (medium) scenario provides a global context for emissions of a full suite of GHGs and ozone precursors for the Reference Case. There are some inconsistencies between the overall assumptions used by IPCC in its SRES (Nakicenovic *et al.* 2000) to develop global emissions scenarios and the assumptions used in the Volpe model in terms of economic growth, energy prices, energy supply, and energy demand. However, these inconsistencies affect the characterization of each CAFE alternative in equal proportion, so the relative estimates provide a reasonable approximation of the differences in environmental impact among the alternatives. NHTSA used the A1B scenario as the primary scenario for evaluating climate effects, but used the A2, B1, B2, and the A1FI scenarios to evaluate the sensitivity of the results to alternative emissions scenarios.[6]

Separately, each of the other alternatives was simulated by calculating the difference in annual GHG emissions with respect to the No Action Alternative, and subtracting this change in the A1B (medium) scenario to generate modified global-scale emissions scenarios, which each show the effect of the various regulatory alternatives on the global emissions path. For example, the emissions from U.S. passenger cars and light trucks in 2020 for the No Action Alternative (Alternative 1) are 1,651 million metric tons of carbon dioxide ($MMTCO_2$); the emissions in 2020 for the Optimized Alternative (Alternative 3) are 1,581 $MMTCO_2$. The difference is 70 $MMTCO_2$. Global emissions for the A1B (medium) scenario in 2020 are 46,339 $MMTCO_2$, and represent the emissions under the No Action Alternative. Global emissions for the Optimized Alternative are 70 $MMTCO_2$ less, or 46,269 $MMTCO_2$.

NHTSA's assumptions in the Volpe model for growth in the number of vehicles and miles driven for cars and light trucks in the United States are based on the AEO assumptions for 2008 (EIA, 2008a). These alone cannot be compared to the SRES assumptions because the IPCC SRES results are reported

[6] From SRES, NHTSA used the A1B scenario to represent the A1B storyline, the A2-ASF scenario to represent the A2 storyline, the B1-IMAGE scenario to represent the B1 storyline, the B2-MESSAGE scenario to represent the B2 storyline, and the A1G-MINICAM scenario to represent the A1FI storyline.

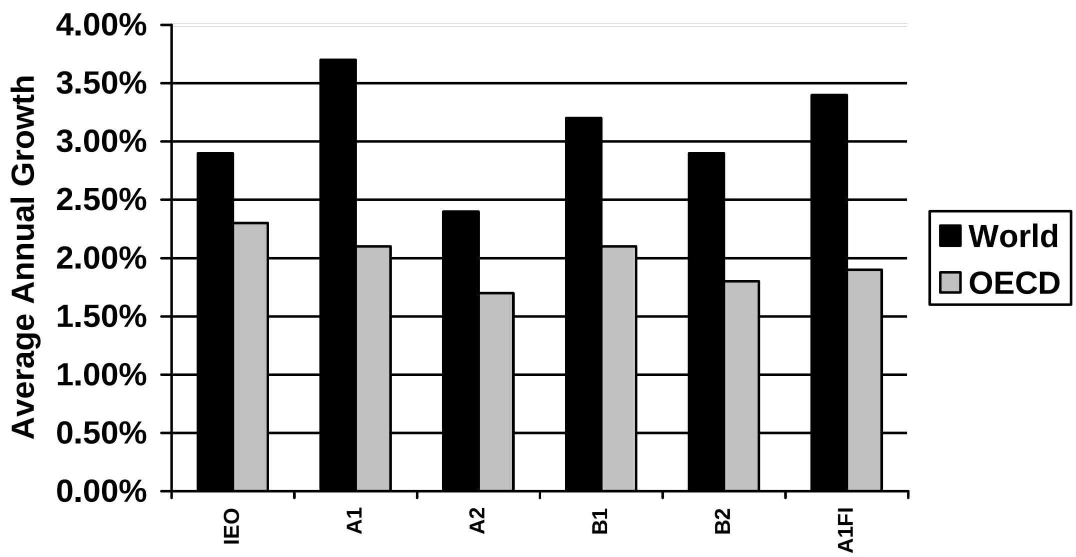
for four global regions including the Organization for Economic Cooperation and Development (OECD) and not for the United States separately. The EIA also published the IEO 2008 (EIA 2008c), which provides a global forecast of energy use and CO_2 from energy use through 2030 and which is consistent in assumptions to the IEO 2008.[7]

Figures 4.4-2 to 4.4-5 provide the forecast of gross domestic product (GDP), CO_2 emissions from energy use, primary energy use from the IEO-2008, and the five SRES scenarios for the World and the OECD 90 region.[8] The GDP growth assumptions for A1B for the OECD are close to those of the IEO-2008, but the A1B scenario has much higher GDP growth outside the OECD. This leads to higher global primary energy use by 2030, as shown in Figure 4.4-4, with much of the increase in natural gas use and higher emissions of CO_2, as shown in Figure 4.4-3. The global primary liquids energy use in A1B and the IEO-2008 compare well, considering that the IEO forecast for liquid fuels includes about 10 percent of the total in unconventional sources which are accounted for elsewhere in the SRES scenarios.

The forecast estimates for the OECD 90 region vary differently than the global numbers. The EIA shows a similar increase in primary energy use in the OECD 90 region but much greater increase in the use of primary liquid fuels even considering the reporting differences between the IEO and SRES.

Where information in the analysis included in this FEIS is incomplete or unavailable, NHTSA has relied on CEQ regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). For this analysis, despite the inconsistencies between the IPCC assumptions on global trends across all GHG-emitting sectors (and the drivers that affect them) and the particularities of the Volpe model on the U.S. transportation sector, the approach used is valid; these inconsistencies affect all alternatives equally, and thus they do not hinder a comparison of the alternatives in terms of their relative effects on climate.

Figure 4.4-2. Average GDP Growth Rates (1990 to 2030)



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[7] The IEO 2008 uses the energy supply and consumption from the AEO 2008 for the United States and uses the same forecast for world oil prices.
[8] The IEO nuclear primary energy forecast numbers were adjusted to account for differences in reporting primary energy use for nuclear energy and all IEO energy use estimates were converted to exajoules (EJ).

Figure 4.4-3. Global CO_2 Emissions from Fossil Fuel Use

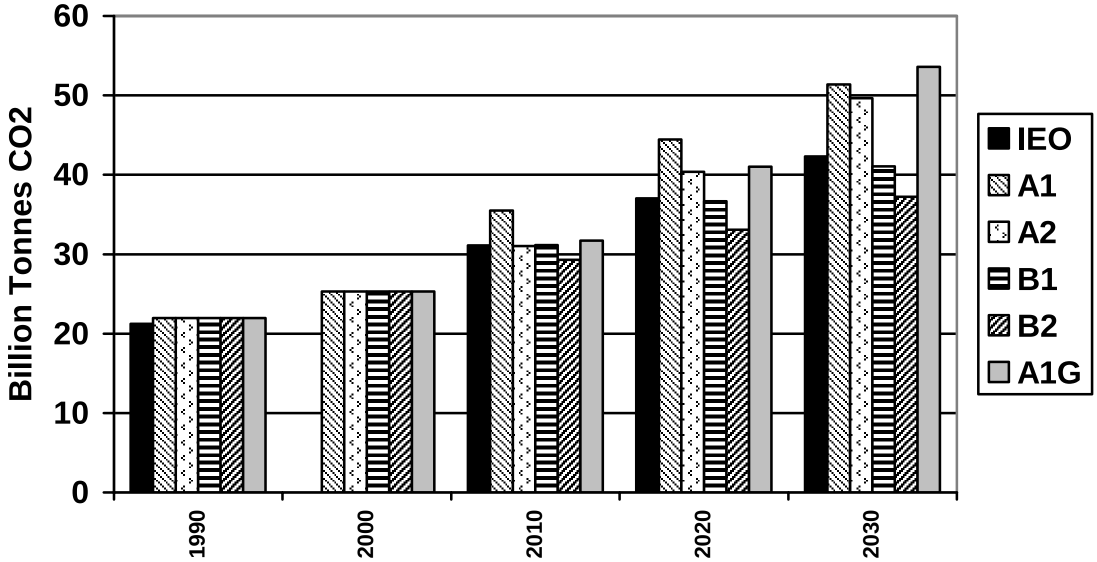


Figure 4.4-4. World Primary Energy Use Forecast

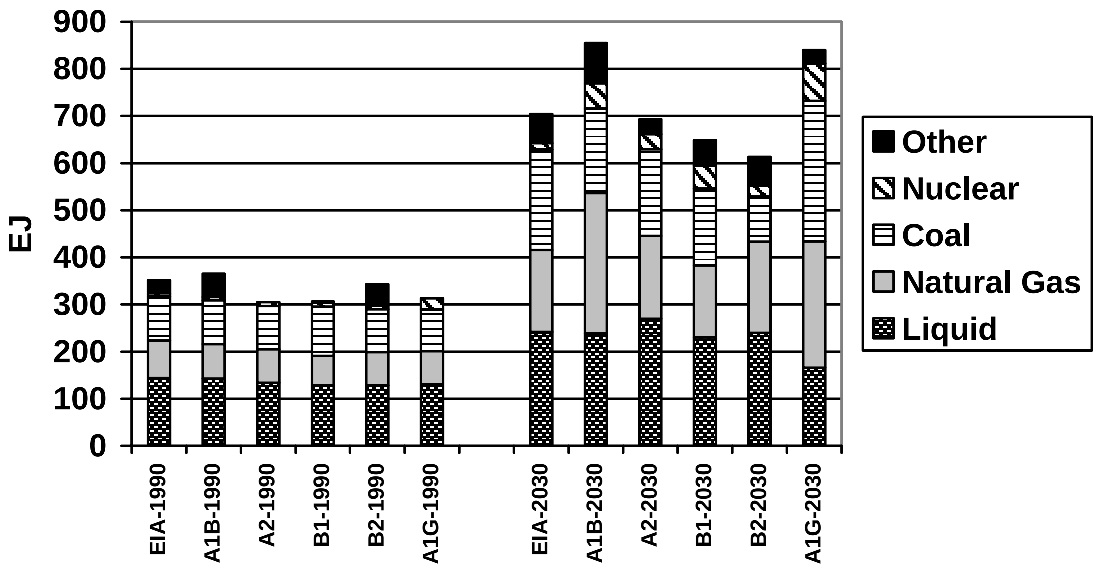
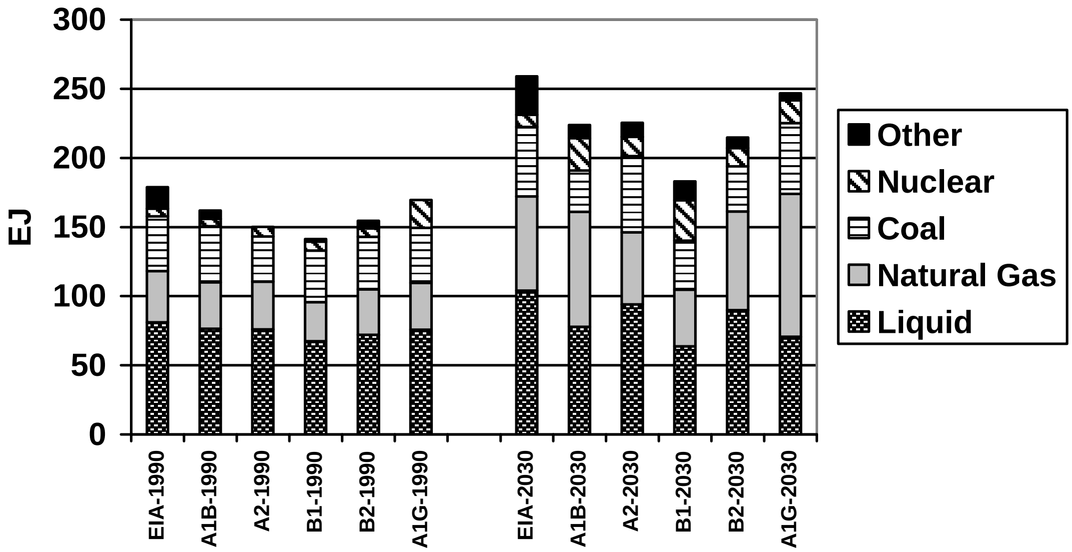


Figure 4.4-5. OECD 90 Primary Energy Use Forecast a/



a/ The SRES results provide forecasts for countries that were members of the OECD in 1990 only and the IEO 1990 and 2030 estimates have been scaled to reflect only countries in the OECD in 1990.

The approaches focus on the marginal climate effects of marginal changes in emissions. Thus, they generate a reasonable characterization of climate changes for a given set of emissions reductions, regardless of the underlying details associated with those emissions reductions. The discussion that follows characterizes projected climate change under the No Action Alternative and the changes associated with each action alternative.

The SRES and climate sensitivity variants (*see* Section 4.4.4.2.5) analysis also uses the B1 (low), B2, A2 (high), and A1F1 emissions scenarios (Nakicenovic *et al.* 2000) as "reference" scenarios. This provides a basis for determining climate responses to varying levels of emissions and climate sensitivities for the Optimized Alternative (Alternative 3). Some responses of the climate system are believed to be non-linear; by using a range of emissions cases and climate sensitivities, it is possible to estimate the effects of the alternatives in relation to different reference cases.

4.4.3.5.1 Tipping Points and Abrupt Climate Change

The phrase "tipping point" is most typically used, in the context of climate change and its consequences, to describe situations in which the climate system (the atmosphere, oceans, land, cryosphere,[9] and biosphere) reaches a point at which there is a disproportionately large or singular response in a climate-affected system as a result of only a moderate additional change in the inputs to that system (such as an increase in the CO_2 concentration). Exceeding one or more tipping points, which "occur when the climate system is forced to cross some threshold, triggering a translation to a new state at a rate determined by the climate system itself and faster than the cause" (Committee on Abrupt Climate Change 2002), could result in abrupt changes in the climate or any part of the climate system. These changes would likely produce impacts at a rate and intensity far greater than the slower, steady changes currently being observed (and in some cases, planned for) in the climate system.

[9] The cryosphere describes the portion of Earth's surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.

The phrase tipping point is also used outside the climate modeling community. In addition to climate scientists, many others – including biologists, marine chemists, engineers, and policymakers – are concerned about tipping points, because it is not just the climate that can change abruptly. The same type of non-linear responses exist in physical, environmental, and societal systems that climate affects. For example, ocean acidity resulting from an elevated atmospheric concentration of CO_2 might reach a point at which there would be a dramatic decline in coral ecosystems. Consideration of possible tipping points could therefore encompass sharp changes in climate-affected resources and not be restricted to climate change alone.

Using the broad definition of the term tipping point to include both climate change and its consequences, the scale of spatial responses can range from global (e.g., a "supergreenhouse" atmosphere with higher temperatures worldwide) to continental or subcontinental changes (such as dramatically altering the Asian monsoon), to regional (e.g., drying in the southwestern United States leading to increases in the frequency of fires, to local (such as loss of the Sierra Nevada snowpack). The definition of tipping point used by Lenton *et al.* (2008) (discussed below) specifically applies only to subcontinental or larger features, whereas public policy is concerned with a wider range of scales, as the IPCC analysis (discussed below) suggests.

The temporal scales considered are also important. On crossing a tipping point, the evolution of the climate-affected system is no longer controlled by the time scale of the climate forcing (such as the heat absorption by GHGs), but rather is determined by its internal dynamics, which can either be much faster than the forcing, or substantially slower. The much faster case – abrupt climate change – might be said to occur when the:

- Rate of change is sharply greater than (or a different sign than) what has been prevailing over previous decades;
- State of the system exceeds the range of variations experienced in the past; or
- Rate has accelerated to a pace that substantially exceeds the resources and ability of nations to respond to it.

Climate changes could occur in many ways as tipping points are reached. These mechanisms range from the appearance or unusual strengthening of positive feedbacks – self-reinforcing cycles – and reversible-phase transitions in climate-affected systems to irreversible-phase transitions – where a threshold has been crossed that could lead to either abrupt or unexpected changes in the rate or direction of change in climate-affected systems. Although climate models incorporate many positive (and negative, or dampening) feedback mechanisms, the magnitude of these effects and the threshold at which the feedback-related tipping points are reached are only roughly known, especially regarding global impacts. In addition, models of climate and climate-affected systems do not contain all feedback processes. Although substantial progress has been made in understanding the qualitative processes associated with tipping points, there are limits to the quantitative understanding of many of these systems.

In recent years, the concept of a tipping point – or a set of tipping points – in Earth's climate system has been attracting increased attention among climate scientists and policy makers. The following sections draw on perspectives from four key analyses of the issue and other relevant research: the IPCC, the USCCSP, paleoclimate[10] evidence, and Lenton *et al.* (2008). The section concludes with a brief comparative evaluation.

IPCC Perspectives on Tipping Points

In its Fourth Assessment Report, the IPCC addresses the issue of tipping points in the discussion of "major or abrupt climate changes" and highlights three large systems: the meridional overturning circulation (MOC) system that drives Atlantic Ocean circulation, the collapse of the West Antarctic ice sheet, and the loss of the Greenland ice sheet (Meehl *et al.* 2007). The IPCC states that there is uncertainty in the understanding of these systems but concludes that these systems are unlikely to reach their tipping points within the 21st Century (Meehl *et al.* 2007). The IPCC also mentions additional systems, as noted below, that might have tipping points, but does not include estimates for them.

The IPCC WGI report (Meehl *et al.* 2007) describes various climate and climate-affected systems that might undergo abrupt change, contribute to "climate surprises," or experience irreversible impacts. The systems that the IPCC described include:

- Atlantic MOC (AMOC) and other ocean circulation changes
- Arctic sea ice
- Glaciers and ice caps
- Greenland and West Antarctic ice sheets
- Vegetation cover
- Atmospheric and ocean-atmosphere regimes

The IPCC Working Group II (WGII) report provides insight on the uncertainties surrounding tipping points, their systemic and impact thresholds, and the value judgments required to select a critical level of warming (Carter *et al.* 2007). The presence of these thresholds can also present their own physical and ecological limits and informational and cognitive barriers to adaptation (Adger *et al.* 2007). In the case of this FEIS, uncertainty prevents NHTSA from being able to quantify the impacts of the alternatives under consideration on specific tipping-point thresholds.

In the IPCC WG II report, certain thresholds are assumed and then used with analyses of emissions scenarios and stabilization targets to assess how certain impacts might be avoided (Schneider *et al.* 2007). For example, several authors hypothesize that a large-scale climatic event or other impacts (for example, widespread coral-reef bleaching; deglaciation of West Antarctica) would be likely if atmospheric CO_2 concentrations stabilize at levels exceeding 450 ppm, although the location of the tipping points and thresholds is uncertain (O'Neill and Oppenheimer 2002, Lowe *et al.* 2006, and Corfee-Morlot and Höhne 2003, all as cited in Schneider *et al.* 2007).

USCCSP Perspectives on Tipping Points

The USCCSP reaches similar conclusions in its report *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008). The USCCSP report summarizes scientific studies that suggest that there are several "triggers" of abrupt climate change and that "anthropogenic forcing *could* increase the risk of abrupt climate change;" however, "future abrupt changes cannot be predicted with confidence" because of the insufficiencies of current climate

[10] Paleoclimatology is the study of climate change through the physical evidence left on earth of historical global climate change (prior to the widespread availability of records to temperature, precipitation, and other data). *See generally* http://www.giss.nasa.gov/research/paleo/.

models, which reflect the limits of current understanding.[11] However, the USCCSP report does reiterate the conclusion that if it occurs, an abrupt climate change event would likely transpire over the course of many hundreds of years and that it is *"very unlikely"* that any abrupt climate change will occur "during the 21st century."

The USCCSP analysis considers the susceptibility of the same three systems to abrupt change as IPCC highlighted: the AMOC system that drives Atlantic Ocean circulation, the collapse of the West Antarctic ice sheet, and the loss of the Greenland ice sheet (National Science and Technology Council 2008). The USCCSP analysis also suggests that there are thresholds in non-climate systems influenced by CO_2 emissions, such as ocean acidification, where there could be a threshold beyond which existing coral reef ecosystems cannot survive (CCSP 2008e). The USCCSP report concludes that these impacts, including climate-related thresholds, could occur in groups as thresholds are crossed, but, due to the uncertainty, more research is needed to quantify the impacts of crossing particular thresholds and to determine when these thresholds would be reached (CCSP 2008e). A forthcoming USCCSP report, Synthesis and Assessment Product 3.4, "Abrupt Climate Change," will provide additional information on this topic, focusing on glaciers and ice sheets, hydrological change, the MOC, and methane releases.

Paleoclimate Evidence on Tipping Points

The paleoclimate record cited by IPCC, USCCSP, and others gives an indication of sea-level rise from previous ice-sheet melt, and the corresponding temperature for these periods. For example, geological evidence showing the presence of elevated beaches suggests that global sea level was 4 to 6 meters higher during the most recent interglacial period about 125,000 years ago (Jansen *et al.* 2007). Paleoclimatic reconstructions suggest that global average temperature then was about 1 °C (1.8 °F) warmer than during the present interglacial period (Hansen *et al.* 2007b). Corings from the ice sheets to determine their ages, supplemented by simulations of ice-sheet extent, suggest that large-scale retreat of the southern half of the Greenland ice sheet and other Arctic ice fields likely contributed roughly 2 to 4 meters of sea-level rise during the last interglacial, with most of any remainder likely coming from the Antarctic ice sheet (Jansen *et al.* 2007).

Paleoclimatic reconstructions also indicate occurrences of abrupt changes in the terrestrial, ice, and oceanic climatic records. For example, ice-core records suggest that temperatures atop the Greenland ice sheet warmed by 8 to 16 °C (14 to 29 °F) within a few decades during Dansgaard-Oeschger events,[12] which were likely caused by the North Atlantic Ocean being covered by catastrophic outflows of glacial meltwater from the North American ice sheet that was present during glacial times (Jansen *et al.* 2007). A more recent study (Steffensen *et al.* 2008) provides more detail, indicating that a there was a sharp warming over 1 to 3 years (that is, "abrupt climate change happens in [a] few years"), followed by a more gradual warming over 50 years.

Based on the IPCC estimates of temperature increases of approximately 2 to 4 °C in the next 100 years, MacCracken (2008) notes that paleoclimatic research indicates that corresponding sea-level rise could be 10 to 20 meters or more from the melting of the West Antarctic and Greenland ice sheets. The time required to melt the ice sheets is uncertain, ranging from decades to centuries or longer. MacCracken (2008) suggests that "significant sea level rise [over 1 meter] could happen relatively

[11] *See* U.S. Climate Change Science Program, Synthesis and Assessment Product 3.1 (Climate Models: An Assessment of Strengths and Limitations), Final Report (July 2008), *available at* http://www.climatescience.gov/Library/default.htm#sap.

[12] Dansgaard-Oeschger events are very rapid climate changes—up to 7 °C in some 50 years—during the Quaternary geologic period, and especially during the most recent glacial cycle. (A Dictionary of Geography. Oxford University Press, 1992, 1997, 2004.)

quickly," meaning less than a century. For example, the average rate of rise from 20 kiloannum[13] (ka) to 8 ka was about 1 meter per century, so there have been periods with high rates of rise, although the melting North American ice sheet was an order of magnitude larger than Greenland is today (MacCracken, personal communication, 2008). For the future, Hansen *et al.* (2007b) asserts that positive feedback mechanisms in the climate system have the potential to cause large and rapid shifts in climate and in factors like glacial melt and sea-level rise that are closely dependent on the climate; Rahmstorf (2007) presents a projected sea-level rise in 2100 of 0.5 to 1.4 meters above the 1990 level.

In a study utilizing model runs and paleoclimatic data[14], Hansen *et al.* (2007b) conclude that "…a CO_2 level exceeding about 450 ppm is 'dangerous,'" where "dangerous" is defined by the authors to be global warming of more than 1 ºC (1.8 ºF) above the level in 2000, potentially leading to highly disruptive effects. Although this 450-ppm estimate has limitations and uncertainties, Hansen actually considers this estimate of dangerous CO_2 concentration to be an upper limit because it depends on several simplifying assumptions (Hansen 2008b). He warns that the limit might be lower and that a "safe" level of CO_2 could be 350 ppm – lower than the CO_2-equivalent concentration, including the offsetting effects of aerosols, is today (Hansen 2008b).

The range of views linking past and future sea-level rise is clearly broad, with uncertainty attributable to each view. Therefore, the forthcoming USCCSP report – Synthesis and Assessment Product 3.4, "Abrupt Climate Change" – should provide additional, more complete information on the issue.

Perspectives on Tipping Points from a Critical Review of the Literature and an Expert Elicitation as Presented by Lenton *et al.* (2008)

Building on the IPCC and USCCSP research, during a workshop titled "Tipping Points in the Earth System," experts identified several climate systems that have tipping points and conducted an expert elicitation involving 52 members of the international scientific community, many of whom participated in the IPCC. This study identified nine systems facing separate tipping points due to increased CO_2 and temperature levels that met four scientifically based criteria to be considered "policy-relevant potential future tipping elements in the climate system" (Lenton *et al.* 2008). Additional systems were identified but insufficient information precluded these systems from meeting the definition of policy relevant. The systems at risk that the researchers identified are:

- Arctic sea ice
- Greenland ice sheet
- West Antarctic ice sheet
- Atlantic thermohaline circulation (a component of the AMOC)
- El-Niño-Southern oscillation
- Indian summer monsoon
- Sahara/Sahel and West African monsoon
- Amazon rainforest
- Boreal forest

[13] Kiloannum means 1,000 years ago.
[14] The authors compare the corresponding GHG concentrations and associated temperature increases alongside paleoclimatology research to demonstrate that abrupt changes have occurred in Earth's past, resulting from a similar range in increased temperature as those being predicted, and to argue the existence of a CO_2 concentration equivalent level (in atmospheric GHG concentration) at which the probability of abrupt, irreversible changes in climate-affected systems might occur.

The discussion that follows is drawn primarily from the Lenton *et al.* (2008) study, including the citations therein.

Arctic sea ice. The surface of Arctic sea ice has a higher reflectivity (albedo) than the darker ocean surface. As sea ice melts from higher air and ocean temperatures, more of the ocean is exposed, which allows more radiation to be absorbed, amplifying the sea-ice melt. In summer, Arctic sea-ice loss could lead to the ice cap melting beyond a certain size/thickness, making it unstable and leading to an ice-free Arctic. Recent record ice losses and modeling studies have led some researchers to suggest that the summer Arctic will be ice free within a decade or less, that there is a critical threshold for summer Arctic sea-ice loss, and that this threshold has already been crossed (Borenstein and Joling 2008).

Greenland ice sheet. The Greenland ice sheet is also susceptible to positive feedbacks. Melting at the glacial margins lowers the edge of the ice sheet to elevations that are warmer and where more melting will occur. The IPCC estimated the Greenland ice sheet threshold for negative surface mass at 1.9 to 4.6 °C (3.4 to 8.3 °F) above pre-industrial temperature, well within the predicted temperature range for this century. Dynamic ice-melting processes, regional temperatures, warming surrounding oceans, and recent observations indicating that both Greenland and Antarctica are now losing mass have led researchers to conclude that the timescale for Greenland ice-shelf collapse is conceivably on a scale of hundreds rather than thousands of years.

West Antarctic ice sheet. The West Antarctic ice sheet is grounded below sea level and positive feedbacks could result from the loss of buttressing sea-ice shelves and the ingress of warmer ocean water. While centuries or millennia could to pass before a collapse, the thresholds for ocean and surface atmospheric warming temperature are likely to be crossed this century. A recent study of ice-core records suggests strong links between past West Antarctic climate, and potentially its ice sheet, to large-scale changes in global climate, particularly major El Niño events (Schneider and Steig 2008). It should be noted that ice-sheet loss, even over millennia, could cause the sea level to rise at a rate greater than 1 meter per century – more than five times the rate of rise during the 20th Century. The level reached would be higher than has been the case during at least the past few thousand years when coastal cities were established.

Atlantic thermohaline circulation. The term thermohaline circulation (THC) refers to the physical driving mechanism of ocean circulation, resulting from fluxes of heat and freshwater across the sea surface, subsequent interior mixing of heat and salt, and geothermal heat sources. The MOC, discussed in the IPCC and USCCSP reports, is the observed response in an ocean basin to this type of ocean circulation coupled with wind-driven currents. The Lenton *et al.* (2008) paper refers to risk to the Atlantic THC instead of the AMOC because they are discussing the influence of climate change on the underlying cooling or freshwater forcing of the Atlantic Ocean circulation, even though this in turn dramatically affects the AMOC.

If enough freshwater enters the North Atlantic (such as from melting sea ice or the Greenland ice sheet), the density-driven sinking of North Atlantic waters might be reduced or even stopped, as evidence indicated occurred happened during the last glacial cycle. This would likely reduce the northward flow of energy in the Gulf Stream and result in less heat transport to the North Atlantic. At the same time, reduced formation of very cold water would likely slow the global ocean THC, leading to impacts on global climate and ocean currents. The IPCC review of the results of model simulations suggests that an abrupt transition of the Atlantic Ocean's component of the global THC is *very unlikely* this century. However, more recent modeling that includes increased freshwater inputs suggests there could be initial changes this century, with larger and more intense reductions in the overturning circulation persisting for many centuries (Mikolajewicz *et al*. 2007).

El-Niño-Southern oscillation (ENSO). The changes that might lead to increasingly persistent (and frequent) El Niño (or La Niña) conditions are particularly uncertain. Increases in ocean heat content could have an effect on ENSO conditions, but predictive and paleoclimate modeling studies do not agree on the magnitude, frequency, and direction of these effects. However, ENSO has substantial and large-scale effects on the global climate system.

Indian summer monsoon. The Indian summer monsoon is the result of land-to-ocean pressure gradients and advection of moisture from ocean to land. By warming the land more than the ocean, climate change generally strengthens the monsoon. However, reductions in the amount of solar radiation that is absorbed by the land surface, such as land-use change, generally weaken it. An albedo greater than roughly 50 percent is necessary to simulate the collapse of the Indian summer monsoon in a simple model (Zickfield *et al.* 2005). IPCC projections do not project passing a threshold this century, although paleoclimatic reconstructions do indicate that the monsoon has changed substantially in the past.

West African monsoon. Sahara/Sahel rainfall depends on the West African monsoon circulation, which is affected by sea-surface temperature. By warming the land more than the ocean and therefore causing greater upward movement of the air, GHG forcing is expected to draw more moist oceanic air inland and thereby increase rainfall in the region, which has been shown by some models. Other models, however, project a less productive monsoon. The reasons for this inconsistency are not clear.

Amazon rainforest. The recycling of precipitation in the Amazon rainforest means that deforestation, reductions in precipitation, a longer dry season, and increased summer temperature could cause forest dieback. These conditions are thought to be linked to a more persistent El Niño and an increase of global average temperature by 3 to 4 °C (5.4 to 6.8 °F). Important additional stressors also present include forest fires and human activity (such as land clearing). A critical threshold might exist in canopy cover, which could be reached through changes in land use or regional precipitation, ENSO variability, and global forcing.

Boreal Forest. The dieback of boreal forest could result from a combination of increased heat stress and water stress, leading to decreased reproduction rates, increased disease vulnerability, and subsequent fire. Although highly uncertain, studies suggest a global warming of 3 °C (5.4 °F) could be the threshold for loss of the boreal forest.

Comparative Evaluation

The Lenton *et al.* (2008) group's list differs slightly from that of the IPCC because of differences in definition and criteria, an attempt to be more explicit than the IPCC, and the inclusion of more recent studies. The scientists defined these tipping points as "tipping elements" and attempted to estimate when the tipping element of the various systems might be reached, ranging from about 1 year (rapid) to more than 300 years (slow). As with the IPCC and USCCSP conclusions, this group also concluded that the loss of the Greenland ice sheet, the collapse of the West Antarctic ice sheet, and the disruption of the Atlantic THC systems are not expected to cross their estimated tipping elements in this century (though actions this century could create enough momentum in the climate system to cross the threshold in future centuries[15]). However, this group determined that several other systems could reach a tipping threshold within the century: loss of Arctic sea ice, Indian summer monsoon disruption, Sahara/Sahel and West African monsoon changes, drying of the Amazon rainforest, and warming of the boreal forest.

Another factor that might accelerate climate change at rates faster than those currently observed is the possible shift of soil and vegetation-carbon feedbacks, causing the soil and vegetation to become

[15] *See* Lenton *et al.* (2008), p. 1787.

carbon sources rather than carbon sinks. Currently, soil and vegetation act as sinks, absorbing carbon from the atmosphere as plant material and storing carbon in the soil when the plants die. However, by mid-century (about the time the IPCC predicts the global average temperature reaches 2 ºC (3.6 ºF) above pre-industrial levels), increasing temperatures and precipitation could cause increased rates of transpiration, resulting in soil and vegetation becoming a potential source of carbon emissions (Cox *et al.* 2000 as cited in Meehl *et al.* 2007). Warming could also thaw frozen Arctic soils (permafrost), causing the wet soils to emit more methane, a GHG. There is evidence that this process is already taking place (Walter *et al.* 2007). This additional research clarifies the concept of tipping points by further revealing that several climate systems might have tipping points that could occur within the century, and in some systems changes are currently being observed. However, uncertainties exist, especially for timing estimates, and the uncertainties are at least partly responsible for the broad spectrum of views regarding the tipping point. Exactly where these tipping points exist, and the levels at which they occur, are still a matter in need of further scientific investigation before precise quantitative conclusions can be made.

Where information in this FEIS analysis is incomplete or unavailable, as here due to current climate modeling limitations, NHTSA has relied on CEQ regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). CEQ regulations state, in part, that when an agency is evaluating "reasonably foreseeable significant adverse impacts on the human environment and …information relevant to…[the] impacts cannot be obtained because the overall costs of obtaining it are exorbitant or the means to obtain it are not known, the agency shall include within the [EIS]:

1. a statement that such information is incomplete or unavailable;
2. a statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment;
3. a summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment; and
4. the agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community. For the purposes of this section, "reasonably foreseeable" includes impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason." 40 CFR § 1502.22 (b).

This FEIS addresses the requirements of 40 CFR § 1502.22 appropriately. The above survey of the current state of climate science tipping points provides a "summary of existing credible scientific evidence which is relevant to evaluating the…adverse impacts of the CAFE standards." In *Colorado Environmental Coalition v. Dombeck,* the Tenth Circuit found that the ultimate goal of the agency is to ensure that the EIS's "form, content, and preparation foster both informed decision making and informed public participation" (185 F.3d 1162, 1172 [10th Cir. 1999] [quoting *Oregon Envtl. Council v. Kunzman*, 817 F.2d 484, 492 (9th Cir. 1987)]. The Tenth Circuit held that 40 CFR § 1502.22 could not be read as imposing a "data gathering requirement under circumstances where no such data exists." *Id.*

In this case, this FEIS acknowledges that information on tipping points or abrupt climate change is incomplete, and the state of the science does not allow for a characterization of how the CAFE alternatives influence these risks. This action alone, even as analyzed for the most stringent alternative, does not produce sufficient CO_2 emissions reductions to avert levels of abrupt and severe climate change. To the degree that the action in this rulemaking reduces the rate of CO_2 emissions, the rule contributes to the general reduction or delay of reaching these tipping-point thresholds. These conclusions are not meant to be read as expressing NHTSA's view that tipping points in climate-related systems are not areas of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] *of the proposed action*" (42 U.S.C. § 4332(2)(C)(i) [emphasis added]). The above discussion fulfills NHTSA's NEPA obligations regarding this issue.

4.4.4 Environmental Consequences

This section describes the consequences of the MY 2011-2015 CAFE standards in relation to GHG emissions and climate effects.

4.4.4.1 Greenhouse Gas Emissions

To estimate the emissions resulting from changes in passenger car and light truck CAFE standards, NHTSA uses the Volpe model (*see* Section 3.1.3 for a description of the model). The change in fuel use projected to result from each alternative CAFE standard determines the resulting impacts on total and petroleum energy use, which in turn affects the amount of CO_2 emissions. These CO_2 emissions estimates also include upstream emissions, which occur from the use of carbon-based energy during crude oil extraction, transportation, and refining, and in the transportation, storage, and distribution of refined fuel. Because CO_2 accounts for such a large fraction of total GHG emitted during fuel production and use – more than 95 percent, even after accounting for the higher global warming potentials (GWPs) of other GHGs – NHTSA's consideration of GHG impacts focuses on reductions in CO_2 emissions resulting from the savings in fuel use that accompany higher fuel economy.[16]

NHTSA considers three measures of the cumulative impact of alternative CAFE standards (for MY 2011-2015 *and* using the assumption of reaching 35 mpg by 2020 to estimate the foreseeable MY 2016-2020) on CO_2 emissions:

- CO_2 emissions from the vehicles they would affect, namely, MY 2011-2020 passenger cars and light trucks;
- CO_2 emissions by the entire U.S. passenger car and light truck fleets that would result during future years (2021-2100) from each alternative increase in CAFE standards; and
- Cumulative emissions reductions over the history of the CAFE Program, including those projected to result from each alternative increase in CAFE standards considered for NHTSA's proposed action. Emissions reductions represent the differences in total annual emissions by all cars or light trucks in use between their estimated future levels under the No Action Alternative (baseline), and with each alternative CAFE standard in effect.

Under NEPA, the assessment of cumulative impacts must include the impact on the environment resulting from "the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions." 40 CFR § 1508.7. Because EISA directs NHTSA to increase CAFE standards to reach a combined fleet average CAFE level of at least 35 mpg by model year 2020, MY 2016-2020 CAFE standards are reasonably foreseeable and must be accounted for when analyzing the cumulative impacts of the MY 2011-2015 CAFE standards. For each alternative, NHTSA assumed that passenger-car and light-truck CAFE standards would continue to increase over MY 2016-2020 at their average annual rate of increase over MY 2011-2015. This assumption results in passenger-car and light-truck CAFE standards under each action alternative that meet or exceed the EISA requirement of a combined fleet average of at least 35 mpg by model year 2020. NHTSA assumed further that the fuel economy

[16] Although this section only includes a discussion of CO_2 emissions, the climate modeling discussion in Section 3.4.4.4 assesses the direct and indirect effects associated with emissions reductions of multiple gases, including CO_2, CH_4, N_2O, SO_2, CO, NO_x, and VOCs.

standards for model year 2020 would remain in effect through the end of the analysis period. Because the CAFE standards apply to new vehicles, this assumption results in emissions reductions and fuel savings that continue to grow as new vehicles meeting the CAFE standards for MY 2020 and beyond are added to the fleet in each subsequent year, reaching their maximum values when all passenger cars and light trucks in the U.S. fleet meet these standards. Thus, NHTSA evaluated the effect of CAFE standards to date, and potential CAFE standards for MY 2016-2020 because they are considered a reasonably foreseeable action.

NHTSA estimates that the cumulative CO_2 reductions from CAFE to date, from 1978-2007, have been 8,911 $MMTCO_2$, according to the Volpe model. Assuming no further increases in fuel economy standards – that is, the standards for MY 2010 vehicles remain in force through 2100 – NHTSA estimates that continuation of the MY 2010 standards would result in further emissions reductions of 135,535 $MMTCO_2$ as compared to the reference case of no CAFE standards.

Emissions reductions resulting from the CAFE standards for MY 2011-2015 and MY 2016-2020 cars and light trucks were estimated from 2010 to 2100. Reductions begin in the year 2010, the first year that MY 2011 vehicles are on the road. For each alternative, all vehicles after MY 2020 were assumed to meet the MY 2020 CAFE standards. Emissions were estimated for all alternatives through 2100, and these emissions were compared against the NPRM baseline (which assumes all vehicles post-MY 2010 meet the MY 2010 standards) to estimate emissions reductions. The Volpe model estimates emissions through the year 2060. Annual emissions reductions from 2061-2100 were held constant at 2060 levels.

Table 4.4-1 lists total emissions reductions from MY 2010-2100 new passenger cars and light trucks for each of the seven alternatives. Projections of emissions reductions over the 2010 to 2100 period due to the MY 2011-2015 CAFE standards and the potential standards for MY 2016-2020 ranged from 24,321 to 49,157 $MMTCO_2$. Compared to global emissions of 4,850,000 $MMTCO_2$ over this period (projected by the A1B-medium scenario), the incremental impact of this rulemaking is expected to reduce global CO_2 emissions by about 0.5 to 1.0 percent.

Table 4.4-1

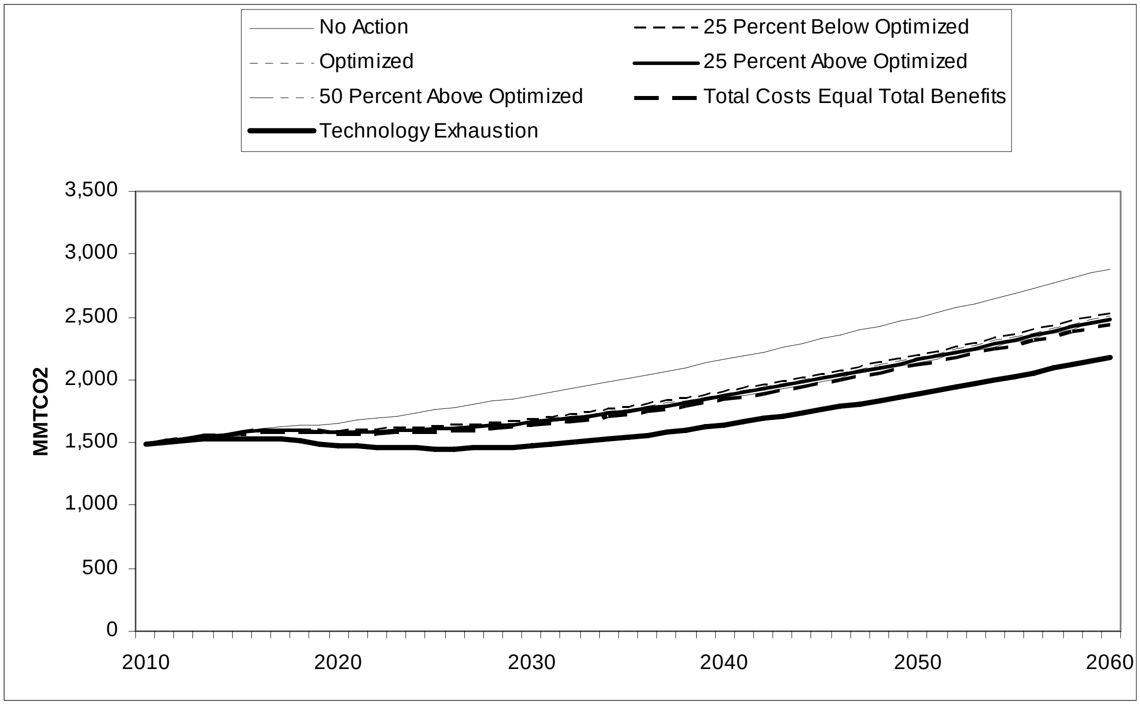
Reference Case Cumulative Emissions and Emissions Reductions Due to the MY 2011-2015 Standards and Potential MY 2016-2020 Standards Projected for 2010-2100 ($MMTCO_2$)

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	221,258	0
2 25 Percent Below Optimized	196,937	24,321
3 Optimized	195,816	25,442
4 25 Percent Above Optimized	194,057	27,201
5 50 Percent Above Optimized	192,478	28,780
6 Total Costs Equal Total Benefits	191,073	30,185
7 Technology Exhaustion	172,101	49,157

To gain a sense of the relative impact of these reductions, it can be helpful to compare them against emissions projections from the transportation sector, and expected or stated goals from existing programs designed to reduce CO_2 emissions. For ease of comparison, NHTSA focuses on the Optimized Alternative for this discussion.

As mentioned earlier, U.S. cars and light trucks account for 19.2 percent of CO_2 emissions in the United States. Thus, with the action alternatives reducing U.S. car and light truck CO_2 emissions by 11 to 22 percent, this would represent a reduction of 2.1 to 4.3 percent of total U.S. CO_2 emissions (assuming the relative contribution of cars and light trucks stays the same). Projected annual emissions from cars and light trucks under the MY 2011-2015 and MY 2016-2020 CAFE standards are shown in Figure 4.4-6.

Figure 4.4-6. Reference Case Cumulative Annual Emissions Under the MY 2011-2015 Standards and Potential MY 2016-2020 Standards (MMTCO$_2$)



Emissions of CO_2, the primary gas that drives climate effects, from the U.S. automobile and light truck fleet represented about 2.5 percent of total global emissions of CO_2 in 2000 (EPA 2008a, WRI 2008). Although substantial, this source is a still small percentage of global emissions. The relative contribution of CO_2 emissions from the U.S. light vehicle fleet is expected to decline in the future, due primarily to rapid growth of emissions from developing economies (which are due in part to growth in global transportation sector emissions). In the SRES A1B (medium) scenario (Nakicenovic *et al.* 2000), the share of liquid fuel use, mostly petroleum and biofuels, from OECD countries declines from 60 percent in 2000 to 17 percent in 2100.

In their *Annual Energy Outlook 2007*, the EIA projects U.S. transportation-derived CO_2 emissions will increase from 2,037 MMTCO$_2$ in 2010 to 2,682 MMTCO$_2$ in 2030, with cumulative emissions from transportation over this period reaching 49,287 MMTCO$_2$. Over this same period, the emissions reductions from this rulemaking are projected to be 1,582 to 3,870 MMTCO$_2$, which would yield a 3- to 8-percent reduction in emissions from the transportation sector. The emissions reductions as a result of increasing fuel economy standards would be expected to increase further as new vehicles enter the fleet and older vehicles are retired. For example, in 2030, projected emissions reductions would be 192 to 402 MMTCO$_2$, a 7- to 15-percent decrease from projected U.S. transportation emissions of 2,682 MMTCO$_2$ in 2030. It is important to note that the EIA did not account for the expected effects of this rulemaking in their forecast (EIA 2007), thus allowing a comparison of the impact of this rulemaking to U.S. transportation emissions under the No Action Alternative.

As another measure of the relative environmental impact of this rulemaking, these emissions reductions can be compared to existing programs designed to reduce GHG emissions in the United States. In 2007, Arizona, California, New Mexico, Oregon, and Washington formed the Western Climate

Initiative (WCI) to develop regional strategies to address climate change. WCI has a stated goal of reducing 350 $MMTCO_2$ equivalent over the period from 2009 to 2020 (WCI 2007a). Emissions levels in 2020 would represent a 33-percent reduction from the future baseline, and a 15-percent reduction from the beginning of the action (WCI 2007b). By comparison, this rulemaking is expected to reduce CO_2 emissions by 197 to 755 $MMTCO_2$ over the same time period, with emissions levels in 2020 representing a 4- to 11-percent reduction from the future baseline emissions for cars and light trucks. In the Northeast, nine Northeast and Mid-Atlantic states have formed the Regional Greenhouse Gas Initiative (RGGI) to reduce CO_2 emissions from power plants. Emissions reductions from 2006 to 2024 are estimated at 268 $MMTCO_2$ (RGGI 2006).[17] This represents a 23-percent reduction from the future baseline and a 10-percent reduction from the beginning of the action (RGGI 2006). By comparison, NHTSA forecasts that this rulemaking will reduce CO_2 emissions by 593 to 1,731 $MMTCO_2$ over this timeframe, with emissions levels in 2024 representing a 7- to 16-percent reduction from the future baseline emissions for cars and light trucks.

Two points are important to note. First, emissions from sources addressed in the WCI and RGGI both *decrease* compared to the beginning of the action, while emissions from cars and trucks continue to *increase* under this rulemaking – despite increased fuel efficiency – due to increases in VMT. Second, these projections are only estimates, and the scopes of these climate programs differ from this rulemaking in geography, sector, and purpose. Also, the approach, goals, and methods of reductions vary between NHTSA's action and these initiatives. However, the expected end result – reduction of tons of CO_2 – for all these initiatives is similar.

The Stabilization Wedge Theory described by Pacala and Socolow (2004) for climate change mitigation includes a graphical representation of the contributions of many GHG reduction initiatives and the ability for all of these "wedges," over time, to add up to a climate change solution. The reductions from this rulemaking could be viewed in this context as being one of many needed to reduce U.S. transportation emissions.

Where information in the analysis included in this FEIS is incomplete or unavailable, NHTSA has relied on CEQ regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). In this case, the comparison of emissions reductions from the action alternatives to emissions reductions associated with other programs is intended to aid decisionmakers by providing relative benchmarks, rather than absolute metrics for selecting among alternatives. In summary, the alternatives analyzed here deliver GHG emissions reductions that are on the same scale as many of the most progressive and ambitious GHG emissions reduction programs underway in the United States.

4.4.4.2 Direct and Indirect Effects on Climate Change

The approach to estimating the cumulative effects of climate change from the MY 2011-2015 CAFE standards combined with the potential MY2016-2020 CAFE standards mirrors that used to estimate the direct and indirect effects of the MY 2011-2015 CAFE standards. Again, because EISA requires average fuel economy of the passenger cars and light trucks to reach a combined average of at least 35 mpg by 2020, the MY 2016-2020 CAFE standards are a reasonably foreseeable future action and, therefore, must be accounted for when analyzing the cumulative impacts of the MY 2011-2015 CAFE standards. For each alternative, NHTSA assumed that passenger-car and light-truck CAFE standards would continue to increase over MY 2016-2020 at their average annual rate of increase over MY 2011-2015. This assumption results in passenger-car and light-truck CAFE standards under each action alternative that meet or exceed the EISA requirement of a combined fleet average of at least 35 mpg by

[17] Emission reductions were estimated by determining the difference between the RGGI Cap and the Phase III RGGI Reference Case. These estimates do not include offsets.

model year 2020. NHTSA assumed further that the fuel economy standards for model year 2020 would remain in effect through the end of the analysis period. Because the CAFE standards apply to new vehicles, this assumption results in emissions reductions and fuel savings that continue to grow as new vehicles meeting the CAFE standards for MY 2020 and beyond are added to the fleet in each subsequent year, reaching their maximum values when all passenger cars and light trucks in the U.S. fleet meet these standards. Overall, the emissions reductions for the MY 2011-2015 CAFE standards have a small impact on climate change. The emissions reductions and resulting climate impacts for the MY 2011-2015 and MY 2016-2020 CAFE standards are larger, although they are still relatively small in absolute terms.

The direct and indirect effects of the alternatives on climate change are described in the following section in terms of (1) atmospheric CO_2 concentrations, (2) temperature, (3) precipitation, and (4) sea-level rise.

4.4.4.2.1 Atmospheric Carbon Dioxide Concentrations

MAGICC is a simple climate model that is well calibrated to the mean of the multi-model ensemble results for three of the most commonly used emissions scenarios – B1 (low), A1B (medium), and A2 (high) from the IPCC SRES series – as shown in Table 4.4-2.[18] As the table indicates, the model runs developed for this analysis achieve relatively good agreement with IPCC WGI estimates in terms of both CO_2 concentrations and surface temperature.

Table 4.4-2

Comparison of MAGICC Results and Reported IPCC Results (IPCC 2007a)

Scenario	CO_2 Concentration (ppm) IPCC WGI (2100)	CO_2 Concentration (ppm) MAGICC (2100)	Global Mean Increase in Surface Temperature (°C) IPCC WGI (2080-2099)	Global Mean Increase in Surface Temperature (°C) MAGICC (2090)	Sea-level Rise (cm) IPCC WGI (2090-2099) a/	Sea-level Rise (cm) MAGICC (2095)
B1	550	538.3	1.79	1.81	28	26
A1B	715	717.2	2.65	2.76	35	35
A2	836	866.8	3.13	3.31	37	38

a/ The IPCC values represent the average of the 5- to 95-percent range of the rise of sea level between 1980 to 1989 and 2090 to 2099.

A comparison of the sea-level rise from MAGICC 5.3 and the IPCC Fourth Assessment Report can be found in the release documentation for MAGICC 5.3 (Wigley 2008). In Table 3 of the documentation, Wigley (2008) presents the results for six SRES scenarios that show the comparable value for sea-level rise from MAGICC 5.3 (total sea-level rise minus estimates for contributions from non-melt sources such as warming of the permafrost) within 0.01 centimeter (cm) in 2095.

As discussed earlier in Section 3.4.2, the SRES A1B scenario was used to represent the No Action Alternative (Alternative 1) in the MAGICC runs for this FEIS. Table 4.4-3 and Figures 4.4-7 to 4.4-10 show the mid-range results of MAGICC model simulations for Alternative 1 and the six action alternatives for CO_2 concentrations and increase in global mean surface temperature in 2030, 2060, and 2100. As Figures 4.4-7 and 4.4-8 show, the impact on the growth in CO_2 concentrations and temperature is just a fraction of the total growth in CO_2 concentrations and global mean surface temperature. However, the relative impact of the CAFE alternatives is illustrated by the reduction in growth of both CO_2 concentrations and temperature in the Technology Exhaustion Alternative (Alternative 7).

[18] NHTSA used the default climate sensitivity in MAGICC of 3.0 °C.

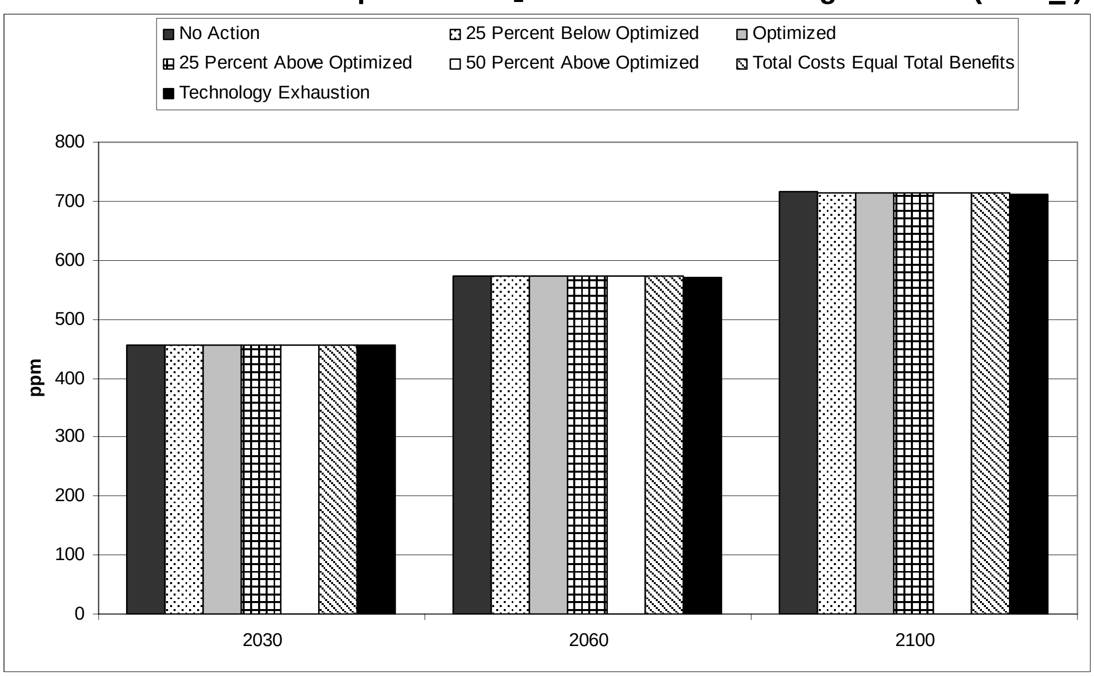
Table 4.4-3

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on CO_2 Concentrations, Surface Temperature Increase, and Sea-level Rise Using MAGICC (A1B a/)

	CO_2 Concentration (ppm)			Surface Temperature Increase (°C)			Sea-level Rise (cm)		
	2030	2060	2100	2030	2060	2100	2030	2060	2100
Totals by Alternative									
1 No Action (A1B-AIM)	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.4	572.7	714.9	0.873	1.940	2.950	7.99	19.27	37.02
3 Optimized	455.4	572.7	714.8	0.873	1.940	2.950	7.99	19.27	37.02
4 25 Percent Above Optimized	455.3	572.6	714.7	0.873	1.940	2.949	7.99	19.27	37.01
5 50 Percent Above Optimized	455.3	572.5	714.5	0.873	1.940	2.948	7.99	19.27	37.01
6 Total Costs Equal Total Benefits	455.3	572.5	714.4	0.873	1.939	2.948	7.99	19.26	37.00
7 Technology Exhaustion	455.1	571.7	712.6	0.871	1.934	2.938	7.99	19.23	36.92
Reduction under CAFE Alternatives									
2 25 Percent Below Optimized	0.1	1.0	2.3	0.001	0.004	0.009	0.00	0.03	0.08
3 Optimized	0.1	1.0	2.4	0.001	0.004	0.009	0.00	0.03	0.08
4 25 Percent Above Optimized	0.2	1.1	2.5	0.001	0.005	0.010	0.00	0.03	0.09
5 50 Percent Above Optimized	0.2	1.2	2.7	0.001	0.005	0.011	0.00	0.03	0.09
6 Total Costs Equal Total Benefits	0.2	1.2	2.8	0.001	0.005	0.011	0.00	0.04	0.10
7 Technology Exhaustion	0.4	2.0	4.6	0.002	0.010	0.020	0.00	0.07	0.18

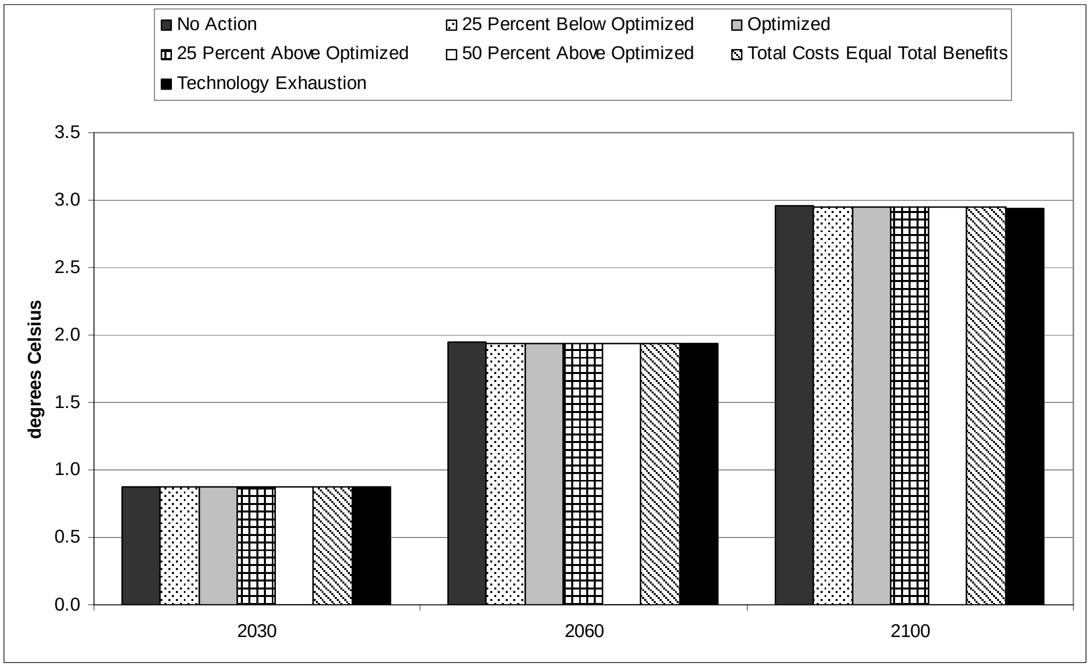
a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 4.4-7. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on CO_2 Concentrations Using MAGICC (A1B a/)



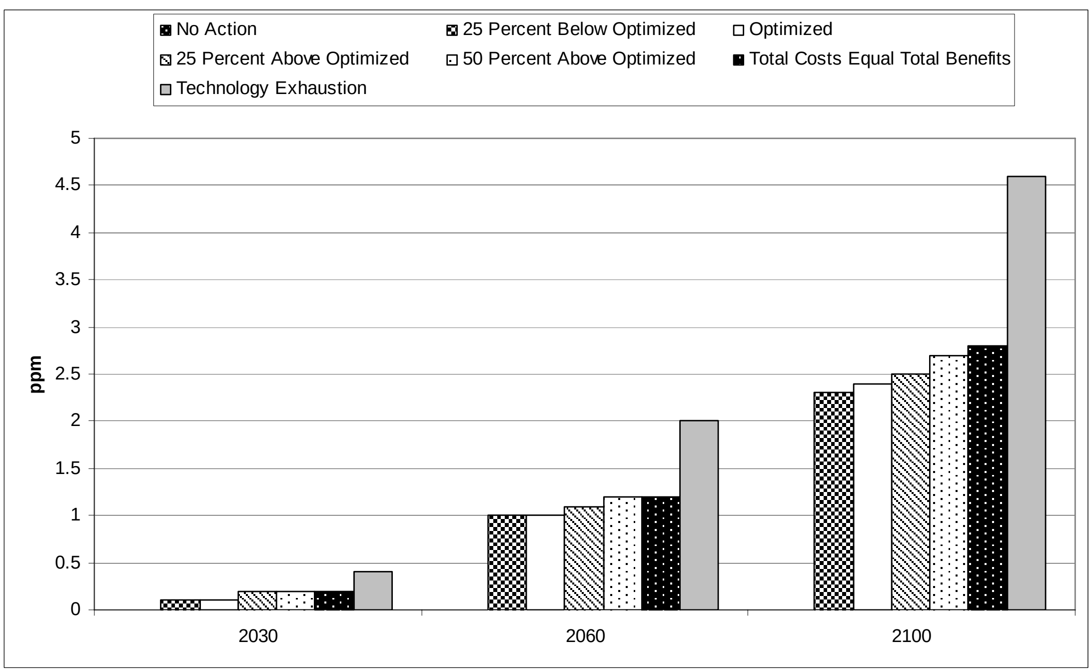
a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 4.4-8. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on the Global Mean Surface Temperature Increase Using MAGICC (A1B a/)



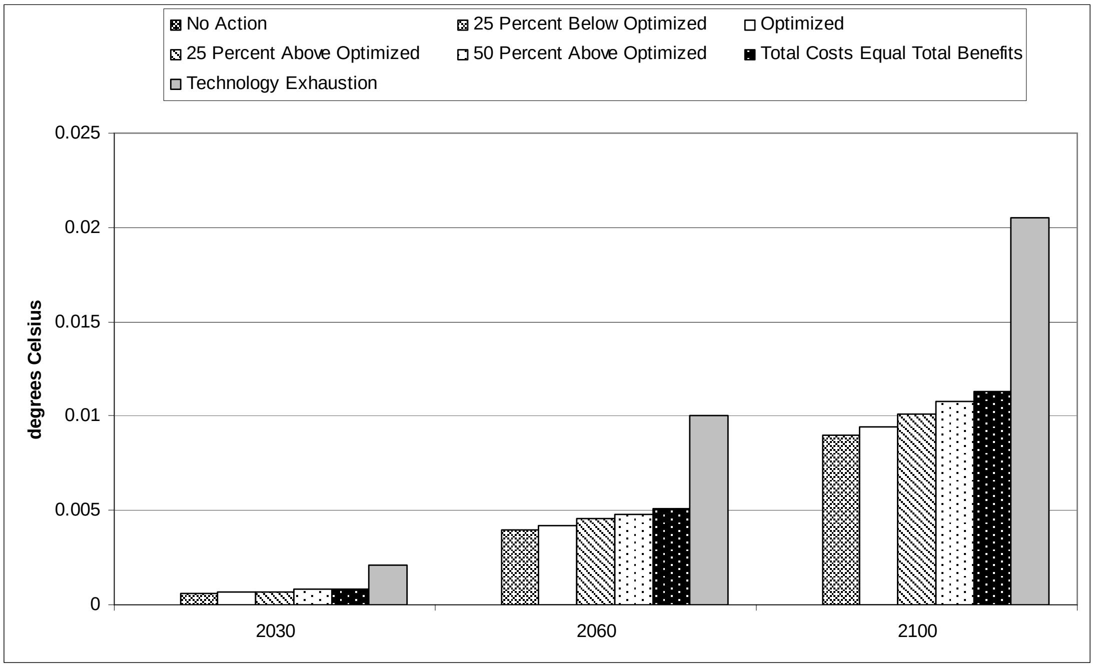
a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 4.4-9. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on the Reduction in the Growth of CO_2 Concentrations Using MAGICC (A1B a/)



a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Figure 4.4-10. Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on the Reduction in the Growth of Global Mean Temperature Using MAGICC (A1B a/)



a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

As shown in Figures 4.4-9 and 4.4-10, the reduction in increase of CO_2 concentrations and the reduction in increase of temperature under the No Action Alternative is nearly twice that of the 25 Percent Below Optimized Alternative (Alternative 2).

As shown in the table and figures, there is a fairly narrow band of estimated CO_2 concentrations as of 2100, from 713 ppm for the Technology Exhaustion Alternative to 717 ppm for the No Action Alternative. For 2030 and 2060, the range is even smaller. Because CO_2 concentrations are the key driver of all other climate effects, this leads to small differences in these effects.

4.4.4.2.2 Temperature

The MAGICC simulations of mean global surface air temperature increases are shown above in Table 4.4-3. For all alternatives, the cumulative global mean surface temperature increase is about 0.87 °C as of 2030, 1.93 to 1.94 °C as of 2060, and 2.94 to 2.96 °C as of 2100 (Table 4.4-3). The differences among alternatives are small. For 2100, the reduction in temperature increase relative to the No Action Alternative ranges from 0.009 °C to 0.02 °C.

Table 4.4-4 summarizes the regional changes to warming and seasonal temperatures from the IPCC Fourth Assessment Report. Quantifying the changes to regional climate from the CAFE alternatives is not possible at this point, but it is expected that the alternatives would reduce the changes relative to the reduction in global mean surface temperature.

Table 4.4-4

Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment Report (Christensen *et al.* 2007)

Land Area	Sub-region	Mean Warming	Maximum Summer Temperatures
Africa	Mediterranean area and northern Sahara	*Likely* larger than global mean throughout continent and in all seasons	
	Southern Africa and western margins		
	East Africa		
Mediterranean and Europe	Northern Europe	*Likely* to increase more than the global mean with largest warming in winter	
	Southern and Central Europe		Maximum Summer Temperatures *likely* to increase more than average
	Mediterranean area		
Asia	Central Asia	*Likely* to be well above the global mean	
	Tibetan Plateau	*Likely* to be well above the global mean	
	Northern Asia	*Likely* to be well above the global mean	
	Eastern Asia	*Likely* to be above the global mean	*Very likely* that heat waves/hot spells in summer will be of longer duration, more intense and more frequent *Very likely* fewer very cold days
	South Asia	*Likely* to be above the global mean	*Very likely* fewer very cold days
	Southeast Asia	*Likely* to be similar to the global mean	
North America	Northern regions/Northern North America	*Likely* to exceed the global mean	Warming *likely* to be largest in winter Minimum winter temperatures *likely* to increase more than the average
	Southwest		Warming *likely* to be largest in summer Maximum summer temperatures *likely* to increase more than the average
	Northeast USA		
	Southern Canada		
	Canada		
	Northernmost part of Canada		

Table 4.4-4 (cont'd)

Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment Report (Christensen *et al.* 2007)

Land Area	Sub-region	Mean Warming	Maximum Summer Temperatures
Central and South America	Southern South America	*Likely* to be similar to the global mean	
	Central America	*Likely* to be larger than global mean	
	Southern Andes		
	Tierra del Fuego		
	Southeastern South America		
	Northern South America		
Australia and New Zealand	Southern Australia	*Likely* comparable to the global mean but less than in the rest of Australia	Increased frequency of extreme high daily temperatures and a decrease in the frequency of cold extremes *very likely*
	Southwestern Australia	*Likely* comparable to the global mean	
	Rest of Australia	*Likely* comparable to the global mean	
	New Zealand, South Island	*Likely* less than the global mean	
	Rest of New Zealand	*Likely* comparable to the global mean	
Polar Regions	Arctic	*Very likely* to warm during this century more than the global mean	Warming largest in winter and smallest in summer
	Antarctic	*Likely* to warm	
Small Islands		*Likely* to be smaller than the global annual mean	

MAGICC 5.3 estimates radiative forcing from black carbon, a primary aerosol emitted through the incomplete combustion of fossil fuel and biomass burning. However, emissions trends for black carbon are "hard-wired" in the model to follow emissions of SO_2, which means they cannot be specified separately in the model.[19] The radiative forcing of black carbon is difficult to quantify accurately as it is a function of microphysical properties, the geographic and vertical placement, and lifetime of the aerosol; however, black carbon clearly contributes substantially to global warming (Jacobson 2001). Total global black carbon emissions are estimated to be approximately 8 TgC/yr (Bond *et al.* 2004, as cited in Forster *et al.* 2007), with estimates of fossil fuel contributions ranging from 2.8 TgC/yr (Ito and Penner 2005, as cited in Forster *et al.* 2007) to 8.0 TgC/yr (Haywood and Boucher 2000, as cited in Forster *et al.* 2007). The United States is estimated to contribute 6.1 percent of the global soot emissions, with non-road vehicles, on road vehicles, stack emissions, and fugitive sources comprising major sources (Jacobson Testimony 2007). In summary, the climate modeling does take into account the effects of black carbon on climate variables.

[19] Accurately determining the magnitude of mobile source emissions of black carbon is difficult because the emissions vary with fuel properties and fluctuations in the combustion environment. MOBILE6.2 outputs particulate matter mass that is then incorporated in the Volpe model. This particulate matter is based on tailpipe emissions and thereby includes carbon emissions from the combustion process. Because the carbon emissions are lumped into the particulate matter and not treated independently, the Volpe model does not provide direct results of the impact of the carbon emissions.

4.4.4.2.3 Precipitation

According to the IPCC WGI (Meehl *et al.* 2007), global mean precipitation is expected to increase under all scenarios. Generally, precipitation increases would occur in the tropical regions and high latitudes, with decreases in the sub-tropics. The results from the AOGCMs suggest considerable uncertainty in future precipitation for the five SRES scenarios. Where information in the analysis included in this FEIS is incomplete or unavailable, the agency has relied on CEQ regulations regarding incomplete or unavailable information *(see* 40 CFR § 1502.22(b)). In this case, the IPCC (Meehl *et al.* 2007) summary of precipitation represents the most thoroughly reviewed, credible assessment of this highly uncertain factor. NHTSA expects that the CAFE alternatives would reduce the changes in precipitation in proportion to their effects on temperature.

The global mean change in precipitation provided by the IPCC for the A2 (high), A1B (medium), and B1 (low) scenarios (Meehl *et al.* 2007) is given as the scaled change in precipitation (as a percentage change from 1980-1999 averages) divided by the increase in global mean surface warming for the same period (per °C), as shown in Table 4.4-5 below. IPCC provided scaling factors in the year ranges 2011-2030, 2046-2065, 2080-2099, and 2180-2199. The scaling factors for the A1B (medium) scenario were used in this FEIS analysis because MAGICC does not directly estimate changes in global mean precipitation.

Table 4.4-5

Global Mean Precipitation Change (scaled, % per °C) (Meehl *et al.* 2007)

Scenario	2011-2030	2046-2065	2080-2099	2180-2199
A2	1.38	1.33	1.45	NA
A1B	1.45	1.51	1.63	1.68
B1	1.62	1.65	1.88	1.89

Applying these scaling factors to the reductions in global mean surface warming provides estimates of changes in global mean precipitation. Given that the action alternatives would reduce temperature increases slightly relative to the No Action Alternative, they also would reduce predicted increases in precipitation slightly, as shown in Table 4.4-6 (again, based on the A1B [medium] scenario).

In addition to changes in mean annual precipitation, climate change is anticipated to affect the intensity of precipitation as described below (Meehl *et al.* 2007):

> "Intensity of precipitation events is projected to increase, particularly in tropical and high latitude areas that experience increases in mean precipitation. Even in areas where mean precipitation decreases (most subtropical and mid-latitude regions), precipitation intensity is projected to increase but there would be longer periods between rainfall events. There is a tendency for drying of the mid-continental areas during summer, indicating a greater risk of droughts in those regions. Precipitation extremes increase more than does the mean in most tropical and mid- and high-latitude areas."

Regional variations and changes in the intensity of precipitation events cannot be quantified further. This inability is due primarily to the lack of availability of AOGCMS required to estimate these changes. AOGCMS are typically used to provide results among scenarios having very large changes in emissions such as the SRES B1 (low), A1B (medium), and A2 (high) scenarios; very small changes in emissions profiles produce results that would be difficult to resolve among scenarios having relatively small changes in emissions. Also, the multiple AOGCMs produce results that are regionally consistent in some cases but are inconsistent in others.

Table 4.4-6

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on Reductions in Global Mean Precipitation based on A1B a/ SRES Scenario (% change), Using Increases in Global Mean Surface Temperature Simulated by the MAGICC Model

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaled, % K-1)			
	1.45	1.51	1.63
Global Temperature above average 1980-1999 levels (°C) for the A1B scenario and CAFE Alternatives, mid-level results			
1. No Action	0.560	1.764	2.765
2. 25 Percent Below Optimized	0.560	1.759	2.753
3. Optimized	0.560	1.758	2.752
4. 25 Percent Above Optimized	0.560	1.758	2.751
5. 50 Percent Above Optimized	0.560	1.757	2.750
6. Total Costs Equal Total Benefits	0.560	1.757	2.750
7. Technology Exhaustion	0.559	1.756	2.749
Reduction in Global Temperature (°K) for CAFE Alternatives, mid-level results (compared to No Action Alternative)			
2. 25 Percent Below Optimized	0.000	0.005	0.011
3. Optimized	0.000	0.006	0.013
4. 25 Percent Above Optimized	0.000	0.006	0.014
5. 50 Percent Above Optimized	0.000	0.007	0.015
6. Total Costs Equal Total Benefits	0.000	0.007	0.015
7. Technology Exhaustion	0.000	0.008	0.016
Mid Level Global Mean Precipitation Change (%)			
1. No Action	0.81%	2.66%	4.51%
2. 25 Percent Below Optimized	0.81%	2.66%	4.49%
3. Optimized	0.81%	2.65%	4.49%
4. 25 Percent Above Optimized	0.81%	2.65%	4.48%
5. 50 Percent Above Optimized	0.81%	2.65%	4.48%
6. Total Costs Equal Total Benefits	0.81%	2.65%	4.48%
7. Technology Exhaustion	0.81%	2.65%	4.48%
Reduction in Global Mean Precipitation Change for CAFE Alternatives (% compared to No Alternative Action)			
2. 25 Percent Below Optimized	0.00%	0.01%	0.02%
3. Optimized	0.00%	0.01%	0.02%
4. 25 Percent Above Optimized	0.00%	0.01%	0.02%
5. 50 Percent Above Optimized	0.00%	0.01%	0.02%
6. Total Costs Equal Total Benefits	0.00%	0.01%	0.02%
7. Technology Exhaustion	0.00%	0.01%	0.03%

a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Table 4.4-7 summarizes the regional changes to precipitation from the IPCC Fourth Assessment Report. Quantifying the changes to regional climate from the action alternatives is not possible at this point, but the action alternatives would reduce the changes relative to the reduction in global mean surface temperature.[20]

Table 4.4-7

Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment (Christensen *et al.* 2007)

Land Area	Sub-region	Precipitation	Snow Season and Snow Depth
Africa	Mediterranean area and northern Sahara	*Very likely* to decrease	
	Southern Africa and western margins	Winter rainfall *likely* to decrease in southern	
	East Africa	*Likely* to be an increase in annual mean precipitation	
Mediterranean and Europe	Northern Europe	*Very likely* to increase and extremes are *likely* to increase	*Likely* to decrease
	Southern and Central Europe		
	Mediterranean area	*Very likely* to decrease and precipitation days *very likely* to decrease	
Asia	Central Asia	Precipitation in summer *likely* to decrease	
	Tibetan Plateau	Precipitation in boreal winter *very likely* to increase	
	Northern Asia	Precipitation in boreal winter *very likely* to increase Precipitation in summer *likely* to increase	
	Eastern Asia	Precipitation in boreal winter *likely* to increase Precipitation in summer *likely* to increase *Very likely* to be an increase in the frequency of intense precipitation Extreme precipitation and winds associated with tropical cyclones *likely* to increase	

[20] *See* 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures … which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1984), *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (last visited June 20, 2008) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

Table 4.4-7 (cont'd)

Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment (Christensen *et al*. 2007)

Land Area	Sub-region	Precipitation	Snow Season and Snow Depth
	South Asia	Precipitation in summer *likely* to increase *Very likely* to be an increase in the frequency of intense precipitation Extreme precipitation and winds associated with tropical cyclones *likely* to increase	
	Southeast Asia	Precipitation in boreal winter *likely* to increase in southern parts Precipitation in summer *likely* to increase in most parts of southeast Asia Extreme precipitation and winds associated with tropical cyclones *likely* to increase	
North America	Northern regions/Northern North America		Snow season length and snow depth *very likely* to decrease
	Southwest	Annual mean precipitation is *likely* to decrease	
	Northeast USA	Annual mean precipitation *very likely* to increase	
	Southern Canada		
	Canada	Annual mean precipitation *very likely* to increase	
	Northernmost part of Canada		Snow season length and snow depth *likely* to increase
Central and South America	Southern South America		
	Central America	Annual precipitation *likely* to decrease	
	Southern Andes	Annual precipitation *likely* to decrease	
	Tierra del Fuego	Winter precipitation *likely* to increase	
	Southeastern South America	Summer precipitation *likely* to increase	
	Northern South America	Uncertain how precipitation will change	
Australia and New Zealand	Southern Australia	Precipitation *likely* to decrease in winter and spring	
	Southwestern Australia	Precipitation *very likely* to decrease in winter	
	Rest of Australia		
	New Zealand, South Island	Precipitation *likely* to increase in the west	
	Rest of New Zealand		

Table 4.4-7 (cont'd)

Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment (Christensen *et al*. 2007)

Land Area	Sub-region	Precipitation	Snow Season and Snow Depth
Polar Regions	Arctic	Annual precipitation *very likely* to increase; *Very likely* that the relative precipitation increase will be largest in winter and smallest in summer	
	Antarctic	Precipitation *likely* to increase	
Small Islands		Mixed, depending on the region	

4.4.4.2.4 Sea-level Rise

IPCC identifies four primary components to sea-level rise: thermal expansion of ocean water, melting of glaciers and ice caps, loss of land-based ice in Antarctica, and loss of land-based ice in Greenland (IPCC 2007c). Ice sheet discharge is an additional factor that could influence sea level over the long term. MAGICC calculates the oceanic thermal expansion component of global-mean sea-level rise, using a non-linear temperature- and pressure-dependent expansion coefficient (Wigley 2003 to 2008). The model also addresses the other three primary components using ice-melt models for small glaciers and the Greenland and Antarctic ice sheets, and excludes non-melt sources, which the IPCC Fourth Assessment Report also excluded. Neither MAGICC 5.3 nor the Fourth Assessment Report include the more recent information suggesting accelerated ice flow from Greenland and Antarctica, which the Fourth Assessment Report estimates to be between 9 and 17 centimeters by 2100 (Wigley 2008).

The state of the science reflected in the IPCC Fourth Assessment Report projects sea level to rise 18 to 59 centimeters by 2090-2099 (Parry *et al.* 2007, as cited in National Science and Technology Council 2008). This projection does not include all changes in ice sheet flow or the potential for rapid acceleration in ice loss (Alley *et al.* 2005, Gregory and Huybrechts 2006, Hansen 2005, all as cited in Pew 2007). Several recent studies have found that the IPCC projections of potential sea-level rise could underestimate ice loss from the Greenland and Antarctic ice sheets (Shepherd and Wingham 2007, Csatho *et al.* 2008) and ice loss from mountain glaciers (Meier *et al.* 2007). Further, IPCC might underestimate sea-level rise that would be gained through changes in global precipitation (Wentz *et al.* 2007, Zhang *et al.* 2007). Rahmstorf (2007) used a semi-empirical approach to project future sea-level rise. The approach yielded a proportionality coefficient of 3.4 millimeters (mm) per year per °C of warming, and a projected sea-level rise of 0.5 to 1.4 meter (m) above 1990 levels in 2100 when applying IPCC Third Assessment Report warming scenarios. Rahmstorf (2007) concludes that, "A rise over 1 m [meter] by 2100 for strong warming scenarios cannot be ruled out." Section 4.5.5 of this FEIS discusses sea-level rise in more detail.

The impact on sea-level rise from the scenarios is presented in Table 4.4-3, showing sea-level rise in 2100 ranging from 37.10 centimeters for the No Action Alternative to 36.92 centimeters for the Technology Exhaustion Alternative, for a maximum reduction of 0.18 centimeter by 2100 from the CAFE alternatives.

In summary, the impacts of the MY 2011-2015 and MY 2016-2020 standards on global mean surface temperature, sea-level rise, and precipitation are relatively small in the context of the expected changes associated with the emissions trajectories in the SRES scenarios. This is due primarily to the global and multi-sectoral nature of the climate problem.

4.4.4.2.5 SRES and Climate Sensitivity Variants

NHTSA examined the sensitivity of climate effects to key assumptions used in the analysis. This examination included reviewing the impact of the Optimized Alternative (Alternative 3) with various scenarios of global emissions and with various climate sensitivities. The results from the additional sensitivity runs for the action alternatives are presented with the Reference Case results (medium-level CAFE assumptions, 3.0 °C for a doubling of CO_2 climate sensitivity, SRES A1B emissions scenario).

The use of alternative global emissions scenarios can influence the results in several ways. Emissions reductions can lead to larger reductions in the CO_2 concentrations in later years because more of the anthropogenic emissions can be expected to stay in the atmosphere. The use of different climate sensitivities (the equilibrium warming that occurs at a doubling of CO_2 from pre-industrial levels) can affect not only warming but also indirectly affect sea-level rise and CO_2 concentration.

As shown in Table 4.4-8, the sensitivity of the simulated CO_2 emissions in 2030, 2060, and 2100 to assumptions of global emissions and climate sensitivity is low. The Optimized Alternative (Alternative 3) has the greatest impact in the SRES scenarios with the highest CO_2 emissions (A2 and A1FI) and the least impact in the scenarios with the lowest CO_2 emissions (B1). The total range of the impact of the Optimized Alternative on CO_2 concentrations in 2100 is from 2.1 to 2.6 ppm. The Reference Case using A1B and a 3.0 °C climate sensitivity has an impact of 2.4 ppm.

The sensitivity of the simulated global mean surface temperatures for 2030, 2060, and 2100 varies, as shown in Table 4.4-9. In 2030, the impact is low due primarily to the rate at which the global mean surface temperature increases in response to increases in radiative forcing. In 2100, the impact is large due not only to the climate sensitivity but also to the change in emissions. In 2030, the change from the 2.5 °C climate sensitivity to the 4.5 °C climate sensitivity is consistently 0.3 °C, as listed in Table 4.4-9. The impact on global mean surface temperature due to assumptions concerning global emissions of GHG is also important. The scenarios with the higher global emissions of GHGs such as A2 and A1FI have a lower reduction in global mean surface temperature and the scenarios with lower global emissions have a higher reduction. This is in large part due to the non-linear and near-logarithmic relationship between radiative forcing and CO_2 concentrations. At high emissions levels, CO_2 concentrations are high and, as a result, a fixed reduction in emissions yields a lower reduction in radiative forcing and global mean surface temperature.

The sensitivity of the simulated sea-level rise to change in climate sensitivity and global GHG emissions mirrors that of global temperature as shown in Table 4.4-10. Scenarios with lower climate sensitivities have lower increases in sea-level rise; the reduction in the increase in sea-level rise is lower with the Optimized Alternative. Conversely, scenarios with higher climate sensitivities have higher sea-level rise and the reduction in the increase of sea-level rise is less with the Optimized Alternative. Higher global GHG emissions have higher sea-level rise but the impact of the Optimized Alternative is less; conversely, lower global GHG emissions have lower sea-level rise and the reduction in sea-level rise is greater in the Optimized Alternative.

Table 4.4-8

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards: Cumulative Impact on CO_2 Concentration (ppm) for Varying Climate Sensitivities and SRES Scenarios

SRES Scenario	CAFE Alternative	Climate Sensitivity (°C for $2xCO_2$)	2030	2060	2100
A1B	1 No Action	2.5	454.9	570.9	708.8
		3.0	455.5	573.7	717.2
		4.5	457.1	580.5	739.1
	3 Optimized	2.5	454.7	569.9	706.4
		3.0	455.4	572.7	714.8
		4.5	456.9	579.5	736.7
	Reduction compared to No Action	2.5	0.2	1.0	2.4
		3.0	0.1	1.0	2.4
		4.5	0.2	1.0	2.4
A2	1 No Action	2.5	450.1	579.0	856.8
		3.0	450.7	581.6	866.8
		4.5	452.3	588.1	892.4
	3 Optimized	2.5	449.9	578.0	854.4
		3.0	450.5	580.6	864.3
		4.5	452.1	587.1	889.8
	Reduction compared to No Action	2.5	0.2	1.0	2.4
		3.0	0.2	1.0	2.5
		4.5	0.2	1.0	2.6
B1	1 No Action	2.5	436.1	505.4	533.2
		3.0	436.7	507.5	538.3
		4.5	438.3	512.7	551.5
	3 Optimized	2.5	435.9	504.4	531.1
		3.0	436.6	506.5	536.1
		4.5	438.1	511.7	549.3
	Reduction compared to No Action	2.5	0.2	1.0	2.1
		3.0	0.1	1.0	2.2
		4.5	0.2	1.0	2.2
B2	1 No Action	2.5	427.3	499.4	613.3
		3.0	428.0	501.9	619.9
		4.5	429.7	507.8	637.1
	3 Optimized	2.5	427.1	498.5	611.1
		3.0	427.8	500.9	617.7
		4.5	429.5	506.8	634.8
	Reduction compared to No Action	2.5	0.2	0.9	2.2
		3.0	0.2	1.0	2.2
		4.5	0.2	1.0	2.3
A1F1	1 No Action	2.5	455.5	640.1	980.4
		3.0	456.2	643.4	993.5
		4.5	457.8	651.5	1026.9
	3 Optimized	2.5	455.3	639.1	977.9
		3.0	456.0	642.4	990.9
		4.5	457.7	650.5	1024.3
	Reduction compared to No Action	2.5	0.2	1.0	2.5
		3.0	0.2	1.0	2.6
		4.5	0.1	1.0	2.6

Table 4.4-9

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards: Cumulative Impact on Global Mean Surface Temperature Increase (°C) for Varying Climate Sensitivities and SRES Scenarios

SRES Scenario	CAFE Alternative	Climate Sensitivity (°C for $2xCO_2$)	2030	2060	2100
A1B	1 No Action	2.5	0.777	1.715	2.569
		3.0	0.874	1.944	2.959
		4.5	1.099	2.493	3.937
	3 Optimized	2.5	0.777	1.711	2.560
		3.0	0.873	1.940	2.950
		4.5	1.098	2.488	3.925
	Reduction compared to No Action	2.5	0.001	0.004	0.008
		3.0	0.001	0.004	0.009
		4.5	0.001	0.005	0.012
A2	1 No Action	2.5	0.719	1.685	3.343
		3.0	0.811	1.906	3.812
		4.5	1.027	2.436	4.959
	3 Optimized	2.5	0.719	1.681	3.336
		3.0	0.810	1.902	3.803
		4.5	1.026	2.431	4.948
	Reduction compared to No Action	2.5	0.001	0.004	0.007
		3.0	0.001	0.004	0.008
		4.5	0.001	0.005	0.011
B1	1 No Action	2.5	0.671	1.206	1.615
		3.0	0.759	1.377	1.880
		4.5	0.968	1.796	2.557
	3 Optimized	2.5	0.670	1.202	1.605
		3.0	0.758	1.373	1.868
		4.5	0.967	1.790	2.543
	Reduction compared to No Action	2.5	0.001	0.004	0.010
		3.0	0.001	0.005	0.011
		4.5	0.001	0.006	0.014
B2	1 No Action	2.5	0.756	1.401	2.256
		3.0	0.854	1.598	2.597
		4.5	1.086	2.077	3.456
	3 Optimized	2.5	0.755	1.397	2.247
		3.0	0.853	1.594	2.587
		4.5	1.085	2.071	3.443
	Reduction compared to No Action	2.5	0.001	0.004	0.009
		3.0	0.001	0.005	0.010
		4.5	0.001	0.006	0.013
A1F1	1 No Action	2.5	0.810	2.185	3.864
		3.0	0.911	2.463	4.414
		4.5	1.146	3.118	5.762
	3 Optimized	2.5	0.809	2.182	3.857
		3.0	0.910	2.459	4.406
		4.5	1.145	3.113	5.753
	Reduction compared to No Action	2.5	0.001	0.003	0.007
		3.0	0.001	0.004	0.007
		4.5	0.001	0.005	0.009

Table 4.4-10

Reference Case MY 2011-2015 Standards and Potential MY 2016-2020 Standards: Cumulative Impact on Sea-level Rise (cm) for Varying Climate Sensitivities and SRES Scenarios

SRES Scenario	CAFE Alternative	Climate Sensitivity (°C for 2xCO_2)	2030	2060	2100
A1B	1 No Action	2.5	7.22	17.25	32.76
		3.0	7.99	19.30	37.10
		4.5	9.78	24.11	47.67
	3 Optimized	2.5	7.21	17.23	32.69
		3.0	7.99	19.27	37.02
		4.5	9.78	24.08	47.57
	Reduction compared to No Action	2.5	0.01	0.02	0.07
		3.0	0.00	0.03	0.08
		4.5	0.00	0.03	0.10
A2	1 No Action	2.5	7.08	16.86	36.98
		3.0	7.85	18.83	41.71
		4.5	9.63	23.48	53.11
	3 Optimized	2.5	7.08	16.83	36.91
		3.0	7.85	18.81	41.63
		4.5	9.62	23.45	53.01
	Reduction compared to No Action	2.5	0.00	0.03	0.07
		3.0	0.00	0.02	0.08
		4.5	0.01	0.03	0.10
B1	1 No Action	2.5	6.87	14.15	24.14
		3.0	7.63	15.86	27.40
		4.5	9.38	19.94	35.42
	3 Optimized	2.5	6.86	14.12	24.05
		3.0	7.62	15.83	27.30
		4.5	9.38	19.90	35.30
	Reduction compared to No Action	2.5	0.01	0.03	0.09
		3.0	0.01	0.03	0.10
		4.5	0.00	0.04	0.12
B2	1 No Action	2.5	7.14	15.30	28.84
		3.0	7.94	17.17	32.68
		4.5	9.79	21.63	42.06
	3 Optimized	2.5	7.14	15.27	28.76
		3.0	7.94	17.14	32.59
		4.5	9.79	21.60	41.94
	Reduction compared to No Action	2.5	0.00	0.03	0.08
		3.0	0.00	0.03	0.09
		4.5	0.00	0.03	0.12
A1F1	1 No Action	2.5	7.35	19.40	43.01
		3.0	8.15	21.67	48.59
		4.5	9.99	26.97	62.05
	3 Optimized	2.5	7.35	19.38	42.94
		3.0	8.15	21.64	48.52
		4.5	9.98	26.94	61.96
	Reduction compared to No Action	2.5	0.00	0.02	0.07
		3.0	0.00	0.03	0.07
		4.5	0.01	0.03	0.09

4.4.5 Input Scenarios

In response to public comments, and to test how different economic assumptions might affect estimates of emissions reductions and resulting climate effects, NHTSA modeled three additional scenarios – High, Mid-1, and Mid-2 – and compared the results to the Reference Scenario. Variables that were altered include fuel price, the social cost of carbon, oil import externalities, and the discount rate for other benefits.

For the High Scenario, NHTSA used the AEO 2008 high fuel prices, a social cost of carbon of $33/ton (2007 dollars), and a 3-percent discount rate for other benefits. Tables 4.4-11 and 4.4-12 show the emissions and emissions reductions due to the High Scenario.

Table 4.4-11

High Scenario MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Emissions and Emissions Reductions for 2010 through 2100 (MMTCO$_2$)

Alternative	Emissions	Emissions Reductions
1 No Action	195,501	0
2 25 Percent Below Optimized	160,903	34,598
3 Optimized	157,088	38,413
4 25 Percent Above Optimized	154,618	40,884
5 50 Percent Above Optimized	151,781	43,721
6 Total Costs Equal Total Benefits	150,919	44,583
7 Technology Exhaustion	152,290	43,211

Table 4.4-12

High Scenario MY 2011-2015 Standards and Potential MY 2016-2020 Standards Cumulative Impact on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC (A1B a/)

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
	2030	2060	2100	2030	2060	2100	2030	2060	2100
1 No Action (A1B-AIM)	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
2 25 Percent Below Optimized	455.3	572.3	714.0	0.873	1.938	2.946	7.99	19.26	36.99
3 Optimized	455.2	572.1	713.6	0.872	1.937	2.944	7.99	19.25	36.97
4 25 Percent Above Optimized	455.2	572.0	713.4	0.872	1.937	2.943	7.99	19.25	36.96
5 50 Percent Above Optimized	455.2	571.9	713.1	0.872	1.936	2.942	7.99	19.25	36.95
6 Total Costs Equal Total Benefits	455.2	571.9	713.0	0.872	1.936	2.942	7.99	19.24	36.95
7 Technology Exhaustion	455.2	571.9	713.1	0.872	1.935	2.941	7.99	19.24	36.94
Reduction under CAFE Alternatives									
2 25 Percent Below Optimized	0.2	1.4	3.2	0.001	0.006	0.013	0.00	0.04	0.11
3 Optimized	0.3	1.6	3.6	0.001	0.007	0.015	0.00	0.05	0.13
4 25 Percent Above Optimized	0.3	1.7	3.8	0.001	0.007	0.016	0.00	0.05	0.14
5 50 Percent Above Optimized	0.3	1.8	4.1	0.001	0.008	0.017	0.00	0.05	0.15
6 Total Costs Equal Total Benefits	0.3	1.8	4.2	0.002	0.008	0.017	0.00	0.06	0.15
7. Technology Exhaustion	0.3	1.8	4.1	0.002	0.009	0.018	0.00	0.06	0.16

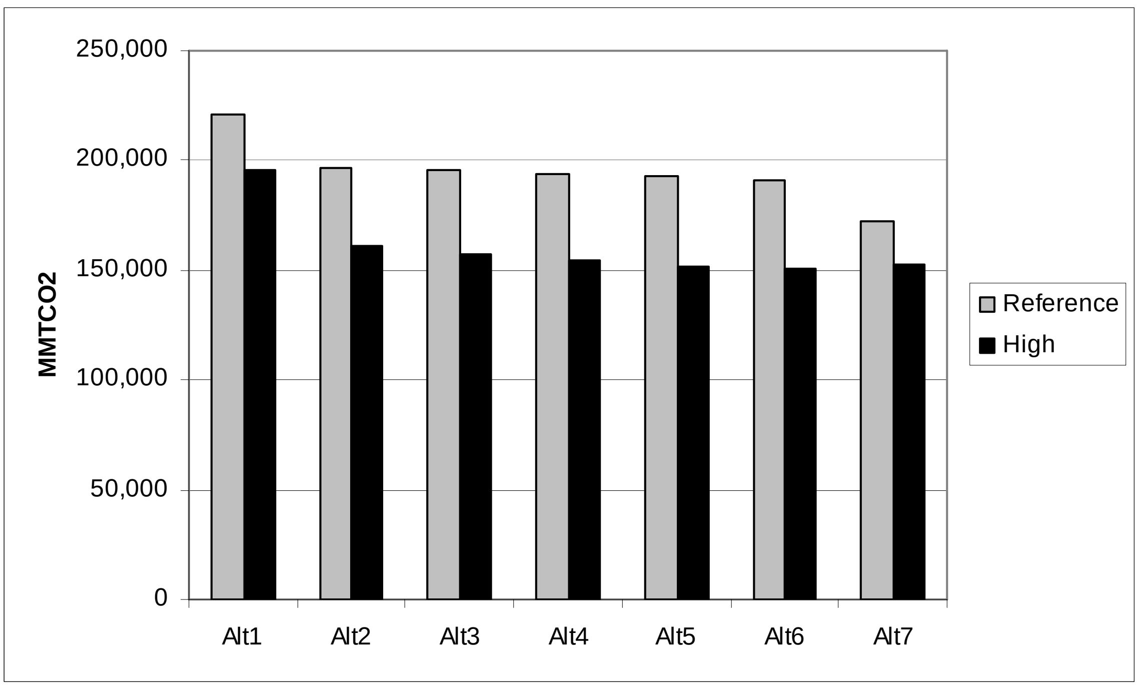
a/ The A1B scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Compared to the Reference Case, total emissions under the High Scenario were lower for all alternatives (*see* Figure 4.4-11). The primary reason for this difference is the lower VMT forecast under the High Scenario. Emissions reductions for Alternatives 2 through 7 compared to the No Action Alternative were all higher under the High Scenario than under the Reference Case, except for the Technology Exhaustion Alternative (*see* Figure 4.4-12). Emissions reductions were greater under the Technology Exhaustion Alternative for the Reference Case than for the High Scenario.

Table 4.4-12 lists the resulting effects on CO_2 concentration, global mean surface temperature, and sea-level rise. Under the High Scenario, the resulting CO_2 concentration, global mean surface temperature, and sea-level rise were lower than under the Reference Case for all action alternatives except the Technology Exhaustion Alternative. Thus, the differences for the action alternatives compared to the No Action Alternative are greater under the High Scenario than under the Reference Case, except for the Technology Exhaustion Alternative.[21]

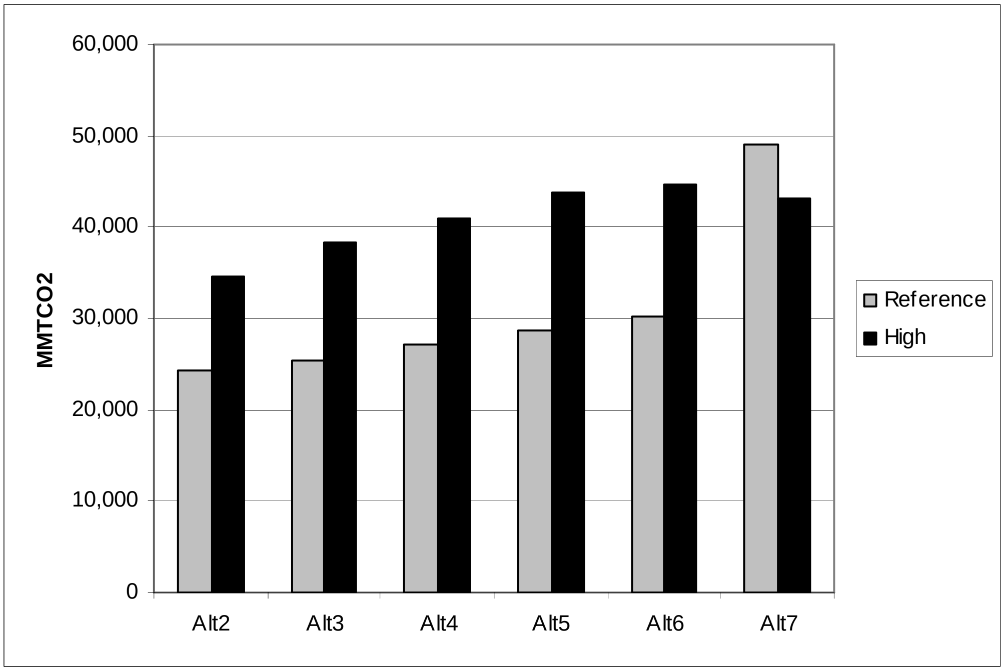
For the Mid-1 Scenario, NHTSA used the AEO 2008 high fuel prices, a social cost of carbon of $33/ton (2007 dollars), and a 7-percent discount rate for other benefits. Compared to the Reference Case, total emissions under the Mid-1 Scenario were lower for all alternatives. Emission reductions for all alternatives compared to the No Action Alternative were higher under the Mid-1 Scenario as compared to the Reference Case, except for the Technology Exhaustion Alternative. The primary reason for this

Figure 4.4-11. Comparison of Cumulative Emissions under the Reference Case and High Scenario Due to the MY 2011-2020 CAFE Standards from 2010-2100 (MMTCO$_2$)



[21] Note that in both the Reference Case and the High Scenario, the No Action Alternative is modeled to have the same emissions, *viz*. emissions set to the A1B scenario. This is the case even though, in absolute terms, U.S. passenger-care and light-truck emissions are lower in the High Scenario than in the Reference Case. In other words, the MAGICC model runs are intended to show relative differences in relation to a no action case; they are not intended to show absolute differences between Volpe model assumptions.

Figure 4.4-12. Comparison of Cumulative Emissions Reductions under the Reference Case and High Scenario Due to the MY 2011-2020 CAFE Standards from 2010-2100 ($MMTCO_2$)



difference is the lower VMT forecast under the Mid-1 Scenario. The resulting CO_2 concentration, global mean surface temperature, and sea-level rise were lower for all alternatives under the Mid-1 Scenario than under the Reference Case, except for the Technology Exhaustion Alternative. Thus, the differences between the action alternatives and the No Action Alternative are greater for the Mid-1 Scenario than for the Reference Case except for the Technology Exhaustion Alternative.

For the Mid-2 Scenario, NHTSA used the AEO 2008 high fuel prices, a social cost of carbon of $2/ton (2007 dollars), and a 7% discount rate for other benefits. Compared to the Reference Case, total emissions under the Mid-1 Scenario were lower for all alternatives. Emissions reductions compared to the No Action alternative were higher for all alternatives under the Mid-2 Scenario as compared to the Reference Case, except for the Technology Exhaustion Alternative. The primary reason for this difference is the lower VMT forecast under the Mid-2 Scenario. The resulting CO_2 concentration, global mean surface temperature, and sea-level rise were lower for all alternatives under the Mid-2 Scenario, except for the Technology Exhaustion Alternative. Thus, the differences between the action alternatives and to the No Action Alternative are greater under the Mid-2 Scenario than under the Reference Scenario, except for the Technology Exhaustion Alternative.

Appendix B presents the results from analysis of the Mid-1 and Mid-2 Scenarios.

4.5 RESOURCE IMPACTS OF CLIMATE CHANGE

4.5.1 Introduction

The effects of the alternative CAFE standards on climate as described in Section 4.4 – CO_2 concentrations, temperature, precipitation, and sea-level rise – can translate into impacts on key natural and human resources, including freshwater resources; terrestrial ecosystems; coastal systems and low-lying areas; managed ecosystems that produce food, fiber, and forest products; industry, settlements, society, and other aspects of the built environment; and human health. This section describes the impacts associated with climate change on each resource.

After a discussion of methodology, Section 4.5 is divided into six sections, one for each resource area. Each section discusses the affected environment, provides an overview of the resource globally and in the United States, and addresses the consequences of climate change on that resource. Observed changes are also reported. In each section, both positive and negative effects of climate change, as they are represented in the literature, are presented. The sections are:

- Freshwater resources
- Terrestrial ecosystems
- Coastal systems and low-lying areas
- Food, fiber, and forests
- Industry, settlements, and society
- Human health

The sections generally follow the organization of topic areas in the climate literature, notably by IPCC, which is a key source for much of the information presented in this section, and by USCCSP. These categories do not follow the classification of resources typically found in an EIS. *See* the chart in Section 4.1 to find where specific NEPA topics are covered.

As shown in Section 4.4, although the alternatives could substantially decrease GHG emissions, they do not prevent climate change from occurring; instead they would only result in small reductions in the anticipated increases in CO_2 concentrations, temperature, precipitation, and sea level. As discussed below, NHTSA's assumption is that these reductions in climate effects would be reflected in reduced impacts on affected resources. However, the magnitude of the changes in climate effects that the alternatives produce – a few ppm of CO_2, a hundredth of a °C difference in temperature, a small percentage change in the rate of precipitation increase, and 1 or 2 mm of sea-level rise – are too small to address quantitatively in terms of their impacts on resources. Given the enormous resource values at stake, these distinctions could be important – very small percentages of huge numbers can still yield substantial results – but they are too small for current quantitative techniques to resolve. Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but rather provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change.

4.5.2 Methodology

NHTSA reviewed various reports to assess the cumulative impacts of the proposed action. The key reports consulted for material include the IPCC Fourth Assessment Report by Working Group II (WGII) entitled *Climate Change 2007 – Impacts, Adaptation, and Vulnerability* (IPCC 2007b), and the

USCCSP SAP Reports. NHTSA reviewed the National Science and Technology Council's *Scientific Assessment of the Effects of Global Climate Change on the United States*, and SAP Reports, as follows:

- SAP 4.1, Coastal Elevations and Sensitivity to Sea Level Rise
- SAP 4.2, Thresholds of Change in Ecosystems
- SAP 4.3, The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity
- SAP 4.4, Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources
- SAP 4.5, Effects of Climate Change on Energy Production and Use in the United States
- SAP 4.6, Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems
- SAP 4.7, Impacts of Climate Variability and Change on Transportation Systems and Infrastructure — Gulf Coast Study

Not all of the SAP Reports are final; although publicly available and generally in later stages of review and revision, some were still in draft form at the time NHTSA prepared this FEIS. More information on the SAP Reports can be found at www.climatescience.gov/Library/sap. Researchers also referenced additional studies published since the release of the IPCC and SAP reports.

NHTSA compiled research was compiled on freshwater resources; ecosystems and biodiversity; coastal and low-lying areas; industry, settlement and society; food, fiber, and forest products; and human health. Each section provides an introduction and addresses the impacts and adaptations anticipated for both the United States and the global environment. To assess the impacts of climate change on the United States, NHTSA first consulted the SAP Reports and then examined more recent materials of relevance, such as the Natural Resources Defense Council (NRDC) *Cost of Climate Change* (NRDC 2008), the Union of Concerned Scientists (UCS) *Confronting Climate Change in the U.S. Northeast* (Frumhoff *et al.* 2007), and the University of Maryland's (UMD) *The US Economic Impacts of Climate Change and the Costs of Inaction* (CIER 2007). The global impacts sections focus on the IPCC Fourth Assessment Report because it is the most recent, comprehensive, and peer-reviewed material on this topic. Articles and studies cited within the IPCC Report also were consulted for additional information on various topics.

To accurately reflect the likelihood of climate change impacts for each sector, NHTSA referenced the IPCC uncertainty guidelines. This approach provided a consistent methodology to define confidence levels and percent probability of a predicted outcome or impact. More information on the uncertainty guidelines is provided in the *Treatment of Uncertainties in the IPCC's Working Group II Assessment* in Solomon *et al.* (2007).

4.5.2.1 Cumulative Climate Impacts of Alternative CAFE Standards

As described in Chapter 3, the alternative CAFE standards being considered result in different periods of CO_2 emissions associated with the operation of U.S. vehicles. These emissions, in combination with U.S. GHG emissions from other sources (such as power plants, natural gas use, and agricultural production) and with emissions of all GHGs globally, would alter atmospheric concentrations of GHGs. As the modeling results presented in Section 4.4 show, different atmospheric concentrations of GHGs will be associated with long-term changes in global climate variables, including global average temperature, precipitation, and rising sea level. In turn, these climate changes would result in changes to a range of natural and human resources and systems, including water supplies, human health, the built environment, and a host of others.

The most common approach to assessing the impacts of climate change is to construct future scenarios that represent combinations of changes in levels, and sometimes patterns or variability, of temperature, precipitation, sea-level rise, and other relevant climatic and related variables (IPCC 2007b). In some cases these scenarios will represent the results of specific climate modeling (the output of General Circulation Models [GCMs]), often downscaled to provide results at a finer level of geographic resolution. In other cases, scenarios might be designed to be representative of the *types* and *ranges* of effects that are expected to occur under climate change, and not the results of specific models (Parsons *et al.* 2007). Impacts associated with these scenarios are then estimated using a variety of techniques, including models of individual systems (specific ecosystems or geographic areas, such as a park) and examination of performance under similar historical conditions.

The impacts literature suggests that some regions and sectors will experience positive effects of future climate change, particularly at lower levels of temperature change (less than 1 to 3 °C above 1990 levels), while others will experience negative effects (IPCC 2007b). The IPCC WGII for the Fourth Assessment Report found that, at higher levels of temperature, on balance the net global effects are expected to be negative: "while developing countries are expected to experience larger percentage losses, global mean losses could be 1 to 5 percent gross domestic product (GDP) for 4 °C of warming" (IPCC 2007b). To put these numbers in context, the IPCC has projected longer term warming (associated with a doubling of CO_2 concentrations) in the range of 2 to 4.5 °C (IPCC 2007a). The modeling results presented in Section 4.4 suggest that, for the CAFE alternatives, the cumulative climate effects in terms of temperature rise under a moderate emissions scenario lie in the range of 2.7 to 2.8 °C as of 2100.

NHTSA's presumption, consistent with the general literature cited above and reviewed for Section 4.5, is that reducing emissions and concomitant climate effects will reduce the net negative long-term effects that have been projected for climate change. NHTSA has not, however, conducted a quantitative comparison of the climate impacts of the alternative CAFE standards, for several reasons.

First, as indicated above, analyses of impacts often focus on discrete climate scenarios, rather than a continuum of climate outcomes; the information to analyze small changes in climate variables is not, therefore, generally available in the literature. Moreover, as the global climate changes, so will regional and local climates. Changes in global climate variables will be reflected in regional and local changes in average climate variables, and in the variability and patterns of climate, such as seasonal and annual variations, the frequency and intensity of extreme events, and other physical changes, such as the timing and amount of snowmelt. Impacts assessments often rely on highly localized data for both climate and other conditions and circumstances (CCSP 2008f). Thus, changes in impacts due to changes in global average climate, as projected in this analysis, likely will not be adequately represented by a simple scaling of results. Where information in the analysis included in the FEIS is incomplete or unavailable, the agency has relied on CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). Information on the effect of very small changes in temperature, precipitation, and sea-level rise (at the scale of the distinctions among the alternative CAFE standards) is not currently available. Nevertheless, NHTSA's qualitative characterization – that the greater the reductions in GHG emissions, the lower the environmental impact – is consistent with theoretical approaches and research methods generally accepted in the scientific community.

Second, there is considerable debate about the likely shape of a global climate impacts damage function; although many believe the function to be upwardly sloped (so that marginal net damages increase with increasing levels of climate change), fewer agree on its shape, that is, how *rapidly* net climate damages increase as temperature and other variables increase (IPCC 2007b). There is also the important question of whether thresholds exist, that is, stress points at which ecosystems collapse or the negative impacts rapidly accelerate – a topic important enough to warrant attention in an SAP Report on which the U.S. Geological Survey (USGS) is the lead agency. Finally, much of the work on impacts – both global and more localized – is, in and of itself, qualitative and so does not lend itself to further quantification.

NHTSA assumes that reductions in climate effects due to the alternative CAFE standards would be reflected in reduced impacts on affected resources. However, the magnitudes of the changes in these climate effects that the alternatives might produce – a few ppm of CO_2, a hundredth of a °C difference in temperature, a small percentage change in the rate of precipitation increase, and 1 or 2 mm of sea level – are too small to address quantitatively in terms of their impacts on resources. Consequently, the discussion of resource impacts does not distinguish among the alternative CAFE standards, but rather provides an overview of climate impacts and therefore a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change.

NHTSA assumes that reductions in emissions and, therefore, climate effects would be reflected in reduced impacts on affected resources. However, the magnitudes of the changes in the climate effects that the alternative CAFE standards might produce are too small to address quantitatively in terms of their impacts on resources. Consequently, as discussed further in Section 4.5.2, the discussion of resource impacts does not distinguish among the CAFE alternatives. Where information in the analysis included in this FEIS is incomplete or unavailable, the agency has relied on CEQ regulations related to incomplete or unavailable information (40 CFR § 1502.22(b)). Information on the effects of very small changes in temperature, precipitation, and sea-level rise (at the scale of the distinctions among the CAFE alternatives) is not currently available. Nevertheless, NHTSA's qualitative characterization - that the greater the reductions in GHG emissions, the lower the environmental impact - is consistent with theoretical approaches and research methods generally accepted in the scientific community.

4.5.2.2 Treatment of Uncertainties in the Working Group I Assessment

Uncertainties can be classified in several different ways. "Value uncertainties" and "structural uncertainties" are two primary types of uncertainties. When data are inaccurate or do not fully represent the phenomenon of interest, value uncertainties arise. These types of uncertainties are typically estimated with statistical techniques, and then expressed probabilistically. An incomplete understanding of the process that controls particular values or results generates structural uncertainties. These types of uncertainties are described by presenting the authors' collective judgment of their confidence in the correctness of a result. As stated in the WGI Assessment, a "careful distinction between levels of confidence in scientific understanding and the likelihoods of specific results" are drawn in the uncertainty guidance provided for the Fourth Assessment Report.

The standard terms used to define levels of confidence are:

Confidence Terminology	Degree of Confidence in Being Correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

The standard terms used to define the likelihood of an outcome or result where the outcome or result can be estimated probabilistically are:

Likelihood Terminology	Likelihood of the Occurrence/Outcome
Virtually certain	Greater than 99% probability
Extremely likely	Greater than 95% probability
Very likely	Greater than 90% probability
Likely	Greater than 66% probability
More likely than not	Greater than 50% probability
About as likely as not	33 to 66% probability
Unlikely	Less than 33% probability
Very unlikely	Less than 10% probability
Extremely unlikely	Less than 5% probability
Exceptionally unlikely	Less than 1% probability

4.5.3 Freshwater Resources

This section addresses climate-related impacts on freshwater resources. Water is necessary to support life, societal welfare, and economic activity. "Given water's importance, plant, animal, and human communities are all sensitive to variations in the availability, storage, fluxes, and quality of surface and groundwater. These, in turn, are sensitive to climate change" (National Science and Technology Council 2008).

4.5.3.1 Affected Environment

This affected environment section for freshwater resources is based on information contained in *World Water Resources at the Beginning of the 21st Century* (Shiklomanov and Rodda 2003), the United Nations Educational, Scientific and Cultural Organization – World Water Assessment Program (UNESCO-WWAP) *World Water Development Report 2* (UNESCO and WWAP 2006), and *Pilot Analysis of Global Ecosystems: Freshwater Systems* (Revenga *et al.* 2000).

Water supports all life on Earth. About 70 percent of Earth's surface is covered by water, and most (97.5 percent) is contained in the oceans. Freshwater refers to the 2.5 percent of Earth's hydrosphere that is not saline. The freshwater resource is divided among glaciers (68.7 percent), groundwater (30.1 percent), permafrost (0.8 percent), and surface and atmospheric water (0.4 percent). The 0.4 percent occurs as freshwater lakes (67.4 percent) and wetlands (8.5 percent), rivers (1.6 percent), soil moisture (12.2 percent), water in the atmosphere (9.5 percent), and water in living organisms (0.8 percent) (Shiklomanov and Rodda 2003, as cited in UNESCO and WWAP 2006).

The largest volume of freshwater is frozen in glaciers and ice sheets, most of which occur in Antarctica (almost 90 percent), with the remainder found in Greenland (almost 10 percent) and in mountain glaciers. Permafrost extends over northeastern Europe and the northern and northeastern parts of Asia, including the Arctic islands, northern Canada, the fringes of Greenland and Antarctica, and the high-altitude areas of South America.

Groundwater is the second largest source of freshwater. Groundwater occurs in the pores of soils and fractures of rocks and is the largest source of unfrozen freshwater. Groundwater feeds springs, streams, and lakes; supports wetlands; and is a critical source of water for human consumption. Groundwater also includes aquifers, underground strata of water-bearing permeable rock or unconsolidated materials (sand, gravel, and some silts and clays) from which water can be extracted using well systems.

Lakes, which can be broadly defined as bodies of water collected in depressions in Earth's surface, are widespread and numerous (there are around 15 million) and store the largest volume of fresh surface waters. Reservoirs, which could be considered lakes, are enclosed areas constructed for the storage of water, and are typically created by damming a river channel in a valley.

Wetlands, such as marshes, swamps, bogs, and estuaries, are transitional zones between land and water environments where the soil is frequently or permanently waterlogged. Wetlands of various types exist all over the world. During the 20^{th} Century, half of them are estimated to have been lost as land was converted to agriculture and urban use or filled to combat disease.

Rivers are bodies of flowing water that drain surface runoff from land to the seas and oceans. They begin in higher elevations such as mountains and hills where rainwater and snowmelt collect, forming small tributary streams that flow into larger streams and rivers.

Soil moisture is water that drains into the soil, mainly the top 2 meters, and becomes part of the soil water store, where it is used by plants.

Water exists in the atmosphere in the form of water vapor, water drops, and ice crystals, and falls as precipitation, which occurs as rain, snow, sleet, hail, frost, or dew. Biological water is the water contained in living organisms such as plants and animals.

Much of the discussion that follows below is drawn from the following studies and their citations: the IPCC *Freshwater Resources and their Management* (Kundzewicz *et al.* 2007), the National Science and Technology Council *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008), *World Water Resources at the Beginning of the 21^{st} Century* (Shiklomanov and Rodda 2003), *Pilot Analysis of Global Ecosystems: Freshwater Systems* (Revenga *et al.* 2000), and *Threats to the World's Freshwater Resources* (Glick *et al.* 2001).

4.5.3.2 Non-climate Threats to Freshwater Resources

Pressure on global freshwater resources during recent decades is a result of non-climatic as well as climatic drivers. The non-climate threats include changes in population, economy, and technology. Population growth and economic development create increasing demands from the industrial, municipal, and agricultural sectors. For example, irrigated agriculture to support the demand for food accounts for nearly 70 percent of global freshwater withdrawals and for more than 90 percent of global consumptive use (Shiklomanov and Rodda 2003, as cited in Kundzewicz *et al.* 2007). The extent of irrigated areas, which is expected to expand in areas that are already water-stressed, will determine the effect that this use will have on global water use in the future.

The driving threats to the world's supply of freshwater resources are consistently reported in the literature: population growth and increased demand; infrastructure development (dams, dikes, levees, and river diversions); poor land use (urbanization, conversion to crop or grazing lands, wetland removal or reduction, deforestation); overexploitation (groundwater aquifer depletion and reduced water levels in lakes, rivers, and wetlands); water pollution from industrial, municipal, and agricultural sources (phosphorus and nitrogen from fertilizers, pesticides, pathogens and microbial contaminants, heavy metals, toxic organic compounds and micro-organic pollutants); silt and suspended particles (from soil erosion); acidification (from air pollution); and thermal pollution (from industrial discharges and slow flows caused by dams and reservoirs).

Shiklomanov and Rodda (2003) state that "Every year human influences grow and cause more and more changes to natural processes…These changes bring about alterations to the water balance and to water resources and their availability. The rapid growth of population, the development of industrial production and the rise of agriculture have resulted in the increased use of water…Human activities have also changed the character of groundwater…more often the water table has been lowered to provide water for drinking…The construction of reservoirs has led to the slowing down of the movement of river waters. Slowing the movement of water can influence its quality particularly by the accumulation of pollutants."

The freshwater resources in the United States are affected by the same non-climate threats discussed above. The National Science and Technology Council (2008) found that "most water quality changes observed so far across the continental United States are likely attributable to causes other than climate change." EPA cites siltation, nutrients, and metals (*e.g.*, mercury) as the main sources of pollution in U.S. waters, primarily as a result of nonpoint source pollution from urban and agricultural lands (EPA 2000b, EPA 2002b).

Ecosystem integrity, as defined by Glick *et al.* (2001), is the interaction between the biological processes and chemical processes that support the functioning of an ecosystem and the health of the species it supports. Water withdrawal and consumption by humans is directly connected to the integrity of freshwater ecosystems, because these uses compete with natural systems for water and lead to pollution, disrupting natural ecosystem processes. As a result, the health of habitats, and the species that live in them, is affected. Revenga *et al.* (2000) found that between 1900 and 1995, world water withdrawals increased six-fold, more than twice the rate of population growth. As water withdrawals increase, more stress will be put on freshwater ecosystems.

4.5.3.3 Environmental Consequences

Much of the discussion that follows is drawn from the following studies including the citations therein: the IPCC *Freshwater Resources and their Management* (Kundzewicz *et al.* 2007), *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008), and *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* (Lettenmaier *et al.* 2008). Additional recent studies from peer-reviewed literature are also cited.

Non-climate-related impacts on freshwater resources have received more attention than climate-related impacts to date. However, "climate change is expected to result in increasing effects in the future" (National Science and Technology Council 2008). Climate change effects are especially relevant to freshwater resource management for the future. Freshwater resource infrastructure has been designed to accommodate the variability in water supply based on the historical record. This assumption – that, on average, the future will be the same as the past – is referred to as the "stationarity assumption" (Lettenmaier *et al.* 2008, as cited in National Science and Technology Council 2008). However, this assumption is now challenged by the demonstrated occurrence of climate change (Arnell 2002, Lettenmaier 2003, and Milly *et al.* 2008, all as cited in National Science and Technology Council 2008). As a result, "the global population is highly vulnerable to climate change impacts on freshwater resources" (National Science and Technology Council 2008).

Global warming resulting from the enhanced greenhouse effect causes changes in temperature, precipitation, ice melt, and other climate change effects. Evaporation, transpiration, and the water-holding capacity of the atmosphere all increase at higher temperatures. Increased atmospheric water content favors increased climate variability – more intense droughts and more intense precipitation (Trenberth *et al.* 2003, as cited in Kundzewicz *et al.* 2007).

"While temperatures are expected to increase everywhere over land and during all seasons of the year, although by different increments, precipitation is expected to increase globally and in many river basins, but to decrease in many others" (Kundzewicz *et al.* 2007). Precipitation might also increase in one season and decrease in another (Meehl *et al.* 2007, Section 10.3.2.3, as cited in Kundzewicz *et al.* 2007). Changes in temperature and precipitation are the main climatic drivers observed to affect freshwater availability, quality, and water use. A recent study by Allan and Soden (2008) using satellite observations and model simulations showed a link between rainfall extremes and temperature. The observed amplification of rainfall extremes was larger than other model predictions, leading the authors to infer that "projections of future changes in rainfall extremes due to anthropogenic global warming may be underestimated."

4.5.3.3.1 Globally Observed Climate Effects

General climate change impacts on hydrology and freshwater resources identified to date include the following (Arnell *et al.* 2001, as cited in Kundzewicz *et al.* 2007):

- Changes in streamflow volume – increases and decreases
- Variation in streamflow and groundwater recharge – largely following precipitation
- Shifts in peak streamflow timing – earlier snowmelt
- Lower streamflow in summer and autumn
- Glacier retreat and disappearance of small glaciers
- Water quality degradation – higher water temperatures
- Increases in flood magnitude and frequency

Climate-related trends have already been observed in various inputs, throughputs, and outputs to the freshwater system, including the following (Kundzewicz *et al.* 2007):

- Precipitation – increasing over northern (30°N) latitudes; decreasing over middle latitudes (10°S to 30°N); increasing in intensity

- Snow cover – decreasing in most regions

- Glaciers – decreasing almost everywhere

- Permafrost – thawing between 0.08 inch per year (Alaska) and 1.8 inches per year (Tibetan plateau)

- Streamflow – increasing in Eurasian Arctic, measurable increases or decreases in some river basins; earlier spring peak flows and increased winter-based flows in North America and Eurasia

- Evapotranspiration – increased actual evapotranspiration in some areas

- Lakes – warming, substantial increases and decreases in some lake levels, and reduction in ice cover

For other anticipated changes in the freshwater system, data are insufficient to observe a climate trend, especially when compared to the non-climatic pressures mentioned previously. The absence of an observed trend does not indicate that freshwater resources will not be sensitive to future climate trends. As described in the section on impacts below, changes are also anticipated for groundwater levels, floods, droughts, water quality, erosion and sediment transport, and irrigation water demand (Kundzewicz *et al.* 2007).

4.5.3.3.2 Observed and Projected Impacts of Climate Change on Freshwater Resources in the United States

Most of the freshwater resource analyses are keyed either to climate scenarios (what happens if temperature increases by 6 °F, and precipitation declines by 10 percent) or to global climate model outputs pegged to IPCC-reported emission scenarios. The projected impacts resulting from such analyses, current sensitivities, and potential vulnerabilities (including extreme events) are summarized in this section for the United States and in the next section for the globe.

The climate change impacts on freshwater resources in the United States are described by National Science and Technology Council (2008), Lettenmaier *et al.* (2008), and Field *et al.* (2007).

"In regards to the hydrologic observing systems on which these sections are based, Lettenmaier *et al.* (2008) found that the current hydrologic observing system was not designed specifically for the purpose of detecting the effects of climate change on water resources. In many cases, the resulting data are unable to meet the predictive challenges of a rapidly changing climate" (National Science and Technology Council 2008).

Several recent state and regional studies have examined specific climate change impacts on freshwater resources. For example, many impacts on freshwater resources described above have been predicted for New Mexico (D'Antonio 2006), New Jersey (EPA 1997b), and the West (Saunders *et al.* 2008).

"Projections for the western mountains of the United States suggest that warming, and changes in the form, timing, and amount of precipitation will *very likely* lead to earlier melting and significant reductions in snowpack by the middle of the 21st century" (*high confidence*). "In mountainous snowmelt-dominated watersheds, projections suggest advances in the timing of snowmelt runoff, increases in winter and early spring flows (raising flooding potential), and substantially decreased summer flows. Heavily utilized water systems of the western United States that rely on capturing snowmelt runoff, such as the Columbia River system, will be especially vulnerable" (Field *et al.* 2007, as cited in National Science and Technology Council 2008). Trends in declining snowpack are perhaps best illustrated from studies conducted for California. Reduced snowpack has been identified as a major concern for the State (California Energy Commission 2006, as cited in National Science and Technology Council 2008). Several authors anticipate a coming crisis in water supply for the western United States (Barnett *et al.* 2008), and have projected that Lake Mead (on the Colorado River system) might go dry (Barnett and Pierce 2008). While these studies focus on issues already identified in the literature, their findings suggest that freshwater resources might be more sensitive to climate change than previously projected. A recent article by Rauscher *et al.* (2008) used a high-resolution nested climate model to investigate future changes in snowmelt-driven runoff over the western United States; and modeled increases in seasonal temperature of approximately 3 to 5 °C by 2100, which could cause snowmelt-driven runoff to occur as much as two months earlier than present – twice as early as other predictions – affecting reservoir water storage and hydroelectric generation, and impacting land use, agriculture, and water management.

4.5.3.3.3 Precipitation

Precipitation is the primary driver of the land surface hydrological system. Precipitation variability, and subsequent surface water availability varies regionally across the United States depending on a catchment's (watershed) physical, hydrological, and geological characteristics (National Science and

Technology Council 2008). In general, conditions become increasingly dry from east to west. Upslope areas in the Cascade and coastal mountain ranges are more humid with relatively low precipitation variability. The Intermountain West and Southwest are driest, and the greatest precipitation variability is in the arid and semi-arid West (Lettenmaier *et al.* 2008, as cited in National Science and Technology Council 2008). Stream gauge data (Mauget 2003, as cited in Lettenmaier *et al.* 2008) showed increases in streamflow from 1939 through 1998 in the eastern United States and a more or less reverse pattern in the western United States (National Science and Technology Council 2008).

4.5.3.3.4 Surface Water

The observed impacts on surface water (Field *et al.* 2007, as cited in National Science and Technology Council 2008) include the following:

- Streamflow in the eastern United States has increased 25 percent in the past 60 years (Groisman *et al.* 2004), but over the past century has decreased by about 2 percent per decade in the central Rocky Mountain region (Rood *et al.* 2005).

- Since 1950, stream discharge in both the Colorado and Columbia River Basins has decreased, while over the same time period annual evapotranspiration from the conterminous United States increased by 2.2 inches (Walter *et al.* 2004).

- In regions with winter snow, warming has shifted the magnitude and timing of hydrologic events (Mote *et al.* 2005, Regonda *et al.* 2005, Stewart *et al.* 2005). From 1949 to 2004, the fraction of annual precipitation falling as rain (rather than snow) increased at 74 percent of the weather stations studied in the western mountains of the United States (Knowles *et al.* 2006).

- Spring and summer snow cover has decreased in the western United States (Groisman *et al.* 2004). April snow water equivalent has declined 15 to 30 percent since 1950 in the western mountains of North America, particularly at lower elevations and primarily due to warming rather than changes in precipitation (Mote *et al.* 2003, 2005, Lemke *et al.* 2007, as cited in National Science and Technology Council).

- Streamflow peaks in the snowmelt-dominated western mountains of the United States occurred 1 to 4 weeks earlier in 2002 than in 1948 (Stewart *et al.* 2005).

Lettenmaier *et al.* (2008) assessed the following potential impacts on surface water in the United States (National Science and Technology Council 2008):

- There is a trend toward reduced mountain snowpack and earlier spring snowmelt runoff peaks across much of the western United States. Evidence suggests this trend is *very likely* attributable, at least in part, to long-term warming, although decadal-scale variability, including a shift in Pacific decadal oscillation in the 1970s, might have played some part. Where shifts to earlier snowmelt peaks and reduced summer and fall low flows have already been detected, continuing shifts in this direction are expected and could have substantial impacts on the performance of reservoir systems.

- Recent climate model simulations reported in the IPCC Fourth Assessment Report project increased runoff over the eastern United States, gradually transitioning to little change in the Missouri and lower Mississippi, to substantial decreases in annual runoff in the interior of the West (Colorado and Great Basin). The projected drying in the interior of the West is quite consistent among models. These changes are, very roughly, consistent with observed trends in the second half of the 20th Century, which show increased streamflow over much of the United States, but sporadic decreases in the West.

- Snowpack in the mountainous headwater regions of the western United States generally declined over the second half of the 20th Century, especially at lower elevations and in locations where average winter temperatures are close to or above 0 °C. These trends toward reduced winter snow accumulation and earlier spring melt are also reflected in a tendency toward earlier runoff peaks in the spring, a shift that has not occurred in rainfall-dominated watersheds in the same region.

- Climate model projections of increased temperatures and slight precipitation increases indicate that modest streamflow increases are expected in the East, but that larger (in absolute value) declines are expected in the West, where the balance between precipitation and evaporative demand will shift toward increased evaporative demand. However, because of the uncertainty in climate model projections of precipitation change, future projections of streamflow are highly uncertain across most of the United States. One exception is watersheds that are dominated by spring and summer snowmelt, most of which are in the western United States. In these cases, where shifts to earlier snowmelt peaks and reduced summer and fall low flows have already begun to be detected, continuing shifts in this direction are generally expected and could have substantial impacts on the performance of reservoir systems.

4.5.3.3.5 Groundwater

The effects of climate on groundwater – especially groundwater recharge – is a topic that requires further research to determine effects resulting from climate change. The available literature (Vaccaro 1992, Loaiciga *et al.* 2000, Hanson and Dettinger 2005, Scibek and Allen 2006, Gurdak *et al.* 2007, all as cited in Lettenmaier *et al.* 2008) implies that groundwater systems generally respond more slowly to climate change than surface water systems do. Groundwater levels correlate most strongly with precipitation. Temperature is a more important factor for shallow aquifers during warm periods (National Science and Technology Council 2008).

Groundwater and surface water might also be affected by sea-level rise. Saltwater intrusion into aquifers might occur in coastal areas, and increased salinity of ground and estuary water might reduce freshwater availability.

4.5.3.3.6 Water Quality

Chemical and microbial inputs, biogeochemical processes, water temperature, and water levels control water quality. Water temperature and water quantity are sensitive to climate change. However, pollution from land use – especially agricultural runoff, urban runoff, and thermal pollution from energy production – have caused most of the observed changes in water quality (National Science and Technology Council 2008).

Rising water temperatures negatively affect aquatic biota, especially certain fish species such as salmon (Bartholow 2005, Crozier and Zabel 2006, both as cited in Lettenmaier *et al.* 2008). Rising temperatures also affect dissolved oxygen, oxidation/reduction potentials, lake stratification, and mixing rates. However, the direction of climate change effects associated with water quantity on water quality is not as evident. Increased streamflow can dilute pollutant concentrations or transport additional pollutants into surface water sources. Extreme events – floods and droughts – generally exacerbate water quality problems.

Region-specific studies conducted for the United States were reviewed by IPCC (Field *et al.* 2007, Kundzewicz *et al.* 2007). Projected impacts on water quality include the following (National Science and Technology Council 2008):

- Changes in precipitation could increase nitrogen loads from rivers in the Chesapeake and Delaware Bay regions by up to 50 percent by 2030 (Kundzewicz *et al.* 2007).

- Decreases in snow cover and increases in winter rain on bare soil will *likely* lengthen the erosion season and enhance erosion intensity. This will increase the potential for sediment-related water quality impacts in agricultural areas (Field *et al.* 2007).

- Increased precipitation amounts and intensities will lead to greater rates of erosion in the United States and in other regions unless protection measures are taken (Kundzewicz *et al.* 2007). Soil management practices (crop residue, no-till) in some regions (*e.g.*, the Corn Belt) might not provide sufficient erosion protection against future intense precipitation and associated runoff (Field *et al.* 2007).

- For the Midwest, in simulated low flows used to develop pollutant discharge limits (Total Maximum Daily Loads) flows decrease more than 60 percent with a 25-percent decrease in mean precipitation, declining by 100 percent with the incorporation of irrigation demands (Eheart *et al.* 1999).

- Restoration of beneficial uses (to address habitat loss, eutrophication, beach closures) under the Great Lakes Water Quality Agreement will *likely* be vulnerable to declines in water levels, warmer water temperatures, and more intense precipitation (Mortsch *et al.* 2003).

- Based on simulations, phosphorus remediation targets for the Bay of Quinte (Lake Ontario) and the surrounding watershed could be compromised as 5.4- to 7.2-°F warmer water temperatures contribute to 77 to 98 percent increases in summer phosphorus concentrations in the Bay (Nicholls 1999), and as changes in precipitation, streamflow, and erosion lead to increases in average phosphorus concentrations in streams of 25 to 35 percent (Walker 2001, as cited in Field *et al.* 2007).

Kundzewicz *et al.* (2007) also concluded (*high confidence*) that climate change is *likely* to make achieving existing water quality goals for North America more difficult (National Science and Technology Council 2008).

4.5.3.3.7 Extreme Events—Floods and Drought

Extreme events such as floods and drought affect freshwater resources. Climatic phenomena – intense/long-lasting precipitation, snowmelt, ice jams – and non-climatic phenomena – dam failure, landslides – can exacerbate floods and drought.

As previously mentioned, research to date has not provided clear evidence for a climate-related trend in floods during past decades. However, evidence suggests that the observed increase in precipitation intensity and other observed climate changes could have affected floods (National Science and Technology Council 2008).

Because the intensity and mean amount of precipitation will increase across the United States at middle and high latitudes, the risk of flash flooding and urban flooding will increase in these areas (Kundzewicz *et al.* 2007, as cited in National Science and Technology Council 2008). At the same time, greater temporal variability in precipitation increases the risk of drought (Christensen *et al.* 2007, as cited in National Science and Technology Council 2008).

There is some evidence of long-term drying and increase in drought severity and duration in the West and Southwest (National Science and Technology Council 2008) that is probably a result of decadal-scale climate variability and long-term change (Lettenmaier *et al.* 2008, as cited in National Science and Technology Council 2008).

Over-allocation and continuing competition for freshwater resources for agriculture, cities, and industry increases vulnerability to extended drought in North America (Field *et al.* 2007), despite the fact that per capita water consumption has declined over the past two decades in the United States (Lettenmaier *et al.* 2008). Reducing water consumption will mitigate the impacts of climate change on freshwater resources.

4.5.3.4 Projected Impacts of Climate Change on Global Fresh Water Resources

The IPCC report is the most recent, comprehensive, and peer-reviewed summary of impacts on global freshwater resources available. Kundzewicz *et al.* (2007) summarized the conclusions from the freshwater resources and management chapter as follows:

- The impacts of climate change on freshwater systems and their management are mainly due to the observed and projected increases in temperature, sea level, and precipitation variability (*very high confidence*).

- More than one-sixth of the world's population lives in glacier- or snowmelt-fed river basins and will be affected by the seasonal shift in streamflow, an increase in the ratio of winter to annual flows, and possibly the reduction in low flows caused by decreased glacier extent or snow water storage (*high confidence*).

- Sea-level rise will extend areas of salinization of groundwater and estuaries, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas (*very high confidence*).

- Increased precipitation intensity and variability is projected to increase the risks of flooding and drought in many areas (*high confidence*).

- Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater (*high confidence*).

- Many of these areas (Mediterranean basin, western United States, southern Africa, and northeastern Brazil) will suffer a decrease in water resources due to climate change (*very high confidence*).

- Efforts to offset declining surface water availability due to increasing precipitation variability will be hampered by the fact that groundwater recharge will decrease considerably in some already water-stressed regions (*high confidence*), where vulnerability is often exacerbated by the rapid increase in population and water demand (*very high confidence*).

- Higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate many forms of water pollution, with impacts on ecosystems, human health, water system reliability, and operating costs (*high confidence*).
- These pollutants include sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt, and thermal pollution.
- Climate change affects the function and operation of existing water infrastructure as well as water management practices (*very high confidence*).
- Adverse effects of climate on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land use change, and urbanization (*very high confidence*).
- Globally, water demand will grow in the coming decades, primarily due to population growth and increased affluence; regionally, large changes in irrigation water demand as a result of climate change are *likely* (*high confidence*).
- Current water management practices are very likely to be inadequate to reduce the negative impacts of climate change on water supply reliability, flood risk, health, energy, and aquatic ecosystems (*very high confidence*).
- Improved incorporation of current climate variability into water-related management would make adaptation to future climate change easier (*very high confidence*).
- Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions (the Caribbean, Canada, Australia, Netherlands, United Kingdom, United States, and Germany) that have recognized projected hydrological changes with related uncertainties (*very high confidence*).
- Since the IPCC Third Assessment, uncertainties have been evaluated, their interpretation has improved, and new methods (*e.g.*, ensemble-based approaches) are being developed for their characterization (*very high confidence*).
- Nevertheless, quantitative projections of changes in precipitation, river flows, and water levels at the river-basin scale remain uncertain (*very high confidence*).
- The negative impacts of climate change on freshwater systems outweigh its benefits (*high confidence*).
- All IPCC regions (*see* Chapters 3 through16 of the IPCC report) show an overall net negative impact of climate change on water resources and freshwater ecosystems (*high confidence*).
- Areas in which runoff is projected to decline are *likely* to face a reduction in the value of the services provided by water resources (*very high confidence*).
- The beneficial impacts of increased annual runoff in other areas will be tempered by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality, and flood risks (*high confidence*).

Observed global climate-related trends affecting freshwater resources were identified previously. The following discussion identifies key projected impacts on surface waters, groundwater, extreme events, and water quality.

4.5.3.4.1 Surface Water

Data from 24 climate model runs generated by 12 different general circulation models (Milly *et al.* 2005, as cited in Kundzewicz *et al.* 2007) generally agreed that by 2050:

- Annual average river runoff and water availability will increase by 10 to 40 percent at high latitudes (North America, Eurasia) and in some wet tropical areas.
- Annual average river runoff and water availability will decrease by 10 to 30 percent over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water-stressed areas (Mediterranean, southern Africa, and western United States/northern Mexico).

Hydrological impact studies have shown that warming leads to changes in the seasonality of river flows where much winter precipitation currently falls as snow, including the European Alps, the Himalayas, western North America, central North America, eastern North America, the Russian territory, Scandinavia, and Baltic regions. Winter flows will increase, summer flows will decrease, and peak flow will occur at least one month earlier in many cases (Kundzewicz *et al.* 2007).

Higher temperatures increase glacier melt. Glacier melt sustains many rivers during the summer in the Hindu Kush Himalaya and the South American Andes (Singh and Kumar 1997, Mark and Seltzer 2003, Singh 2003, Barnett *et al.* 2005, all as cited in Kundzewicz *et al.* 2007). The mass of some northern hemisphere glaciers is projected to decrease up to 60 percent by 2050 (Schneeberger *et al.* 2003, as cited in Kundzewicz *et al.* 2007).

Predictions for rain-fed basins describe higher flows in peak-flow season with either lower flows in low-flow season or extended dry periods (Kundzewicz *et al.* 2007).

Lake levels are determined by river and rain water inputs and evaporation outputs. By the end of the 21st Century, water levels are predicted to change between −4.5 feet and +1.15 feet in the Great Lakes (Lofgren *et al.* 2002, Schwartz *et al.* 2004b, both as cited in Kundzewicz *et al.* 2007) and to drop about 29.5 feet in the Caspian Sea (Elguindi and Giorgi 2006, as cited in Kundzewicz *et al.* 2007).

From 2010 to 2015, the ice cover on Siberian rivers is expected to melt 15 to 27 days sooner than it did from 1950 to 1979. The maximum ice cover is also expected to be 20 to 40 percent thinner (Vuglinsky and Gronskaya 2005, as cited in Kundzewicz *et al.* 2007).

A combination of land-use changes and climate change could affect annual runoff. Land-use changes are predicted by model studies to have a small effect compared to climate change in the Rhine basin, southeastern Michigan, Pennsylvania, and central Ethiopia. In southeastern Australia and southern India, predictions are comparable, with climate change having the potential to exacerbate reductions in runoff caused by afforestation (Kundzewicz *et al.* 2007).

Evapotranspiration – water loss from plant leaves – responds to increases in carbon dioxide in two distinct ways. First, higher CO_2 concentrations cause leaf stomata to close, reducing evapotranspiration. Second, CO_2 fertilization encourages plant growth, increasing total leaf area and subsequent evapotranspiration. Considering these vegetation effects, global mean runoff has been predicted to increase by 5 percent for a doubling of CO_2 concentration (Betts *et al.* 2007, Leipprand and

Gerten 2006, both as cited in Kundzewicz *et al.* 2007) compared to a 5 to 17 percent increase under climate change alone (Kundzewicz *et al.* 2007).

4.5.3.4.2 Groundwater

Climate change will mainly affect groundwater recharge rates, although very little research has been done on the issue. Groundwater levels could change as a result of thawing permafrost, vegetation changes, changes in river level (where hydraulic connection is adequate), and changes in floods. Global hydrological models predict that globally averaged groundwater recharge will increase less (2 percent) than total runoff (9 percent) in the 2050s compared to recharge and runoff rates from 1961 to 1990. In northeastern Brazil, southwestern Africa, and the southern Mediterranean coast, groundwater recharge is predicted to decrease by more than 70 percent. In contrast, recharge is predicted to increase by more than 30 percent in the Sahel, Near East, northern China, Siberia, and the western United States (Döll and Flörke 2005, as cited in Kundzewicz *et al.* 2007). Projected impacts on individual aquifers return very site-specific results.

Any decrease in groundwater recharge will exacerbate the effect of saltwater intrusion. Saltwater intrusion has been projected for a sea-level rise of 0.33 feet on two coral islands off the Indian coast – the thickness of the freshwater lens decreasing from 82 feet to 32 feet and from 118 feet to 92 feet (Bobba *et al.* 2000, as cited in Kundzewicz *et al.* 2007). Saltwater intrusion from sea-level rise might also affect groundwater/aquifer water supplies on similar small islands.

4.5.3.4.3 Extreme Events—Floods and Droughts

As discussed earlier, increased climate variability increases the risks of both floods and droughts depending on climatic and non-climatic variables. Extreme floods and extreme droughts are predicted to become more frequent in the future under various climate models (Kundzewicz *et al.* 2007). However, climate change impacts on flood magnitude and frequency can be both positive and negative depending on the global climate model used, snowmelt contributions, catchment characteristics, and location (Reynard *et al.* 2004, as cited in Kundzewicz *et al.* 2007).

By the 2090s, the proportion of the total land surface in extreme drought is predicted to increase from the current rate of 1 to 3 percent to 30 percent; extreme drought events per 100 years are predicted to double; and mean drought duration is predicted to increase by a factor of six (Burke *et al.* 2006, as cited in Kundzewicz *et al.* 2007).

More floods are predicted for northern and northeastern Europe, while more drought is predicted for southern and southeastern Europe (Lehner *et al.* 2005, as cited in Kundzewicz *et al.* 2007).

The area flooded in Bangladesh is projected to increase by 23 to 29 percent for a global temperature rise of 3.6 °F (Mirza 2003, as cited in Kundzewicz *et al.* 2007). Up to 20 percent of the world’s population lives in river basins at risk from increased flooding (Kleinen and Petschel-Held 2007, as cited in Kundzewicz *et al.* 2007).

4.5.3.4.4 Water Quality

Higher water temperatures and runoff variations are *likely* to affect water quality negatively (Patz 2001, Lehman 2002, O’Reilly *et al.* 2003, Hurd *et al.* 2004, all as cited in Kundzewicz *et al.* 2007). Negative impacts on water quality from changes in water quantity include resuspension of bottom sediments, increased turbidity (suspended solids), pollutant introduction, and reduced dilution. Negative impacts from water temperature include algal blooms, increased microbial concentrations, and outgassing of volatile and semi-volatile compounds like ammonia, mercury, dioxins, and pesticides (Kundzewicz *et al.* 2007).

Acidic atmospheric deposition is projected to increase acidification in rivers and lakes (Ferrier and Edwards 2002, Gilvear *et al.* 2002, Soulsby *et al.* 2002, all as cited in Kundzewicz *et al.* 2007).

Salt concentration is expected to increase in estuaries and inland reaches under decreasing streamflows. For example, salinity is projected to increase in the tributary rivers above irrigation areas in Australia's Murray-Darling Basin by 13 to 19 percent by 2050 and by 21 to 72 percent by 2100 (Kundzewicz *et al.* 2007).

No quantitative studies projecting the impact of climate change on microbiological water quality for developing countries are cited by the IPCC. However, climate change will be an additional stressor affecting water quality and public health. Potential impacts include increased waterborne disease with increases in extreme rainfall, and great incidence of diarrheal and water-related diseases in regions with increased drought (Kundzewicz *et al.* 2007). A brief overview of the effects of climate change on the availability and quality of drinking water is provided by Anderson *et al.* (2005).

Developed countries are also experiencing water quality issues in their water and wastewater treatment plants. Increased filtration is required in drinking water plants to address micro-organism outbreaks following intense rain, thus increasing some operating costs by 20 to 30 percent (AWWA 2006, as cited in Kundzewicz *et al.* 2007). Other stressors on water quality include the following (Kundzewicz *et al.* 2007):

- More water impoundments for hydropower (Kennish 2002, Environment Canada 2004).
- Stormwater drainage operation and sewage disposal disturbances in coastal areas resulting from sea-level rise (Haines *et al.* 2000).
- Increasing water withdrawals from low-quality sources.
- Greater pollutant loads resulting from increased infiltration rates to aquifers or higher runoff to surface waters (resulting from high precipitation).
- Water infrastructure malfunctioning during floods (GEO-LAC 2003, DFID 2004).
- Overloading the capacity of water and wastewater treatment plants during extreme rainfall (Environment Canada 2001).
- Increased amounts of polluted storm water.

In many regions, there is no alternative supply even as water quality declines, and reusing wastewater (*e.g.*, to irrigate crops) can introduce other public health problems.

Global adaptation to freshwater resource stressors will require the availability of relevant information, more water resource options (*e.g.*, storage), and proactive responses in the face of climatic changes. These responses will include effluent disposal strategies accounting for reduced biodegradation; water and wastewater treatment plant design accounting for extreme climate conditions; and reducing, reusing, and recycling water (Luketina and Bender 2002, Environment Canada 2004, Patrinos and Bamzai 2005, all as cited in Kundzewicz *et al.* 2007).

4.5.4 Terrestrial Ecosystems

This section addresses climate-related impacts on terrestrial ecosystems. An ecosystem is defined as a complex of biological communities (plants, animals, and microorganisms) and their non-living environments, which act together as a unit (MA 2005e and Reid *et al.* 2005, as cited in Fischlin *et al.* 2007). By definition, relationships within an ecosystem are strong while relationships with components outside the ecosystem boundaries are weak (Reid *et al.* 2005, Part 2, as cited in Fischlin *et al.* 2007).

4.5.4.1 Affected Environment

Earth's biosphere is an interconnected network of individuals, populations, and interacting natural systems, referred to as ecosystems. Ecosystems are critical, in part, because they supply humans with services that sustain life and are beneficial to the functioning of society (Fischlin *et al.* 2007). Ecosystems include:

- Terrestrial communities, such as forests, grasslands, shrublands, savanna, and tundra
- Aquatic communities, such as rivers, coral reefs, lakes, and estuaries
- Wetlands, such as marshes, swamps, and bogs (Peterson *et al.* 2008)

The focus of this section is on terrestrial ecosystems.

4.5.4.1.1 Global Terrestrial Ecosystems

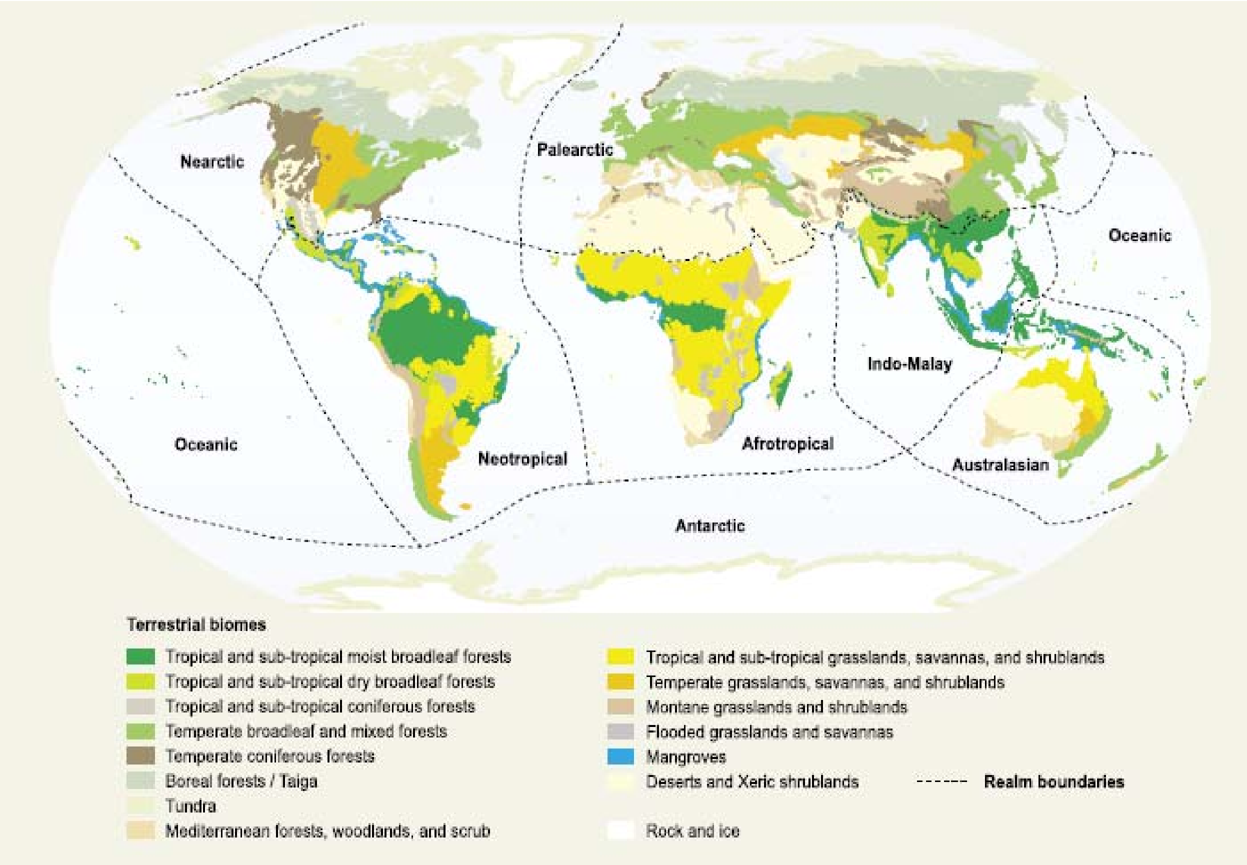
The World Wildlife Fund (WWF) has developed a widely accepted global ecosystem classification that consists of what are referred to as ecozones, biomes, and ecoregions. Similar to the classification of Miklos Udvary's (1975) biogeographical realm, the ecozone is the biogeographic division of Earth's surface at the largest scale. Terrestrial ecozones follow the floral and faunal boundaries that separate the world's major plant and animal communities. The WWF has identified eight ecozones, as indicated in Figure 4.5-1.

Biomes are climatically and geographically defined areas of ecologically similar communities of plants, animals, and microorganisms. These habitat types are defined by factors such as plant structures, leaf types, plant spacing, and climate. The land classification system developed by WWF identifies 14 major terrestrial habitat types, which can be further divided into 825 smaller, more distinct terrestrial ecoregions (WWF 2008a). The 14 primary terrestrial habitats recognized by WWF are as follows.

Tundra is a treeless polar desert found at high latitudes in the polar regions, primarily in Alaska, Canada, Russia, Greenland, Iceland, and Scandinavia, and sub-Antarctic islands. These regions are characterized by long, dry winters, months of total darkness, and extremely frigid temperatures. The vegetation is composed of dwarf shrubs, sedges and grasses, mosses, and lichens. A wide variety of animals thrive in the tundra, including herbivorous and carnivorous mammals and migratory birds.

Boreal Forests and Taiga are forests found at northerly latitudes in inland Alaska, Canada, Sweden, Finland, Norway, and Russia, and parts of the extreme northern continental United States, northern Kazakhstan, and Japan. Annual temperatures are low and precipitation ranges from 15 to 40 inches per year and can fall mainly as snow. Vegetation includes coniferous and deciduous trees, lichens, and mosses. Herbivorous mammals and small rodents are the predominant animal species; however, predatory birds and mammals also occupy this habitat type.

Figure 4.5-1. Ecozones and Biomes of the World a/



a/ Source: MA 2005f

Temperate coniferous forests are found predominantly in areas with warm summers and cool winters. Plant life varies greatly across temperate coniferous forests. In some forests, needleleaf trees dominate, while others consist of broadleaf evergreen trees or a mix of both tree types. Typically, there are two vegetation layers in a temperate coniferous forest: an understory dominated by grasses and shrubs and an overstory of large tree species.

Temperate broadleaf and mixed forests experience a wide range of variability in temperature and precipitation. In regions where rainfall is distributed throughout the year, deciduous trees are mixed with evergreens. Species such as oak, beech, birch, and maple typify the tree composition of this habitat type. Diversity is high for plants, invertebrates, and small vertebrates.

Mediterranean forests, woodlands, and shrub ecoregions are characterized by hot and dry summers, while winters tend to be cool and moist. Most precipitation arrives during winter. Only five regions in the world experience these conditions: the Mediterranean, south-central and southwestern Australia, the fynbos of southern Africa, the Chilean matorral, and the Mediterranean ecoregions of California. These regions support a tremendous diversity of habitats and species.

Tropical and subtropical coniferous forests are found predominantly in North and Central America and experience low levels of precipitation and moderate variability in temperature. These forests are characterized by diverse species of conifers, whose needles are adapted to deal with the variable climate conditions. These forests are wintering ground for a variety of migratory birds and butterflies.

Tropical and subtropical moist broadleaf forests are generally found in large, discontinuous patches centered on the equatorial belt and between the Tropics of Cancer and Capricorn. They are characterized by low variability in annual temperature and high levels of rainfall. Forest composition is dominated by semi-evergreen and evergreen deciduous tree species. These forests are home to more species than any other terrestrial ecosystem. A square kilometer can support more than 1,000 tree species. Invertebrate diversity is extremely high, and dominant vertebrates include primates, snakes, large cats, amphibians, and deer.

Tropical and subtropical dry broadleaf forests are found in southern Mexico, southeastern Africa, the Lesser Sundas, central India, Indochina, Madagascar, New Caledonia, eastern Bolivia, central Brazil, the Caribbean, valleys of the northern Andes, and along the coasts of Ecuador and Peru. Deciduous trees predominate in most of these forests and they are home to a wide variety of wildlife, including monkeys, large cats, parrots, various rodents, and ground-dwelling birds.

Temperate grasslands, savannas, and shrublands are known as prairies in North America, pampas in South America, veld in southern Africa, and steppe in Asia. They differ from tropical grasslands in species composition and the annual temperature regime under which they thrive. These regions are devoid of trees, except for riparian or gallery forests associated with streams and rivers. Biodiversity in these habitats includes a number of large grazing mammals and associated predators, burrowing mammals, numerous bird species, and a diversity of insects.

Tropical and subtropical grasslands, savannas, and shrublands are found in the large expanses of land in the tropics that do not receive enough rainfall to support extensive tree cover. However, there could be great variability in soil moisture throughout the year. Grasses dominate the species composition of these ecoregions, although scattered trees can be common. Large mammals that have evolved to take advantage of the ample forage typify the biodiversity associated with these habitats.

Montane grasslands and shrublands include high-elevation grasslands and shrublands, such as the puna and paramo in South America, subalpine heath in New Guinea and East Africa, steppes of the Tibetan plateaus, and other similar subalpine habitats around the world. Montane grasslands and shrublands are tropical, subtropical, and temperate. Mountain ecosystem services such as water purification and climate regulation extend beyond the geographical boundaries of the grasslands and shrublands and affect all continental mainlands (Woodwell 2004). Characteristic plants of these habitats display features such as rosette structures, waxy surfaces, and abundant pilosity (WWF 2008b).

Deserts and xeric shrublands across the world vary greatly with respect to precipitation and temperature. Generally, rainfall is less than 10 inches annually and evaporation exceeds precipitation. Temperature variability is also extremely diverse in these remarkable lands. Many deserts, such as the Sahara, are hot year-round, but others, such as Asia's Gobi, become quite cold in winter. Woody-stemmed shrubs and plants evolved to minimize water loss characterize vegetation in these regions. Animal species are equally well-adapted to the dry conditions, and species are quite diverse.

Mangroves occur in the waterlogged, salty soils of sheltered tropical and subtropical shores, where they stretch from the intertidal zone to the high tide mark. Associated with these tree species is a whole host of aquatic and salt-tolerant plants. Mangroves provide important nursery habitats for a vast array of aquatic animal species.

Flooded grasslands and savannas are common to four continents. These vast areas support numerous plants and animals adapted to the unique hydrologic regimes and soil conditions. Large congregations of migratory and resident water birds can be found in these regions. Ecosystem services include breeding habitat and the buffering of inland areas from the effects of wave action and storms (MA 2005e).

4.5.4.1.2 Terrestrial Ecosystems in the United States

Published in 1976, *Ecoregions of the United States* was one of the first attempts to divide the Nation into ecosystem regions systematically. Subsequently, Bailey (1980) provided, for each region, a brief description of the dominant physical and biological characteristics based on land-surface form, climate, vegetation, soils, and fauna. Bailey defined four major domains, 12 divisions, and 30 provinces. Since then, the ecoregions of North America have been further refined by the international working group of the Commission of Environmental Cooperation (CEC 1997). Their system divides the continent into 15 broad level I ecoregions, 52 level II ecoregions, and approximately 200 level III ecoregions. The level I ecoregions present in the United States include tundra, taiga, northern forests, northwestern forested mountains, marine west coast forests, eastern temperate forests, great plains, North American deserts, Mediterranean California, southern semi-arid highlands, temperate sierras, and tropical humid forests (*see* Figure 4.5-2).

Ecosystems are dynamic and can change naturally over time as a result of drivers such as climate change (natural or anthropogenic), geological processes (volcanic eruptions, earthquakes, landslides), fire, disease or pest outbreaks, and evolution. All organisms modify their environment to some extent; however, in the past century and especially in the past 50 years, human population growth and technological innovations have affected ecosystems drastically (Vitousek *et al.* 1997). In fact, the structure of the world's ecosystems have changed more rapidly in the second half of the 20th Century than in any time in recorded human history (MA 2005e). It is expected that during the course of this century, the resilience of many ecosystems is likely to be exceeded by anthropogenic pressures (Fischlin *et al.* 2007).

4.5.4.1.3 Non-climate Threats to Global Terrestrial Ecosystems

The Millennium Ecosystems Assessment (MA), a United Nations research project, focuses on identifying the current inventory and conditions of 10 categories of global ecosystems (including 5 categories of natural terrestrial ecosystems) and projecting changes and trends into the future.

In 2005, the MA released five technical volumes and six synthesis reports, providing a scientific appraisal of the condition and trends in the world's ecosystems and the services they provide. From 2001 to 2005, the MA involved the work of more than 1,360 experts worldwide. The MA included the following conclusions regarding the current state of global ecosystems (MA 2005e):

- Cultivated systems now cover one quarter of Earth's terrestrial surface. More than two thirds of the area of 2 of the world's 14 major terrestrial biomes and more than half of the area of 4 other biomes had been converted by 1990, primarily to agriculture.
- Across a range of taxonomic groups, for most species, either the population size or range or both is currently declining.
- The distribution of species on Earth is becoming more homogenous; in other words, the set of species in any one region of the world is becoming more similar to the set in other regions primarily as a result of introductions of species, both intentionally and inadvertently in association with increased travel and shipping.

Figure 4.5-2. Level I Ecoregions in the North America a/

a/ Source: CEC 1997

- The number of species on the planet is declining. Over the past few hundred years, humans have increased the species extinction rate by as much as 1,000 times over background rates typical over Earth's history. Some 10 to 30 percent of mammal, bird, and amphibian species are currently threatened with extinction.

- Only 4 of the 24 ecosystem services examined in this assessment have been enhanced, while 15 have been degraded (Hassan *et al.* 2005).

The MA concluded that biodiversity changes due to human activities were more rapid in the past 50 years than at any time in human history. Moreover, the forces causing biodiversity loss and leading to changes in ecosystem services are either steady, show no evidence of declining over time, or are increasing in intensity. The MA examined four plausible future scenarios and projected that the rates of biodiversity change will continue or accelerate (MA 2005e).

The changes in ecosystems identified in the MA can have impacts on ecological processes, species composition, and genetic diversity. Ecological processes, which include water, nitrogen, carbon, and phosphorous cycling, have all changed more rapidly in the second half of the 20th Century than at any time in recorded human history (MA 2005e). Human actions have not only changed the structure of ecosystems, but also the processes as functions of the ecosystems.

A change in ecosystem structure also affects the species within the system and vice versa. Historically, the natural processes of evolution and the combination of natural barriers to species migration and local adaptation resulted in substantial phenotypic differences in plant and animal species of different ecosystems. These regional differences are now becoming rare.

Some ecosystem changes have been the inadvertent result of activities unrelated to the use of ecosystem services, such as the construction of roads, ports, and cities and the discharge of pollutants. But most ecosystem changes were the direct or indirect result of changes made to meet growing demands for food, water, timber, fiber, and fuel (MA 2005e). Ecosystems change can be affected by a variety of human and natural drivers, including climate change, land use, land degradation, urbanization, pollution, natural climate change, geological processes, and invasive species. These drivers can act independently or in concert with each other (Lepers *et al.* 2004), and are summarized below.

Land Use Change

Land use change represents the anthropogenic replacement of one land use type by another, such as forest converted to cultivated land (or the reverse), and subtle changes of management practices within a given land use type, such as intensification of agricultural practices. Both forms of land use change are affecting 40 percent of the terrestrial surface (Foley *et al.* 2005). Land use change can lead to habitat loss and fragmentation and is an important driver in ecosystem change (Heywood and Watson 1995, Fahrig 2003). Overall, land transformation represents the primary driving force in the loss of biological diversity (Vitousek *et al.* 1997). In 9 of the 14 terrestrial biomes studied by the MA, over half the area has been transformed, largely by agricultural cultivation (Hassan *et al.* 2005). Only the biomes that are less suitable for agriculture, such as deserts, boreal forests, and tundra, have remained largely untransformed by human activity.

Virtually all of Earth's ecosystems have now been substantially transformed through human actions (MA 2005e). Roughly 70 percent of original temperate grasslands and forests and Mediterranean forests were lost by 1950, chiefly from conversion to agricultural lands. More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850 (MA 2005a, Hassan *et al.* 2005).

Historically, terrestrial ecosystems that have been most substantially altered by human activity include temperate broadleaf forests, temperate grasslands, Mediterranean forests, and tropical dry forests (Hassan *et al.* 2005). Of these, more than two thirds of the temperate grasslands and Mediterranean forests, and more than half of tropical dry forests, temperate broadleaf forests, and tropical grasslands have been converted to agriculture (Hassan *et al.* 2005). Forest systems in general have been reduced by half over the past three centuries, and have effectively disappeared in 25 countries. Another 29 countries have lost 90 percent or more of their forest cover (Hassan *et al.* 2005).

Globally, the rate of ecosystem conversion has begun to decelerate, mainly because the rate of expansion of cultivated land has declined. Ecosystems are beginning to return to conditions and species compositions similar to their pre-conversion states. However, rates of ecosystem conversion remain high or are increasing for specific ecosystems and ecoregions (MA 2005f). Land use changes and land degradation are important drivers of ecosystem change globally and in the United States. For example, "between 1982 and 1997, 11 million acres of nonfederal grasslands and shrublands were converted to other uses" (The H. John Heinz III Center for Science 2002).

The increase in cultivated land, especially for the purpose of grazing, has led to an increase in desertification. Desertification involves the expansion of deserts into semi-arid and subhumid regions, and the loss of productivity in arid zones. Desertification is characterized by loss of groundcover and soils, replacement of palatable, mesophytic grasses by unpalatable xerophytic shrubs, or both (Ryan *et al.* 2008). Desertification affects the livelihoods of millions of people, including a large portion of the poor residents of drylands (Hassan *et al.* 2005). While desertification can certainly be exacerbated by changes in climate, there has been long-standing controversy over the relative contributions of climatic and anthropogenic factors as drivers of desertification (National Science and Technology Council 2008).

Fire

Fire influences ecosystem structure by promoting species that tolerate fire or even enhance fire spread, resulting in a relationship between the relative flammability of a species and its relative abundance in a particular community (Bond and Keeley 2005). Intensified and increasing wildfire occurrences appear to be changing vegetation structure and composition in some ecoregions. In the forest-tundra transition in eastern Canada, this transition is observed in a shift from *Picea*- to *Pinus*-dominated communities and 75 to 95 percent reductions in tree densities (Lavoie and Sirois 1998). Across the boreal forests of North America, total burned areas increased by a factor of 2.5 between the 1960s and the 1990s (Kasischke and Turetsky 2006).

Insect Outbreaks

Invasive alien species represent a major threat to endemic or native biodiversity in terrestrial and aquatic systems. Alien species invasions also interact with other drivers, sometimes resulting in unexpected outcomes. The impact of insect damage is substantial and can exceed the impacts of fire in some ecosystems, but especially in boreal forests (Logan *et al.* 2003). For example, spruce budworm defoliated more than 20 times the area burned in eastern Ontario between 1941 and 1996 (Fleming *et al.* 2002). Fires tended to occur 3 to 9 years after a spruce budworm outbreak (Fleming *et al.* 2002), suggesting that insect outbreaks can be a driver of increased fire events. Forest impacts by the forest tent caterpillar have also increased in western Canada over the past 25 years (Timoney 2003).

Species Decline and Extinction

Although extinction is a natural part of Earth's history, observed modern rates of extinction are not part of natural cycles. Over the past few hundred years, humans have increased the extinction rate by as much as 1,000 times over the rate expected based on natural history (Hassan *et al.* 2005). A decrease in global genetic diversity is linked to extinction. The loss of unique populations has resulted in the loss of genetic diversity. The loss of genetic diversity has also declined among cultivated species as farmers have shifted from locally adapted crop populations to more widely adapted varieties produced through formal breeding practices. Currently, for most species across a wide range of taxonomic groups, either the population size, population range, or both is in decline (MA 2005e).

Pollution

Pollution is another substantial threat to terrestrial ecosystems. Over the past four decades, excessive nutrient loading has emerged as one of the most important direct drivers of ecosystem change in terrestrial, freshwater, and marine systems. A known cause is the use of increasing amounts of synthetic nitrogen and phosphorous fertilizers, which can be lost to the environment after application. Consumption of nitrogen fertilizer grew nearly 800 percent between 1960 and 2003 (MA 2005f). In terrestrial ecosystems, excessive nitrogen flows contribute to acidification. Nitrogen also plays a role in ground-level ozone, which can lead to a loss of forest productivity (MA 2005f).

4.5.4.2 Environmental Consequences

This section discusses current climate change impacts that have already been observed and projected impacts (including the potential for adaptation to climate changes). Climate change impacts are discussed generally, and with specific attention to impacts in the United States. The IPCC WGI Fourth Assessment Report (Fischlin *et al.* 2007) was released in 2007, and in 2008 the USCCSP report on climate sensitive ecosystems was released (CCSP 2008a). The 2007 IPCC report is the most comprehensive, recent summary of projected impacts of global climate change. Many of the impacts discussed in this section were gathered from the 2007 IPCC report, which provides an analysis and discussion on a global scale. Information about impacts specific to ecosystems in the United States was obtained primarily from the 2008 USCCSP report. The projected impacts reported below were forecast with varying degrees of certainty. The level of certainty, as defined by IPCC, is noted in this report where relevant.

4.5.4.2.1 Observed Climate Change Impacts

Because terrestrial ecosystems are defined by the interactions of biotic factors (plants, animals, and microorganisms) and abiotic factors (geology, hydrology, weather), climate is a key factor in determining the different characteristics and distributions of natural systems.

<u>Observed Impacts on Terrestrial Ecosystems Globally</u>

Studies have noted the response of biological and chemical characteristics of ecosystems to climate conditions, especially temperature change. Substantial research has examined the effects of climate change on vegetation and wildlife, leading to the conclusion that the changing climate is already having a real and demonstrable effect on a variety of ecosystem types (CCSP 2008b). As noted in the IPCC report, plants and animals can reproduce, grow, and survive only within specific ranges of climate and environmental conditions (Fischlin *et al.* 2008). Changes in climate can affect terrestrial ecosystems in any of the following ways (Rosenzweig *et al.* 2007):

- Shifting the timing of life cycle events such as blooming or migration
- Shifting range boundaries or densities of individuals within their ranges
- Changing species morphology (body size, egg size), reproduction, or genetics
- Causing extirpation or extinction.

These changes are a result of many factors. Phenology – the timing of seasonal activities of animals and plants – is perhaps the simplest process by which to track changes in the ecology of species in response to climate change (Rosenzweig *et al.* 2007). Observed phenological events include leaf unfolding, flowering, fruit ripening, leaf coloring, leaf fall of plants, bird migration, chorusing of amphibians, and appearance or emergence of butterflies. Global daily satellite data, available since 1981, indicate an earlier onset of spring by 10 to 14 days over 19 years, particularly across temperate latitudes of the northern hemisphere (Zhou *et al.* 2001, Lucht *et al.* 2002). Leaf unfolding and flowering in spring and summer have, on average, advanced by 1 to 3 days per decade in Europe, North America, and Japan over the last 30 to 50 years (Fischlin *et al.* 2007). The seasonal timing of bird migration and egg laying has also changed, associated with the increase of temperature in breeding grounds and migration routes. According to IPCC (Rosenzweig *et al.* 2007), "Many small mammals have been observed to come out of hibernation and to breed earlier in the spring than they did a decade ago (Inouye *et al.* 2000, Franken and Hik 2004) and even larger mammals such as reindeer are showing phenological changes (Post and Forchhammer 2002), as are butterflies, crickets, aphids, and hoverflies (Forister and Shapiro 2003, Stefanescu *et al.* 2003, Hickling *et al.* 2005, and Newman 2005). Increasing regional temperatures are also associated with earlier calling and mating and shorter time to maturity of amphibians (Gibbs and Breisch 2001, Reading 2003, and Tryjanowski *et al.* 2003)."

Rapid global warming can directly affect the size of a species' range, the density of individuals within the range, and the abundance of preferred habitat within the range. Climate changes have affected the location of suitable habitat for several species of plants and animals. Changes in the distribution of species have occurred across a wide range of taxonomic groups and geographical locations (Rosenzweig *et al.* 2007). Several different bird species no longer migrate out of Europe in the winter as the temperature continues to warm (Rosenzweig *et al.* 2007). Over the past decades, a poleward extension of various species has been observed, which is probably attributable to increases in temperature (Parmesan and Yohe 2003, as cited in Rosensweig *et al.* 2007). Many Arctic and tundra communities are affected and have been replaced by trees and dwarf shrubs (Kullman 2002 and ACIA 2005, both as cited in Rosensweig *et al.* 2007). In some mountainous areas of the northern hemisphere, including in Alaska, tree lines have shifted to higher altitudes over the past century (Sturm *et al.* 2001, as cited in Rosensweig *et al.* 2007).

Decreases in the size of a species' range, the density of individuals within the range, and the abundance of its preferred habitat factors can lower species population size (Wilson *et al.* 2004, as cited in Rosensweig *et al.* 2007) and can increase the risk of extinction. Examples of declines in populations and subsequent extinction or extirpation are found in amphibians around the world (Alexander and Eischeid 2001, Middleton *et al.* 2001, Ron *et al.* 2003, and Burrowes *et al.* 2004, all as cited in Rosensweig *et al.* 2007).

Changes in morphology and reproduction rates have been attributed to climate change. For example, the egg sizes of many bird species are changing with increasing regional temperatures (Jarvinen 1996 and Tryjanowski *et al.* 2004). Several studies conducted in Asia and Europe found that some birds and mammals are experiencing increases in body size as temperatures increase, on a regional scale, most likely due to the increasing availability of food (Nowakowski 2002, Yom-Tov 2003, Kanuscak *et al.* 2004, and Yom-Tov and Yom-Tov 2004, as cited in Rosenzweig *et al.* 2007). Many northern insects have a 2-year life cycle, and warmer winter temperatures allow a larger fraction of overwintering larvae to survive. The mountain pine beetle has expanded its range in British Columbia into areas previously considered too cold (Carroll *et al.* 2003).

Observed Changes on Terrestrial Ecosystems in the United States

Changes and impacts on ecosystems in the United States are similar to those occurring globally. During the 20th Century, the United States already had begun to experience the effects of climate change. Precipitation over the contiguous United States increased 6.1 percent over long-term averages (CCSP 2008a), while a sea-level rise of 0.06 to 0.12 inch per year has occurred at most of the country's coastlines; the Gulf coast has experienced an even greater rise in sea level at a rate of 0.2 to 0.4 inch per year (CCSP 2008a).

Examples of observed changes to terrestrial ecosystems in the United States attributable to anthropogenic climate change include the following:

- Many plant species are expanding leaves or flowering earlier, for example: earlier flowering in lilac,1.8 days per decade (Schwartz and Reiter 2000) and honeysuckle, 3.8 days per decade (Cayan *et al.* 2001); earlier leaf expansion in apple and grape, 2 days per decade (Wolfe *et al.* 2005) and trembling aspen, 2.6 days per decade (Wolfe *et al.* 2005).

- Warmer springs have led to earlier nesting for 28 migrating bird species on the east coast of the United States (Butler 2003) and to earlier egg laying for Mexican jays (Brown *et al.* 1999) and tree swallows (Dunn and Winkler 1999).

- Several frog species now initiate breeding calls 10 to 13 days earlier than a century ago (Gibbs and Breisch 2001).

- In lowland California, 70 percent of 23 butterfly species advanced the date of first spring flights by an average of 24 days over 31 years (Forister and Shapiro 2003).

- Many North American plant and animal species have shifted their ranges, typically to the north or to higher elevations (Parmesan and Yohe 2003).

- Edith's checkerspot butterfly has become locally extinct in the southern, low-elevation portion of its western North American range but has extended its range 56 miles north and 394 feet higher in elevation (Parmesan 1996, Crozier 2003, and Parmesan and Galbraith 2004). Edith's checkerspot butterfly is important to the survival of its grassland and rocky outcrop habitat, and also provides essential ecosystem services because the adult butterflies pollinate various flowers (Scott 1986, as cited in Kayanickupuram 2002).

- The frequency of large forest fires and the length of the fire season in the western United States have increased substantially since 1985. These phenomena are related to the advances in the timing of spring snowmelt and increases in spring and summer air temperatures (Westerling *et al.* 2006).

- In the Great Basin region, the onset of snow runoff is currently 10 to 15 days earlier than it was 50 years ago (Cayan *et al.* 2001).

- The vegetation growing season has increased on average by about 2 days per decade since 1948, with the largest increase happening in the West (Easterling 2002; Feng and Hu 2004).

- Recently, spruce budworm in Alaska has completed its lifecycle in 1 year, rather than the 2 years previously (Volney and Fleming 2000). This allows many more individuals to survive the overwintering period with impacts on the boreal forests of North America.

- Over the past 3 to 5 decades, all the major continental mountain chains exhibited upward shifts in the height of the freezing level (Diaz *et al.* 2003).

- Populations of the American pika, a mountain-dwelling relative of the rabbit, are in decline (Beever *et al.* 2003). The pika might be the first North American mammal to become extinct as a result of anthropogenic climate change.

- Reproductive success in polar bears has declined as a result of melting Arctic Sea ice. Without ice, polar bears cannot hunt seals, their preferred prey (Derocher *et al.* 2004). On May 15, 2008, the U.S. Fish and Wildlife Service listed the polar bear as a threatened species, reflecting the loss of sea ice habitat that once encompassed more than 90 percent of the polar bear's habitat range (*FR* 73, 28212-28303, May 15, 2008).

4.5.4.2.2 Projected Impacts of Climate Change in the United States

The United States is projected to experience changes in average temperature and precipitation over the 21st Century of an even greater magnitude than those experienced in the 20th Century. Although the entire country is projected to experience some degree of change, particular regions of the United States could experience changes of a greater-than-average magnitude. For example, the greatest changes in temperature are projected for Alaska and the western continental United States (CCSP 2008a). In northern Alaska, the average temperatures are projected to increase 5 °C by the end of the 21st Century. Areas near coasts are projected to witness an increase of approximately 2 °C over the same period; summer temperatures nationwide could increase 3 to 5 °C; and winter temperatures are projected to increase 7 to 10 °C (CCSP 2008a).

Additional expected changes in United States climate include:

- More frequent hot days and hot nights (CCSP 2008a)
- Heavier precipitation events, primarily in the form of rain rather than snow (CCSP 2008a). Annual precipitation in the northeastern United States is projected to increase while precipitation in the Southwest is expected to decrease (Christensen *et al.* 2007)
- A decline in spring snow cover, leading to decreased availability of water in reservoirs (CCSP 2008a)

Ecosystems across the United States are projected to experience both positive and negative impacts from climate change over the next century. The degree of impacts will vary by region. Wildlife species have already responded to climate change and its effects on migration patterns, reproduction, and geographic ranges (Field *et al.* 2007, as cited in National Science and Technology Council 2008). Future, more substantial changes in climate are projected to affect many ecosystem services negatively (CCSP 2008a). The IPCC WGII has projected, with a high level of confidence, "that recent regional changes in temperature have had discernible impacts on many physical and biological systems" (National Science and Technology Council 2008).

The IPCC has determined that areas of the United States that experience temperature increases of 1.5 to 2.5 °C are at highest risk for modifications to ecosystem structure and composition (IPCC 2007b, as cited in CCSP 2008a). Over the next century, it is projected that species could move northward and to higher elevations (Field *et al.* 2007, as cited in National Science and Technology Council, 2008). In one example of possible future threats to ecosystem vegetation, the upward move in elevation of species as the snow and tree line advances suggests that alpine ecosystems could be endangered by the introduction of invasive species (National Science and Technology Council 2008).

Rather than experiencing impacts of climate change directly, most animals could experience the effects of climate change indirectly through changes to their habitat, food sources, and predators (Schneider and Root 1996, as cited in National Science and Technology Council 2008). A changing climate facilitates migration of certain species into non-native habitats, potentially affecting current goods and services (CCSP 2008a).

Animals in ecosystems in the United States are projected to experience a variety of climate change impacts. For example:

- Changes in hydrology as a result of changes in precipitation patterns could interrupt the breeding cycles of amphibians, which depend on the ability to migrate to breeding ponds.

The production of their eggs is also highly dependent on temperature and moisture availability (Fischlin *et al.* 2007, as cited in National Science and Technology Council 2008).

- Changes in climate that occur over at least several years are likely to affect the reproductive success of migratory birds and their ability to survive. A mismatch in timing between the migration and reproduction periods and peak food availability is the potential pathway for such impacts (Stenseth and Mysterud 2002, Visser *et al.* 2004, 2006, Visser and Both 2005, all as cited in National Science and Technology Council, 2008).

- The migration of butterflies is highly dependent on spring temperatures, and anthropogenic climate change is likely to lead to earlier spring arrivals. As with migratory birds, an earlier butterfly migration could result in a mismatch with food supply, thus threatening reproduction and survival (Forister and Shapiro 2003, as cited in National Science and Technology Council, 2008).

- Shifts in migration ranges could result in disease entering new areas, for example, avian malaria in Hawaii could move upslope as climate changes (CCSP 2008a).

In one prominent example of mammals experiencing the effects of a warming climate, the polar bear is specifically adapted to conditions in a narrow ecological slot (an environment with cold temperatures and access to snow, ice, and open water) and spends much of its time on the frozen sea (Gunderson 2007). As the climate warms and sea ice melts, the polar bear loses much of its natural habitat. If current trends in sea ice loss continue, the polar bear could become extirpated from most of their range within 100 years (IUCN 2008). Polar bears were listed as threatened under the Endangered Species Act on May 15, 2008 due to the ongoing and projected loss of their sea-ice habitat from global warming (*FR* 73, p 28212-28303, May 15, 2008).

The vegetation of terrestrial ecosystems in the United States is projected to experience a variety of direct impacts from climate change. For example, national forests, which harbor much of the Nation's biodiversity, and national grasslands are expected to experience an exacerbation of pre-existing stressors, such as wildfires, invasive species, extreme weather events, and air pollution (CCSP 2008a).

Warmer, drier climates weaken resistance of trees to insect infestation, as they are more likely to be wilted and weakened under those conditions. In a healthy state, trees can typically fight off beetle infestation by drowning them with resin as they bore through the bark. Drought reduces the flow of resin and beetles that are able to penetrate the bark introduce decay-causing fungus. This problem has already been documented. Since 1994, winter mortality of beetle larvae in Wyoming has been cut due to mild winters (from 80 percent to less than 10 percent mortality). As a result, the beetles have been able to strip 4 million acres of forests (Egan 2002, as cited in Center for Health & the Global Environment 2005). In the southwestern United States, high temperatures, drought, and the piñon ips bark beetle have had the cumulative effect of causing a mass die-back of piñon trees. From 2002 to 2003 alone, piñon mortality in Mesa Verde National Park in Colorado and Bandelier National Monument in New Mexico exceeded 90 percent. Researchers determined that climate factors drove the die-off (Saunders *et al.* 2008). The United States Forest Service indicates that, by 2012, almost all of the mature lodgepole trees in northern Colorado and southern Wyoming will have been killed by bark beetles. This will affect watersheds, timber production, and wildlife habitats, along with other human activities (USFS 2008).

Additional impacts on vegetation in ecosystems in the United States could include the following:

- Water management in the West would be complicated by increases in temperatures and changes in precipitation patterns, which lead to reduced snow pack, earlier snowmelt, and modified hydrology (CCSP 2008a).
- High latitudes would experience increased vegetation productivity. Regions in the mid-latitudes would experience either increased or decreased productivity, depending on whether the primary impact is more precipitation or higher temperatures (increasing evaporation and dryness) (Bachelet *et al.* 2001, Berthelot *et al.* 2002, Gerber *et al.* 2004, Woodward and Lomas 2004, all as cited in National Science and Technology Council 2008).
- Ecosystems in the East would be statistically "likely to become carbon sources, while those in the west would be likely to remain carbon sinks" (Bachelet *et al.* 2004, as cited in National Science and Technology Council 2008).
- The jet stream would move northward with increasing atmospheric temperatures. The consequence of this shift is a drying of the Southeast. Closed-canopy forest ecosystems could be converted to savanna ecosystems, woodlands, or grasslands, measurably increasing the threat of fire occurrence (CCSP 2008a).
- Growing seasons would lengthen, according to several predictive models; this would beneficially act to sustain carbon sinks (Cox *et al.* 2000, Berthelot *et al.* 2002, Fung *et al.* 2005, all as cited in National Science and Technology Council 2008).
- In the Olympic Range, a temperature increase of 2 °C would move tree species upwards 0.20 to 0.38 miles. Temperate species would replace subalpine species over 300 to 500 years (Zolbrod and Peterson 1999).

Adaptation to Climate Change by Terrestrial Ecosystems

The ability or inability of ecosystems to adapt to change is referred to as adaptive capacity. There could be notable regional differences in the adaptive capacity of ecosystems, and adaptive capacity is moderated by anthropogenic influences and capabilities. The ultimate impact of climate change on ecosystems depends on the speed and extent to which these systems can adapt to a changing climate. Adaptation occurs naturally in a biological system to varying degrees, but it can also be a planned human response to anticipated challenges (CCSP 2008a). Ecosystem managers could "proactively alter the context in which ecosystems develop… they can improve the resilience, *i.e.*, the coping capacity, of ecosystems. Such ecosystem management involves anticipatory adaptation options" (Fischlin *et al.* 2007). A strategy proposed for mitigating some of the loss of ecosystem biodiversity calls for moving species out of their native ranges into less threatened zones. Although this strategy could be viewed with suspicion due to the problems posed by some invasive species, the "assisted colonization" would likely be proposed only in situations and for species that are deemed low risk (Hoegh-Guldberg *et al.* 2007).

Because the effectiveness of specific adaptation strategies is uncertain, a "no regrets" path, consisting of practical adaptation options that account for current, known stressors along with the more uncertain future stressors (CCSP 2008a), is typically sought by ecosystem managers. For example, invasive species pose a known threat to many ecosystems. Future climate change is likely to exacerbate this stressor, so an adaptation strategy to tackle current invasive species problems could also address projected impacts of more serious, future invasive species challenges (CCSP 2008a). Another example of dual-purpose adaptation strategies lies with the construction of riparian buffer strips. These not only reduce agricultural runoff into freshwater systems, but also establish protective barriers against potential increases in both pollution and sediment loadings due to climate change in the future (CCSP 2008a).

4.5.4.2.3 Projected Impacts of Climate Change on Global Terrestrial Ecosystems

The IPCC concludes (*very high confidence*) that anthropogenic temperature rises have visibly altered ecosystems (Parry *et al.* 2007). The exact impacts of climate changes are difficult to discern, however, as they are mediated by other stressors and the capabilities of natural systems to adapt to changing climates to some degree (Parry *et al.* 2007).

Some regions of the world are more vulnerable to changes in climate than others. Regions of snow, ice, and tundra have been visibly altered by changes in global temperature. Observations of frozen regions already show larger glacial lakes and the destabilization of glacial debris that dam these lakes; changes in ecosystems at both poles; and increased melting of ice sheets, glaciers, and ice caps (Parry *et al.* 2007).

Ecosystems in all regions of the world are expected to respond to climate-change impacts with poleward and upward shifts of plants and animals; earlier onset of migration of terrestrial species such as birds and butterflies; and localized disappearance of particular species (Parry *et al.* 2007).

Additional factors, such as projected growth in human populations, are expected to exacerbate the effects of climate change. For example, river basin ecosystems that are already experiencing high levels of stress are projected, with *medium confidence*, to witness growth in human populations from approximately 1.4 to 1.6 billion in 1995 to roughly 4.3 to 6.9 billion by 2050 (Parry *et al.* 2007). River basins experience the stress of increasing human populations as manifested in increasing demands for water (CCSP 2008b) and more inputs of pollutants. A warmer, drier climate could increase these stressors and reduce access to other water sources (CCSP 2008b).

Other projected global impacts of climate change include the following:

- The hardiness of the world's ecosystems is expected (*high confidence*) to be challenged over the 21st Century with "an unprecedented combination of climate change, associated disturbances (*e.g.*, flooding, drought, wildfire, insects, and ocean acidification), and other global change drivers (especially land use, pollution, and over-exploitation of resources) (Fischlin *et al.* 2007).

- CO_2 levels are projected to be much higher than any in the past 650,000 years, and temperatures are projected to be as high as any in the past 740,000 years. Both increases are very likely to impact ecosystems (*very likely*) (Fischlin *et al.* 2007).

- Global average temperature increases in excess of 1.5 to 2.5 °C are statistically likely to threaten 20 to 30 percent of plant and animal species with extinction (Fischlin *et al.* 2007, as cited in National Science and Technology Council 2008).

- Carbon uptake by ecosystems such as forests and grasslands is statistically likely to peak during the 21st Century and might ultimately even reverse (forests and grasslands would emit carbon, rather than taking it in), which would amplify climate change due to increased atmospheric CO_2 (Fischlin *et al.* 2007, as cited in National Science and Technology Council 2008).

In addition to other anthropogenic stressors, "such as extractive use of goods, and increasing fragmentation and degradation of natural habitats" (Bush *et al.* 2004, as cited in Fischlin *et al.* 2007), climate change poses a threat to the wellbeing of ecosystems. Although many ecosystems have been resilient to historical changes in climate, it is not clear whether their resilience is enough to withstand the more rapid and profound changes that are projected given the buildup of GHGs in the atmosphere (Chapin *et al.* 2004, Jump and Peñuelas 2005, as cited in Fischlin *et al.* 2007). Predicted climate change and other anthropogenic stressors are "virtually certain to be unprecedented" (Forster *et al.* 2007, as cited in Fischlin *et al.* 2007). While some of the impacts expected with climate change serve to exacerbate existing stressors on ecosystems, other expected impacts could be altogether new. For example, increasing temperatures could cause some current sinks for GHGs, such as forest vegetation, to actually become sources for these gases (including CO_2 and methane) (Fischlin *et al.* 2007).

Effects of anthropogenic climate change on ecosystems are anticipated at different levels of severity and over varying time scales (decades to centuries) (Lischke *et al.* 2002, as cited in Fischlin *et al.* 2007). Some of the broad impacts on ecosystems associated with climate change are expected to include species extinctions, loss of habitat due to more severe tropical storms (Wiley and Wunderle 1994, as cited in Fischlin *et al.* 2007), changes in the types and abundance of vegetation present in an ecosystem (Schröter *et al.* 2005, Metzger *et al.* 2006, both as cited in Fischlin *et al.* 2007), and increased susceptibility of land to desertification (Burke *et al.* 2006, as cited in Fischlin *et al.* 2007).

Foreseeable pathways of climate change-induced impacts on ecosystems include the following:

- CO_2 fertilization effects on vegetation (Baker *et al.* 2004, Lewis *et al.* 2004, Malhi and Phillips 2004, all as cited in Fischlin *et al.* 2007).

- Higher atmospheric temperatures that could lead to more frequent insect and disease outbreaks (National Science and Technology Council 2008).

- Increased radiation due to a projected decrease in tropical cloud cover (Nemani *et al.* 2003, as cited in Fischlin *et al.* 2007). This is linked to warming, which can directly affect ecosystems and increase the frequency and severity of storms originating in the tropics.

4.5.5 Coastal Systems and Low-lying Areas

This section addresses climate-related impacts on coastal ecosystems. Coastal zones are unique environments where land and water meet. There is no single definition for coastal zones, but what is certain is that all coastal zones include an area of land and an area that is covered by saltwater. Burke *et al.* (2001) defines coastal zones as the "intertidal and subtidal areas on and above the continental shelf (to a depth of about 650 feet) – areas routinely inundated by saltwater – and immediately adjacent lands."

4.5.5.1 Affected Environment

Important ecosystems found in coastal zones can include estuaries, coral reefs, coastal lagoons, mangroves, seagrass meadows, upwelling areas, salt marshes, beaches, bays, deltas, kelp forests, and barrier islands. A variety of terminology exists for describing coastal zone ecosystems. Table 4.5-1 lists some of the more commonly described ecosystems found in coastal zones.

Table 4.5-1

Common Coastal Ecosystem

Coastal Ecosystem	Description
Coastal Wetlands	The broadest definition of wetlands occurring along coastal zones. They include a number of natural communities that share the unique combination of aquatic, semi-aquatic, and terrestrial habitats that results from periodic flooding by tidal waters, rainfall, or runoff. a/
Sandy Shorelines	Sandy areas along coastlines where high-energy wave actions deposit and move around sand and sediment.
Barrier Islands	Long narrow islands running parallel to the mainland that provide protection to the coast.
Tidal Wetlands	A type of coastal wetland that is affected by both tides and freshwater runoff.
Estuaries	Bodies of water and their surrounding coastal habitats typically found where rivers meet the ocean.
Mangroves	Coastal wetlands found in tropical and subtropical regions typically characterized by shrubs and trees with an affinity to saline tidal waters.
Tidal Salt Marshes	A type of coastal wetland frequently or continually inundated with water, characterized by soft-stemmed vegetation adapted to saturated soil conditions. b/
Coral Reefs	A large underwater calcium carbonate formation that includes a diverse collection of biological communities.
Coastal Deltas	Typically a triangular deposit of silt and sand deposited at the mouth of a river along a coast.

a/ California Environmental Resources Evaluation Systems (2000)
b/ EPA (2006b)

The world's coastal length is estimated to be 1,015,756 miles, with North America having the longest coastal length of all continents (Pruett and Cimino 2000, as cited in Burke *et al.* 2001). Canada has the longest coastal length of any country in the world and the United States has the second longest, at 164,988 miles and 82,836 miles, respectively (Pruett and Cimino 2000, as cited in Burke *et al.* 2001).

Coastal zones are areas of substantial biological productivity that provide food, shelter, spawning grounds, and nurseries for fish, shellfish, birds, and other wildlife. The interaction between aquatic and terrestrial components of coastal ecosystems creates a unique environment that is critical to the life cycles of many plant and animal species. In the United States, 85 percent of commercially harvested fish depend on estuaries and coastal waters at some stage in their life cycle (Summers *et al.* 2004), while as much as 95 percent of the world's marine fish harvest is caught or reared in coastal waters (Sherman 1993, as cited in Burke *et al.* 2001). Most historical information available on coastal ecosystems focuses on data related to fisheries. As more research is conducted on other increasingly important coastal ecosystems, new data and information are becoming available. For example, coral reefs alone, while representing only 0.2 percent of the total area of oceans, harbor more than 25 percent of all known marine fish (Bryant *et al.* 1998). In addition, the species in some coral reefs can reach densities of 1,000 per square meter (Tibbets 2004). In the United States, 85 percent of the country's essential nesting, feeding, and breeding habitat for waterfowl and migratory birds is found in coastal ecosystems (Summers *et al.* 2004). Coastal zones have also been found to support a much higher percentage of the world's threatened and endangered species.

Because a disproportionate percentage of the world's population lives in coastal zones, the activities of humans have created environmental pressures that threaten the very resources that make the coastal zones desirable (Summers *et al.* 2004). The impact of these activities varies from place to place and depends on the types and sensitivity of coastal ecosystems involved. A wide range of pressures has been identified as causing adverse changes in coastal ecosystems, but the leading causes of coastal ecosystem degradation include physical alteration, habitat degradation and destruction, water withdrawal, overexploitation, pollution, and the introduction of non-native species (UNESCO and WWAP 2006). In addition, climate change might compound these pressures through the effects of higher sea levels, warmer seawater, altered ocean circulation patterns, increased and extreme storm events, and increased carbon dioxide concentrations (UNESCO and WWAP 2006, Burke *et al.* 2001).

4.5.5.1.1 Coastal Conditions Globally and in the United States

The conditions of coastal ecosystems vary from place to place and depend on many factors. Attempts have been made to assess the global extent and distribution of aquatic habitats, but estimates vary considerably depending on the type and source of data (UNESCO and WWAP 2006). While inventories of coastal zones exist, no high-quality data sets or indicators are available at the global level that track changes in condition over time (UNESCO and WWAP 2006). Despite the lack of high-quality data, it is safe to assume that coastal zones with substantial human populations are vulnerable to a range of human activities that can increase pressure and cause adverse changes to coastal ecosystems. As mentioned above, typical coastal ecosystem degradation would include physical alteration, habitat degradation and destruction, water withdrawal, overexploitation, pollution, and the introduction of non-native species. The effects of sea-level rise from climate change could compound these potential impacts.

EPA considers the current overall coastal condition of the United States to be fair (Summers *et al.* 2004). Six geographic coastal regions (Great Lakes Coastal Area, Northeast Coastal Area, Southeast Coastal Area, Gulf Coast Coastal Area, West Coastal Area and Alaska, Hawaii, and Island Territories) were evaluated by EPA using five ecological health indicators to assess estuarine coastal conditions as good, fair, or poor. The five indicators are water quality, sediment quality, benthic, coastal habitat, and fish tissue contaminants. Of the five indicators, only the coastal habitat index received an overall poor rating. The benthic and sediment quality indices rated fair to poor, while the water quality and fish tissue contaminants indices received fair ratings. Of the six coastal regions, the Southeast Coastal Area ranked highest with all indicators rating fair to good. The region with the worst coastal condition was the Northeast Coastal Area, with four of the five indicators rating poor or fair to poor. In terms of human and aquatic life use, 21 percent of the assessed coastal resources of the country are considered unimpaired (good condition), whereas 35 percent are impaired (poor condition) and 44 percent threatened (fair condition).

4.5.5.1.2 Observed Trends in Coastal Zones Conditions

Impacts to coastal ecosystems are expected to continue as coastal populations increase and demand more coastal space and resources. Many coastal ecosystems around the globe have been substantially degraded, and many have been lost altogether. Quantifying the changes in coastal ecosystems is difficult because historical data describing the previous extent of coastal ecosystems are very limited. More and higher-quality data characterizing the world's coastal zones are needed. Burke *et al.* (2001) found the following trends in the conditions of coastal ecosystems:

- Many coastal habitats are disappearing at a fast pace, with extensive losses occurring in the past 50 years.
- Although some industrial countries have improved coastal water quality, chemical pollutant discharges are increasing overall as agriculture intensifies and new synthetic compounds are developed.
- Pollution filtering capacities are lost as coastal ecosystems are lost.

- Nutrient inputs to coastal waters appear to be increasing because of population increase and agricultural intensification.
- The frequency of harmful algal blooms resulting in mass mortality of marine organisms has increased substantially over the past few decades.
- Increased occurrences of hypoxia (shortage of oxygen in water) have been reported.
- More than 25 different coral reef diseases have been recorded since 1970, and reports of coral bleaching have increased measurably in recent years.
- Many commercial fish species and other marine wildlife have become threatened.
- Large-scale marine oil spills have been declining, but oil discharges from land-based sources are believed to be increasing.
- An increased number of invasive species is being reported throughout the world coastal ecosystems.
- The number of protected marine and coastal areas has increased, indicating greater awareness of the need to protect these environments.
- Global marine fish production has increased six-fold since 1950.
- The capacity of coastal ecosystems to produce fish for human harvest has been highly degraded by overfishing, destructive trawling techniques, and loss of coastal nursery areas.
- Notable ecosystem changes have occurred over the last half-century in some fishery areas, such as the North Atlantic and Northeast Pacific.

A number of marine wildlife species have been or could be adversely affected by environmental changes in temperature, availability of water and nutrients, runoff from land, wind patterns, and storminess that are associated with climate change (Kennedy *et al.* 2002). Marshes and mangroves are particularly susceptible to sea-level rise affecting the feeding or nesting grounds of black rail, clapper rail, some terns, and plovers (Kennedy *et al.* 2002). Over the short term, however, shrimp, menhaden, dabbling ducks, and some shorebirds would benefit from the release of nutrients from the breakup of marshes (Kennedy *et al.* 2002). The southern sea otter, a keystone species, is listed as threatened by the Endangered Species Act where the population has declined as a result of the increased contaminants associated with high runoff produced by El Niño Southern Oscillation-induced Pacific Ocean storms (Environmental and Energy Study Institute 2001). Marine turtles are affected by unusual changes in high/low temperatures, pollutants, infectious agents, and marine biotoxins, and have become threatened by an epidemic of fibropapillomatosis linked to polluted coastal areas, agricultural runoff, and biotoxins from algae (Environmental and Energy Study Institute 2001). The full effect of marine birds and species inhaling or ingesting biotoxins produced by algal blooms is of concern and not fully understood (Environmental and Energy Study Institute 2001).

There is strong evidence that temperature increases caused a rise in the global sea level during the 20th Century (Parry *et al.* 2007). Because each coastal area has its own unique geographic and environmental characteristics, consequences from adaptations to climate change are expected to differ for each community. Areas of critical sensitivity on the global scale include Tokyo, Shanghai, and London, and Thailand, India, and Vietnam (Nicholls *et al.* 2007, as cited in National Science and Technology

Council 2008). These areas share the characteristics of coastal location, low elevation, large population, and currently stressed resources. Because of their proximity to the water's edge and the high level of infrastructure typical of many coastal communities, these urban centers are sensitive to changes in sea-level rise (National Science and Technology Council 2008).

Recent data suggest that the rise in global sea level has had an effect on some coastal zones of the United States. Sea level data have shown a rise of 0.8 to 1.2 inches per decade since the beginning of the 20th Century along most of the Atlantic and Gulf Coasts in the United States (National Science and Technology Council 2008). Most of the Atlantic Ocean demonstrated a sea-level rise over the past decade at a rate greater than 0.1 inch per year in an east-northeast band from the United States east coast (National Science and Technology 2008). Coastal wetland loss is occurring where these ecosystems are squeezed between natural and artificial landward boundaries and rising sea levels (Field *et al.* 2007, as cited in National Science and Technology 2008). Rise in sea level could be contributing to coastal erosion across the eastern United States (Zhang *et al.* 2004, as cited in Rosenzweig *et al.* 2007). Sea-level rise in the Chesapeake Bay has accelerated erosion rates resulting in wetland destruction (National Science and Technology Council 2008). In Mississippi and Texas, more than half of the shorelines have eroded at average rates of 8.5 to 10.2 feet per year since the 1970s, while 90 percent of the Louisiana shoreline has eroded at a rate of 39.4 feet per year (Nicholls *et al.* 2007, as cited in National Science and Technology Council 2008). Areas in Louisiana are experiencing barrier island erosion resulting in an increased height of waves (Nicholls *et al.* 2007, as cited in National Science and Technology Council 2008). Furthermore, regional sea-level rise has contributed to increased storm surge impacts along the North American eastern coast (National Science and Technology Council 2008). Particularly becuase subsidence is occurring in parts of this area, areas such as the Louisiana and Gulf coasts are considered at high risk from erosion and storm surges, and any area along the coast with low elevation, large populations, and currently stressed resources could be expected to be at risk from any future sea-level rise.

4.5.5.2 Environmental Consequences

This section describes the potential cumulative effects of climate change on coastal zones, both in the United States and globally.

4.5.5.2.1 Projected Impacts of Climate Change for the United States

According to the National Science and Technology Council's Scientific Assessment, 50 percent of Americans live in coastal communities (National Science and Technology Council 2008). Coastal urban centers are expected to experience a surge in population growth of an additional 25 million people over the next 25 years. This change in population is expected to compound the anticipated adverse effects of climate change on coastal communities, placing heavier demand on already stressed resources (National Science and Technology Council 2008). Data have confirmed an average rise in sea level of 0.8 to 1.2 inches per decade since the beginning of the 20th Century along most coasts in the United States, with the Gulf Coast experiencing a rise of a few inches per decade (primarily due to land subsidence) and Alaskan coasts experiencing *decreases* in sea level of a few inches per decade (National Science and Technology Council 2008). In one example, the Union of Concerned Scientists' report (Frumhoff *et al.* 2007) discusses the impacts of surging waters during a coastal storm in December 1992, when strong winds and rising water levels disrupted the New York City public transit system and required the evacuation of communities in New Jersey and Long Island. Sea-level rise in the Chesapeake Bay has accelerated erosion rates, resulting in wetland destruction (National Science and Technology Council 2008). Sea-level rise in the 21st Century is expected to exceed that of past years, causing great alarm for coastal communities and the infrastructures they support.

Although a range of adverse effects from climate change is expected in the United States, one of the most damaging is expected to be that of sea-level rise. The IPCC predicts a sea-level rise of 7 to 23 inches by 2090-2099 (Parry 2007, as cited in National Science and Technology Council 2008). These figures do not include the anticipated sea-level rise from melting ice sheets and glaciers in Greenland and Antarctica where scientists have already noted a decrease in the thickness and depth of sea ice (National Science and Technology Council 2008) or the potential for rapid acceleration in ice loss (Alley *et al.* 2005, Gregory and Huybrechts 2006, Hansen 2005, all as cited in Pew Center on Climate Change 2007). Recent studies have found the IPCC's estimates of ice loss from the Greenland and Antarctic ice sheets and from mountain glaciers might be underestimated (Shepherd and Wingham 2007, Csatho *et al.* 2008, Meier *et al.* 2007). Further, IPCC might underestimate sea-level rise that would be gained through changes in global precipitation (Wentz *et al.* 2007, Zhang *et al.* 2007). Rahmstorf (2007) used a semi-empirical approach to project future sea-level rise. The approach yielded a proportionality coefficient of 3.4 mm per year per °C of warming, and a projected sea-level rise of 0.5 to 1.4 meters above 1990 levels in 2100 when applying IPCC Third Assessment Report warming scenarios. Rahmstorf (2007) concludes that "[a] rise over 1 meter by 2100 for strong warming scenarios cannot be ruled out."

Some general effects associated with rising sea levels include:

- Loss of land area due to submergence and erosion of lands in the coastal zone
- Changes to coastal environments
- More flooding due to storm surges
- Salinization of estuaries and groundwater (National Science and Technology Council 2008)

For islands such as those located in Hawaii and other U.S. territories in the Pacific, outcomes could include a reduction in island size and the abandonment of inundated areas (National Science and Technology Council 2008). Approximately one-sixth of U.S. land that is close to sea level is located in the mid-Atlantic region and, consequently, much of the reporting on effects focuses on this region (National Science and Technology Council 2008).

Over the past century, the highest rate of sea-level rise has been observed in the mid-Atlantic region, in part resulting from subsidence of the land surface (Gutierrez *et al.* 2007). For example, Virginia has observed sea-level rise at 4.4 mm per year compared to 1.8 mm per year in Maine (Zervas 2001, as cited in Gutierrez *et al.* 2007). New Jersey, with 60 percent of its population living along the 127 miles of coastline, has experienced coastline subsidence and beach erosion threatening communities and coastal wetlands (Union of Concerned Scientists 2007, Aucott and Caldarelli 2006, Metro East Coast Regional Assessment 2000).

The effects of sea-level rise on some coastal communities could be devastating with increased erosion and flooding. Extensive erosion has already been documented across the East Coast, as have notable decreases in the coastal wetlands of Louisiana, the mid-Atlantic region, New England, and New York (Rosenzweig *et al.* 2007, as cited in National Science and Technology Council 2008). Erosion is expected to be worse in sandy environments along the mid-Atlantic coast, Mississippi, and Texas (National Science and Technology Council 2008; Nicholls *et al.* 2007, as cited in National Science and Technology Council 2008). The IPCC notes that sandy shorelines are already retreating. Furthermore, areas in Louisiana are experiencing barrier island erosion, resulting in increases in the height of waves that make it to shore (Nicholls *et al.* 2007, as cited in National Science and Technology Council 2008). A large storm can affect the shoreline position for weeks to a decade or longer (Morton 1994, Zhang *et al.* 2004, List *et al.* 2006, Riggs and Ames 2003, all as cited in Gutierrez *et al.* 2007). Tidal wetlands, estuarine beaches, marshes, and deltas are expected to be inundated with water in areas such as the Mississippi River, Louisiana Delta, and the Blackwater River marshes in Maryland (Titus *et al.* 2008, as cited in National Science and Technology Council 2008). The "coastal squeeze" phenomenon, where wetlands are trapped between natural and human-made land boundaries, is causing wetland loss and habitat destruction (Field *et al.* 2007, as cited in National Science and Technology Council 2008). Freshwater resources are also at risk given the *likely* intrusion of saltwater into groundwater supplies, adversely affecting water quality and salinization rates (Kundzewicz *et al.* 2007, as cited in National Science and Technology Council 2008).

The height of storm surges will increase if sea level rises, regardless of storm frequency and intensity increases; thus, a storm of similar behavior will cause greater damage with rising sea level (Fisher *et al.* 2000). One study suggests the 100-year flood might actually occur every 25 to 30 years (Najjar *et al.* 1999, as cited in Fisher *et al.* 2000). By mid-century, Boston and Atlantic City could experience a 100-year flood event every 2 to 4 years and annually by the end of the century (Frumhoff *et al.* 2007).

Cayan *et al.* (2006) projected future sea-level rise and its implications for California. The study projected sea-level rise, relative to 2000, to range from 11 to 54 centimeters (4.3 to 21 inches); 14 to 61 centimeters (5.5 to 24 inches); and 17 to 72 centimeters (6.7 to 28 inches) by 2070 to 2099 for B1, A2, and A1 GHG modeling scenarios, respectively. The mean sea-level rise from a survey of several climate models was also determined to range from approximately 10 to 80 centimeters (3.9 to 3.15 inches) between 2000 and 2100. The historic rate of sea-level rise observed at San Francisco and San Diego during the past 100 years was 15 to 20 centimeters (5.9 to 7.9 inches). Parts of the California coast are at risk for flood damage, which could further jeopardize levees in the City of Santa Cruz (California Environmental Protection Agency 2006). Santa Cruz is 20 feet above sea level with levees built to contain the 100-year flood. If sea levels were to increase above 12 inches as predicted for the medium warming range of temperatures, a flood associated with a storm surge event at the 100-year level might happen once every 10 years (California Energy Commission 2006). The ENSO events of 1982-1983 and 1997-1998 corresponded to high sea level episodes (Flick 1998, as cited in Cayan *et al.* 2006). These high-sea-level episodes could intensify in future ENSO events if sea-level rise increases.

The frequency and intensity of storms are expected to become more prevalent at the same time as sea levels rise and sea surface temperatures increase. Some societal effects include the following:

- Infrastructure such as bulkheads, dams, and levees could be damaged by flooding and strong storms (Nicholls *et al.* 2007, as cited in National Science and Technology Council 2008).
- Coastal ports, roads, railways, and airports are at risk of disruption due to power outages, flooded routes, and poor travel conditions (Nicholls *et al.* 2007, as cited in National Science and Technology Council 2008).
- Industries reliant on coastal stability, such as travel and recreation, fishing and hunting, and trade, are expected to become increasingly sensitive to these temperature and precipitation changes in the coming decades (Nicholls *et al.* 2007, as cited in National Science and Technology Council 2008).
- The most at-risk state in the United States is expected to be Alaska because the indigenous communities depend on wildlife for hunting and fishing practices, reside within floodplains, and currently face water shortages (Field *et al.* 2007, as cited in National Science and Technology Council 2008).

Loss of coastal wetlands due to intense storms has been documented on many occasions. A prominent recent example is the loss of coastal lands as a result of Hurricane Katrina in 2005. In Louisiana alone, the loss of land during Hurricane Katrina was approximately 217 square miles. The

Chandeleur Islands, which New Orleans relied on as a tropical storm buffer, lost 85 percent of their surface area (CCSP 2008b).

Increases in storm frequency and severity, and sea-level rise itself, have detrimental effects on coastal areas with sandy beaches. Many species rely on the wellbeing of, and accessibility to, beaches. Examples include the following:

- Diamondback terrapins and horseshoe crabs rely on beach sands to bury their eggs. The eggs not only act to propagate the species, but some shorebirds, such as the piping plover, rely on these eggs as a food source (USFWS 1988, as cited in Titus *et al.* 2008).

- Horseshoe crabs rarely spawn unless sand is deep enough to nearly cover their bodies, about 10 centimeters (4 inches) (Weber 2001). Shoreline protection structures designed to slow beach loss can also block horseshoe crab access to beaches and can trap or strand spawning crabs when wave energy is high (Doctor and Wazniak 2005). So, in this case, the loss of beach, as well as the adaptation strategy selected by the community, can result in harm to local species.

- A rare firefly, *Photuris bethaniensis*, is found only in areas between dunes on Delaware's barrier beaches. Its habitat is at risk due to beach stabilization and hardening of shorelines; this limits migration of dunes and the formation of the swales between dunes where the firefly is found (Titus *et al.* 2008).

4.5.5.2.2 Adaptation to Climate Change

There are uncertainties regarding which effects of climate change could affect individual coastal and low-lying areas. However, because these areas are particularly sensitive to climate and hazardous weather events, adaptation to projected climate change remains a potentially attractive option. Adaptations can be preventative, taken before the arrival of an anticipated impact, or reactive, taken in response to the actual changes. Many of the adaptations for coastal and low-lying areas can overlap between these two categories and might differ only by the timing in which they are implemented. The CCSP (2008a, as cited in National Science and Technology Council 2008) outlines seven approaches to adaptation:

- Protecting key ecosystem features
- Reducing anthropogenic stresses
- Representation (maintaining species diversity)
- Replication of ecosystems to maintain species diversity and habitable lands
- Restoration of disturbed ecosystems
- Refugia (using less affected areas to "seed" new areas)
- Relocation

Some examples of possible adaptation strategies in the United States include shifting populations and infrastructure from coastal communities along the East and Gulf Coasts and mid-Atlantic region further inland (Nicholls *et al.* 2007, as cited in National Science and Technology Council 2008). Other possible strategies include elevating infrastructure, introducing barriers such as levees and dams to hold off storm surges; reducing fertilizer and pesticide use in nearshore coastal communities (Epstein *et al.* 2006); preserving contiguous interconnected water systems (including mangrove stands, spawning lagoons, upland forest and watershed systems, coastal wetlands) (Epstein *et al.* 2006); and constructing watertight containment for essential equipment (NY City DEP 2008). Although the options for adaptation in coastal and low-lying areas are many, the key is to consider the period during which these adaptations are proposed and implemented to best prepare communities. The IPCC in their 2007 Technical Summary has predicted that the costs of adaptation are *virtually certain* to be less than those of inaction (Parry *et al.* 2007).

Current government programs are in effect that assist in subsidizing protection for coastline development, including shoreline protection and beach replenishment, federal disaster assistance, and the National Flood Insurance Program (Fisher *et al.* 2000). In 2006, Maine developed and implemented shoreline regulations to address projected sea-level rise due to climate change (Frumhoff *et al.* 2007). Maine is currently the only state in the Nation with such a program.

4.5.5.2.3 Projected Global Impacts of Climate Change

Globally, coastal systems and low-lying areas are experiencing adverse effects related to climate change and sea-level rise, such as coastal inundation, erosion, ecosystem loss, coral bleaching and mortality at low latitudes, thawing of permafrost, and associated coastal retreat at high latitudes (*very high confidence*) (Nicholls *et al.* 2007). To further exacerbate the stressors, human settlement and encroachment on coastal systems and low-lying areas have been increasing with an estimated 23 percent of the world's population living within about 60 to 65 miles of the coast and no more than about 330 feet above sea level (Small and Nicholls 2003).

Although non-uniform around the world, global sea level is estimated to have risen by 0.07 plus or minus 0.02 inch per year over the past century with western Pacific and eastern Indian Ocean experiencing the greatest rise (Nicholls *et al.* 2007). Sea level is anticipated to continue to increase 0.7 to 2.0 feet or more by the end of the 21st Century (Nicholls *et al.* 2007). This sea-level rise coupled with both projected sea surface temperatures increasing 1 to 3 °C and intensified cyclonic activity could lead to larger waves and storms surges impacting coastal systems and low-lying areas across the globe (Nicholls *et al.* 2007). The loss or degradation of coastal ecosystems has a direct impact on societies that depend on coastal-related goods and services such as freshwater and fisheries with the potential to impact hundreds of millions of people (Parry *et al.* 2007).

There is variability in the projected effects from climate change and sea-level rise on an international scale. For instance, if the global mean annual temperature increases above 1980 to 1999 levels, coastal systems and low-lying areas are anticipated to sustain increased damage due to floods and storms; an additional increase of 2 °C would lead to an increase of millions of people that could experience coastal flooding each year; and an increase of 3 °C is estimated to cause a loss of 30 percent of the global coastal wetlands (*high confidence*; IPCC 2007c, Figure SPM.2). Coastal wetland ecosystems are at substantial risk from sea-level rise if they are sediment-starved or prevented from migrating inland. As sea water temperatures increase, it is *likely* that coral bleaching and mortality will rise unless corals demonstrate thermal adaptation (Nicholls et al 2007). These adverse impacts are expected to increase in severity as the global mean annual temperature increases.

Tide gauges have measured the average rate of sea-level rise to be 0.07 plus or minus 0.02 inch per year from 1961 to 2003 and 0.07 plus or minus 0.02 inches per year (National Science and Technology Council 2008) over the past century. These changes are attributed to thermal expansion associated with rising global temperature, thawing of permafrost, and loss of sea ice (Nicholls *et al.* 2007). The global ocean temperature averaged from the surface to a depth of approximately 2,300 feet has increased by 0.10 °C over the period from 1961 to 2003, contributing to an average increase in sea level of 0.02 plus or minus 0.004 inch per year (National Science and Technology Council 2008). This contribution has increased for the period 1993 to 2003 with a rate of sea-level rise of 0.06 plus or minus 0.02 inch per year. Melting of mountain glaciers, ice caps, and land ice have also contributed to the measured sea-level rise. From 1961 to 2003, the melting of land ice has contributed approximately 0.03

plus or minus 0.02 inch per year to sea-level rise with an accelerated rate of 0.05 ± plus or minus 0.02 inch per year between 1993 and 2003 (Lemke *et al.* 2007, as cited in National Science and Technology Council 2008).

Sea-level rise is non-uniform around the world. In some regions, rates of rise have been as much as several times the global mean, while other regions have experienced falling sea level. This might be the result of variations in thermal expansion and exchanges of water between oceans and other reservoirs, ocean and atmospheric circulation, and geologic processes (Bindoff *et al.* 2007, as cited in National Science Technology Council 2008). Satellite measurements provide unambiguous evidence of regional variability of sea level change for the period 1993 to 2003 with the largest sea-level rise occurring in the western Pacific and eastern Indian oceans (National Science and Technology Council 2008).

Sea level is projected to increase from 0.7 to 2.0 feet or more by the end of the 21^{st} Century (Nicholls *et al.* 2007) with the possibility of additional sea-level rise occurring as a result of the breakdown of West Antarctic and Greenland ice sheets. A temperature increase of 1.1 to 3.8 °C would trigger the breakdown of the Greenland ice sheet, and is *likely* to occur by 2100 (Parry *et al.* 2007). An additional sea-level rise of about 21 to 24 feet would result in the complete disappearance of the Greenland ice sheet (IPCC 2007a, Table 4.1, Epstein *et al.* 2006). This scenario raises concern regarding the viability of coastal communities, salt marshes, corals, and mangroves. A sea-level rise of about 14 inches from 2000 to 2080 is projected to reduce coastal wetlands by 33 percent with the largest impact on the Atlantic and Gulf of Mexico coasts of the Americas, the Mediterranean, the Baltic, and small-islands (Nicholls *et al.* 2007).

IPCC SRES estimated that the coastal population could grow from 1.2 billion people in 1990 to between 1.8 billion and 5.2 billion people by the 2080s with this range dependent on coastal migration. Although the impact of sea-level rise on a specific region can be difficult to quantify given regional and local variations (Parry *et al.* 2007), the IPCC describes the following coastal regions as the most vulnerable to the impact of climate change: South Asia, Southeast Asia, East Asia, Africa, and small islands (Nicholls *et al.* 2007).

Many of the coastal cities that are most vulnerable to adverse impacts of climate change are at further risk due to human activities such as agriculture, aquaculture, silviculture, industrial uses, and residential uses that have degraded the natural protective qualities of the coastal systems (Nicholls *et al.* 2007). Coastal countries at risk for shoreline retreat and flooding due to degradation associated with human activity include Thailand (Durongdej, 2001, Saito 2001, both as cited in National Science and Technology Council 2008); India (Mohanti 2000, as cited in National Science and Technology Council 2008); Vietnam (Thanh *et al.* 2004, as cited in National Science and Technology Council 2008); and the United States (Scavia *et al.* 2002, as cited in National Science and Technology Council 2008), with emphasis on the seven Asian megadeltas that have a combined population greater than 200 million (Nicholls *et al.* 2007). Of particular concern are those highly coastal populated regions within countries with limited financial resources to protect or relocate its populations (Nicholls *et al.* 2007).

Small islands are particularly vulnerable to climate change and sea-level rise, especially those islands prone to subsidence (Parry *et al.* 2007). Beach erosion is projected to increase as sea level rises and sea water temperature increases. Arctic islands could experience increased erosion and volume loss as permafrost and ground ice warms in response to rising global temperatures (Mimura *et al.* 2007).

Positive impacts anticipated to be experienced in high latitudes include a longer tourist season and better navigability (Mimura *et al.* 2007). Without adaptation, IPCC model results suggest more than 100 million people could endure coastal flooding due to sea-level rise every year by 2080 (Nicholls *et al.* 2007).

4.5.5.2.4 Adaptation to Climate Change

In some circumstances, the potential effects from climate change and sea-level rise on coastal systems and low-lying areas can be reduced through widespread adaptation (Nicholls *et al.* 2007). The IPCC modeled results of flood risk associated with rising sea level and storm surges projected to 2080 found substantial benefit associated with upgrading coastline defenses (Nicholls *et al.* 2007). In addition, curtailing the current degradation in coastal systems by anthropogenic activities such as deforestation, fertilizer use, sewage dredging, sand mining, fish harvesting, and sea wall construction would provide a more robust coastal system resistant to extreme water levels during storms.

Small islands in the Indian Pacific Oceans and the Caribbean have much of their infrastructure in coastal locations (Parry *et al.* 2007). Under projected levels of sea-level rise, some infrastructure is *likely* to be at risk from inundation and flooding (Mimura *et al.* 2007). Small islands have limited choices in adaptation to sea-level rise and climate change impact on coastal sections.

4.5.6 Food, Fiber, and Forest Products

This section defines these food, fiber, and product resources and the existing conditions and potential vulnerability of each to climate change impacts. The primary source of information presented in this section is the IPCC Fourth Assessment Report (Easterling *et al.* 2007), specifically, Chapter 5 for food, fiber, and forest products.

The food, fiber, and forest sector is a substantial source of livelihood and food for large numbers of the world's population and a major land cover type at a global level. Cropland, pasture, or natural forests account for approximately 70 percent of the world's land cover. The United Nations Food and Agriculture Organization (FAO) estimates that approximately 450 million of the world's poorest people depend entirely on this sector for their livelihood (Easterling *et al.* 2007).

According to IPCC, this sector includes agriculture, forestry, and fisheries. It also includes subsistence and smallholder agriculture, defined as rural producers who farm or fish primarily with family labor and for whom this activity provides the primary source of income (Easterling *et al.* 2007).

4.5.6.1 Affected Environment

An estimated 40 percent of Earth's land surface is used for cropland and pasture (Foley *et al.* 2005, as cited in Easterling *et al.* 2007). The FAO estimates that natural forests cover another 30 percent of the land surface, and that 5 percent of that natural forest area generates 35 percent of global timber production (FAO 2000, as cited in Easterling *et al.* 2007). Nearly 70 percent of people in lower income countries around the world live in rural areas where agriculture is the primary source of livelihood. Growth in agricultural incomes in developing countries fuels the demand for non-basic goods and services fundamental to human development. The FAO estimates that the livelihoods of roughly 450 million of the world's poorest people depend entirely on managed ecosystem services. Fish provide more than 2.6 billion people with at least 20 percent of their average per-capita animal protein intake, but 75 percent of global fisheries are currently fully exploited, overexploited, or depleted (FAO 2004, as cited in Easterling *et al.* 2007).

4.5.6.1.1 Terrestrial Systems

The distribution of crop, pasture, and forest species between the polar and equatorial latitudes is a function of current climatic and atmospheric conditions, as well as photoperiod. Agricultural, pastoral, and forestry systems depend on total seasonal precipitation and its pattern of variability, as well as wind and humidity. Crops exhibit threshold responses to their climatic environment, which affect their growth, development, and yield (Porter and Semenov 2005, as cited in Easterling *et al.* 2007). Short-term natural extremes, such as storms and floods, interannual and decadal climate variations, and large-scale circulation changes, such as ENSO, all have important effects on crop, pasture, and forest production (Tubiello 2005, as cited in Easterling *et al.* 2007).

For example, Europe experienced a particularly extreme climate event during the summer of 2003, with temperatures up to 6 °C above long-term means, and precipitation deficits up to 12 inches (Trenberth *et al.* 2007, as cited in Easterling *et al.* 2007). Associated with this extreme climate event was a decline in corn yield of 36 percent in the Po River valley in Italy and 30 percent in France. In addition, French fruit harvests declined by 25 percent, winter wheat yields declined by 21 percent, and hay and other forage production declined on average by 30 percent (Ciais *et al.* 2005, as cited in Easterling *et al.* 2007). Moreover, African droughts between 1981 and 1999 caused livestock mortality from 20 percent to more than 60 percent in countries such as Botswana, Niger, Ethiopia, and Kenya (Easterling *et al.* 2007).

Overall, climate change might benefit crop and pasture yields in mid- to high-latitude regions, while decreasing yields in dry and low-latitude regions. Total forest productivity might rise modestly, with considerable global variation. Local extinctions of fish species are expected, particularly at the edges of habitat ranges (Easterling *et al.* 2007).

Agricultural and forest lands are experiencing multiple stresses that increase their vulnerability to climate change impacts. Examples include soil erosion, salinization of irrigated areas, overgrazing, over-extraction of groundwater, loss of biodiversity, and erosion of the genetic resource base in agricultural, forest, and pasture areas. Overfishing, loss of biodiversity, and water pollution in aquatic areas are stresses that increase vulnerability to climate change to fishery resources (Easterling *et al.* 2007).

The vulnerability of these resources depends on both the exposure to climate conditions and capacity to cope with changing conditions. Exposure to conditions highly depends on local geography and environment. Adaptive capacity is dynamic and depends on wealth, human capital, information and technology, material resources and infrastructure, and institutions and entitlements (Easterling *et al.* 2007).

Sub-Saharan Africa offers one example of a region that is currently highly vulnerable to food insecurity (Vogel 2005, as cited in Easterling *et al.* 2007). Drought conditions, flooding, and pest outbreaks are some of the current stressors on food security that could be influenced by future climate change. Options for addressing food insecurity in this region (and overall development initiatives related to agriculture, fisheries, and forestry) could be constrained by health status, lack of information, and ineffective institutional structures. These constraints could limit future adaptations to periods of heightened climate stress (Reid and Vogel 2006, as cited in Easterling *et al.* 2007).

4.5.6.1.2 Aquatic Systems

Spatial adaptation of marine ecosystems to climate change is in some ways less geographically constrained than for terrestrial systems. The rates at which planktonic ecosystems have shifted their distribution have been very rapid over the past three decades, which can be regarded as natural adaptation to a changing physical environment (Beaugrand *et al.* 2002, as cited in Easterling *et al.* 2007). Most fishing communities use stocks that fluctuate due to interannual and decadal climate variability, and consequently have developed considerable coping capacity (King 2005, as cited in Easterling *et al.* 2007).

Research on the relationship between water temperature and the health of freshwater fishes indicates different impacts in summer and winter. Although temperature increases might cause seasonal increases in growth in the winter, mortality risks to fish populations occur at the upper end of their thermal tolerance zone in the summer.

World capture production of finfish and shellfish in 2004 was more than twice that of aquaculture, but since 1997 capture production decreased by 1 percent, whereas aquaculture increased by 59 percent (Easterling *et al.* 2007). The increasingly important aquaculture sector allows for the application of similar types of management adaptations to climate change suggested for crop, livestock, and forestry sectors. This is not the case, however, for marine capture fisheries, which are shared resources subject to varying degrees of effective governance. Adaptation options for marine capture fisheries include altering catch size and effort. Three-quarters of world marine fish stocks are currently exploited at levels close to or above their productive capacity (Bruinsma 2003, as cited in Easterling *et al.* 2007). Reductions in the level of effort and harvest are required to sustain yields. Such a course of action might also benefit fish stocks that are sensitive to climate variability when their population age-structure and geographic sub-structure are reduced (Brander 2005, as cited in Easterling *et al.* 2007).

4.5.6.2 Environmental Consequences

Earth's land surface is composed mostly of managed cropland and pasture (40 percent) and natural forests (30 percent) (Foley *et al.* 2005, as cited in Easterling *et al.* 2007). These sectors provide important commodities that are produced in a variety of geographic and climatic regions (CCSP 2008c). The continued growth and productivity of the world's agriculture and forests is necessary to sustain human economic and social development.

The discussion below is focused on impacts on food and industrial crops, fisheries, agricultural pastures, commercial forestry, and subsistence farming (Easterling *et al.* 2007). The key drivers for climate impacts in this sector are higher temperatures, changed precipitation and transpiration dynamics, the effects of increased CO_2 concentrations on vegetative growth and yield, greater frequency in extreme weather events, and increased stressors to forests and agriculture in the form of pests and weeds (Easterling *et al.* 2007).

The world's food crops, forests, and fisheries have evolved to be in tune with the present climatic environment. The productivity of these systems ultimately relies on the interaction of various climate factors including temperature, radiation, precipitation, wind speed, and water vapor pressure (Easterling *et al.* 2007). Threshold climatic conditions for crops and forests affect their growth and yield, and climatic conditions and their interaction influence the global distribution of agricultural and forest species (Porter and Semenov 2005, as cited in Easterling *et al.* 2007).

The sensitivity to climate change and exposure to various other stressors increases the vulnerability of the forest, food, and fiber systems (Easterling *et al.* 2007). Non-climate stressors such as soil erosion, overgrazing, loss of biodiversity, decreased availability of water resources, increased economic competition among regions, and the adaptive capacity of various species increase overall sensitivity to the climate and thus exacerbate the adverse effects of climate change (CCSP 2008b).

Climate change could also benefit agriculture and silviculture through the CO_2 fertilization effect. CO_2 is essential for plant growth; some research suggests that higher atmospheric concentrations lead to higher productivity of some food, fiber, and forest crops. Milder winters and longer growing seasons could also increase productivity in some regions.

Important examples that highlight the link between large-scale climate changes and the sensitivity of the food, fiber, and forest systems include the effects of ENSO, a relatively well-known phenomenon, on crop yield. In Australia, during ENSO years there is increased probability of a decline in farmers' incomes by as much as 75 percent below the median income as compared to non-ENSO years (Tubiello 2005, as cited in Easterling *et al.* 2007). Another example is the extreme heat wave that occurred in Europe in 2003, which lowered maize yield by 36 percent in Italy and 30 percent in France (Ciais *et al.* 2005, as cited in Easterling *et al.* 2007). Uninsured losses for the entire European Union agriculture sector were estimated at 13 billion euros; 4 billion euros was lost in France alone (Sénat 2004, as cited in Easterling *et al.* 2007).

The most recent comprehensive and peer-reviewed literature on global climate impacts on the food and forestry sectors is from the IPCC Fourth Assessment Report. The SAP 4.3 Report provides an additional source of information on the impacts of climate change on agriculture, land resources, and biodiversity in the United States. Most of the evidence cited in this chapter focuses on the results of the IPCC report and SAP 4.3. However, because new evidence is continuously emerging on the subject of climate change impacts on the agriculture and forest systems, the discussion below also draws on results reported in more recent studies.

4.5.6.2.1 Projected Impacts of Climate Change for the United States

Forests

In the United States, the combination of human management and temperate climate has resulted in a productive and healthy forest system, as exemplified by the southern pine plantations (CCSP 2000). Forests are generally considered the most productive of the terrestrial ecosystems and provide important commodities like timber products. They are also key biodiversity sanctuaries and providers of ecosystem services. Currently, forests cover roughly one third of the land in the United States. Net growth of these forests (growth minus removals minus decomposition) accounts for removing about 883.7 $MMTCO_2$ per year, about 12.5 percent of gross national GHG emissions (EPA 2008b). Globally, forests account for the largest fraction of terrestrial ecosystem sequestered carbon, estimated to be roughly 1,640 petagrams of carbon (Sabine *et al.* 2004, as cited in CCSP 2008b). Climate change could directly affect the ability of forests to provide these key services and commodities in several ways.

One key impact of climate change is the extended risk and increased burn area of forest fires coupled with pathogenic stressors that damage fragile forest systems (Easterling *et al.* 2007). These impacts (forest fires, diseases, and pathogens) might be greatest between 2050 and 2100. It is projected that the forest fire season (summer) could be extended by 10 to 30 percent as a result of warmer temperatures (Parry *et al.* 2007). In the western states, the anticipated warmer spring and summer temperatures are expected to reinforce longer fire seasons and increased frequency of large wildfires. In turn, the carbon pools within forests are expected to be affected by changes in forest composition and reduced tree densities (Westerling 2006). More specifically, the Hadley and Canadian climate and ecological models project an increase in the fire season hazard by 10 percent in the 21st Century in the United States, with small regional decreases in the Great Plains and a 30-percent increase in Alaska and the Southeast (CCSP 2000). Highlighting the geographic differences even within a state, two climate models including the Geophysical Fluid Dynamics Laboratory and the Parallel Climate Model were run using “business as usual” (A2) and “transition to a low GHG emissions” (B1) IPCC SRES emissions scenarios. The results showed increases in fire risk in Northern California (15 to 90 percent), increasing with temperature, whereas, in Southern California, the change in fire risks ranged from a decrease of 29 percent to an increase of 28 percent. These results were largely driven by differences in precipitation between the different scenarios. In Southern California the drier conditions simulated in both the Geophysical Fluid Dynamics Laboratory model scenarios led to reduced fire risks in large parts of southern California, with fire risks increased in parts of the San Bernardino Mountains (Westerling and Bryant 2006).

Historical evidence indicates that the warmer periods in the past millennium correlated with increased frequency in wildfires, particularly in western forests (CCSP 2008b). General circulation models project increased wildfire activity in the western states, particularly from 2010 through 2029 (Flannigan *et al.* 2000, Brown *et al.* 2004, both as cited in CCSP 2008b). In 2060, models have projected forest fire severity increases of 10 to 30 percent in the southeastern states and 10 to 20 percent in the northeastern states (Flannigan *et al.* 2000, as cited in CCSP 2008b). Some models have projected even larger increases in wildfire activity, particularly in the southeastern region of the United States (Bachelet *et al.* 2001, as cited in CCSP 2008b). Potential losses to North American producers from increased disturbances (including wildfires, insects, and diseases) coupled with climate change impacts have been estimated to range from $1 to $2 billion per year averaged throughout the 21st Century (Sohngen and Sedjo 2005, as cited in Field *et al.* 2007).

Ancillary consequences of the projected increase in wildfire frequency across the United States include an increase in emissions expected to affect air quality and continue to be a source of GHGs. Although the GHGs that are released through wildfires could eventually be sequestered by forest regrowth, this carbon release might not be fully recovered in the short term and thus might be an important source of CO_2 in the atmosphere (Kashian *et al.* 2006, as cited in CCSP 2008b). Particularly in forests in the western United States, "If wildfire trends continue, at least initially this biomass burning will result in carbon release, suggesting that the forests of the western United States could become a source of increased atmospheric carbon dioxide rather than a sink, even under a relatively modest temperature increase scenario" (Westerling *et al.* 2006).

Invasive Species

The increasing occurrence of forest fires, which is likely to continue with projected warming temperatures, would impact ecosystem services, reduce the potential for carbon storage via forest management, and provide increased potential habitat for invasive species and insect outbreaks (Parry *et al.* 2007).

Since invasive species and pests are not constrained by the need for pollinators or seed spreaders, these species are more adaptable to the warming climate (Vila *et al.* 2007, as cited in CCSP 2008b). The northward movement of weed species, especially invasive weeds, is likely to be a result of higher projected temperatures and increased CO_2 concentration. This movement northward could further be accelerated, as some studies that have shown that the responsiveness of weeds to glyphosate, an important herbicide used in the United States, diminishes with increases in CO_2 concentration levels (Ziska *et al.* 1999, as cited in CCSP 2008b).

Disease and Pathogens

Warming temperatures might be allowing for the migration of diseases and pathogens (CCSP 2008b). More specifically, the increases in temperature are influencing the development of insect lifecycles, reducing winter mortality rates and "influence[ing] synchronization of mass attacks required to overcome tree defenses" (Ryan *et al.* 2008, as cited in CCSP 2008b).

The warming trends in the United States have already allowed for earlier spring insect activity and the increased proliferation of certain species (CCSP 2008b). These warming trends have also allowed for an increase in the survival rates of diseases and pathogens that affect crops, as well as plant and animal species. Recent research has linked the rising temperatures to increased outbreaks of the mountain pine beetle, the southern pine beetle, and the spruce beetle. Rising temperatures have also been correlated with the expansion of suitable range for the hemlock wooly adelgid and the gypsy moth (Ryan *et al.* 2008, as cited in CCSP 2008b). Not only are the boundaries of insects being shifted by climate change but "tree physiology and tree defense mechanisms" are being altered as well (Kirilenko and Sedjo 2007). The damage to forests is expected to depend on seasonal warming: winter and spring increases in temperature might increase losses to insects such as the southern pine beetle (Gan 2004, as cited in Field *et al.* 2007). In the western United States, particularly in Colorado, a recent measurable decline in aspen trees has been linked to global warming. Unlike earlier episodes of aspen tree dieback, the current decline is occurring more rapidly and over larger areas. The dieback is caused by bark beetles that were not known to have existed in the area (Saunders *et al.* 2008). In effect, "the hotter, drier conditions recently present in Colorado's mountains have enabled these unexpected agents to so quickly kill so many aspen" (Saunders *et al.* 2008). The forest disturbances such as insect outbreaks "are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons" (Field *et al.* 2007, as cited in Saunders *et al.* 2008). The control of increased insect populations, especially in the projected warmer winters and in the southern regions, might require increased applications of insecticides. It is important to control these insect populations because of their ability to spread other pathogens, especially the flea beetle, which is known to be a conduit for the corn damaging bacteria Stewart's Wilt (CCSP 2008b).

Migration

Under future climate warming scenarios, plant and animal species are expected to shift northward and to migrate to higher elevations, thus redistributing North American ecosystems (Parry *et al.* 2007). The southeast and northwest forests could experience carbon losses as a result of increased drought (CCSP 2000). However, the projected increases in precipitation over dry regions might encourage forest growth and displace some grasslands (CCSP 2008b).

A marked change in forest composition and distribution has been noted in Alaska, as indicated by a northward migration of the subarctic boundary tree line by 6 miles, and the displacement of 2 percent of the Alaskan tundra in the past 50 years (Anisimov *et al.* 2007, as cited in CCSP 2008b). Also, as evidenced by remote sensing analysis, the growing season is increasing in length by roughly 3 days per decade (CCSP 2008b). Arctic vegetation is expected to shift northward and cause forests to overtake tundra (ACIA 2004, as cited in CCSP 2008b).

Crops and Agriculture

In the early part of the 21st century, moderate climate change will increase crop yields on agricultural land by 5 to 20 percent (Easterling *et al.* 2007). However, this is dependent on regional differences and for crops that rely on highly utilized water resources (Parry *et al.* 2007). Crops that are near the threshold of their productive temperature range (*i.e.*, crops that are "near the warm end of their suitable range"), such as wine grapes in California, are expected to decrease in yield or quality based on moderate climate change scenarios (Easterling *et al.* 2007).

Grain crops in the United States are likely to initially benefit from the increased temperature and CO_2 levels. However, as temperatures continue to rise, sensitivity of these grain crops could increase. This sensitivity is expected to an even greater extent for horticultural crops such as tomatoes and onions, compromising their productive yield (CCSP 2008b). Various studies have found differing thresholds for maize production in the United States, with one in particular showing a 17 percent reduction of maize yield per 1 degree Celsius increase in temperature (Lobell and Asner 2003, as cited, in CCSP 2008b). Other crops such as wheat are regionally and temporally dependent. Studies show that wheat yield in the Great Plains "is estimated to decline 7 percent per 1 degree Celsius increase in air temperature between 18 and 21 degrees Celsius and about 4 percent per 1 degree Celsius increase in air temperature above 21 degrees C" (Lobell and Field 2007, as cited in CCSP 2008b). Similarly, rice yields are projected to decline about 10 percent per 1 degree Celsius increase for temperature profiles that are above current summer mean air temperatures (CCSP 2008b).

In the Great Lakes region, fruit production might benefit from climate change although there might be increased risk of winter thaws and spring frost (Bélanger *et al.* 2002 and Winkler *et al.* 2002, both as cited in Field *et al.* 2007). In New Jersey, higher summer temperatures are expected to depress the yields of a number of other economically important crops adapted to cooler conditions (*e.g.*, spinach, lettuce) by mid-century, while rising winter temperatures are expected to drive the continued northward expansion of agricultural pests and weeds (such as kudzu) (Frumhoff *et al.* 2007) . Cranberries are especially susceptible because of their requirement to be subjected to long periods of cold winter temperatures for development (Frumhoff *et al.* 2007).

Extreme Weather Events

The negative impacts of increased frequency of extreme weather events on crop yield might temper the beneficial effects of increased CO_2 concentrations with associated temperature increases and longer growing seasons on crop growth (CCSP 2008b).

In the United States, particularly in the north, the average increase in temperature is expected to lead to a longer growing season. However, temperature increases could also lead to increased climate sensitivity in the southeast and the Corn Belt (Carbone *et al.* 2003, as cited in CCSP 2008b). The Great Plains region is not expected to experience increased climate sensitivity (Mearns *et al.* 2003, as cited in CCSP 2008b). In terms of species migration as a result of climate change, the United States has experienced an incursion of perennial herbaceous species that limit the soil moisture available for other crops throughout the growing season (CCSP 2008b). The invasion of these nonnative species could impact how these regions adapt to climate change and could lead to the potential for more frequent wildfires by increasing vegetation density (Fenn *et al.* 2003 and Wisdom *et al.* 2005, both as cited in CCSP 2008b).

Multiyear droughts, which might have been a result of increased temperature conditions in lower-elevation forests in the southwestern region, have had a large impact on forest mortality rates (Breshears *et al.* 2005, as cited in CCSP 2008b). The mortality rate continued to increase even though growth at the forest tree line had been increasing previously (Swetnam and Betancourt 1998, as cited in CCSP 2008b). Forest productivity has decreased from climate change-induced warming in drought-prone regions (McKenzie *et al.* 2001, as cited in CCSP 2008b) and in subalpine regions (Monson *et al.* 2005 and Sacks *et al.* 2007, both as cited in CCSP 2008b).

Livestock

The livestock production infrastructure in the United States is likely to be influenced by the climate change-induced distributional and productivity changes to plant species. Livestock production during the summer season would *very likely* be reduced due to higher temperatures, but livestock production during the winter months could increase, again due to the projected increase in temperatures (CCSP 2008b).

The expected elevated CO_2 concentrations could diminish the grass feed quality. An increase in the carbon to nitrogen ratio would decrease the nutritional value of feed. In turn, grazing livestock that feed on lower quality grasses might be affected in terms of decreased weight and health (CCSP 2008b). Expected future average climate-change conditions could have less effect on livestock productivity and potential livestock loss than the effects of increased climate variability (*e.g.*, droughts and heat waves) (CCSP 2008b).

Climate models have projected decreases in livestock productivity in the United States simply due to projected temperature increases. In 2050, climate models project an average decrease in swine, beef, and milk production of 0.9 to 1.2 percent, 0.7 to 2.0 percent, and 2.1 to 2.2 percent, respectively (Frank *et al.* 2001, as cited in CCSP 2008b). Indeed, higher temperatures directly affect animals' ability to maintain homeostasis and consequently livestock must engage in altered metabolic thermoregulatory processes (Mader *et al.* 1997 and Davis *et al.* 2003, both as cited in CCSP 2008b). The induced thermal stress on livestock often results in a reduction in physical activity and ultimately diminishes feed intake. Livestock production losses and associated economic losses might be attributed to increasing temperatures that are "beyond the ability of the animal to dissipate [and] result in reduced performance (*i.e.*, production and reproduction), health, and well-being" (Hahn *et al.* 1992 and Mader, 2003, both as cited in National Science and Technology Council 2008).

The increased temperature expected as a result of climate change could allow for easier migration of animal pathogens and diseases, especially in the northward transition from the low to mid-latitudes, which would adversely affect livestock well-being in the United States (White *et al.* 2003, Anon 2006, van Wuijckhuise *et al.* 2006, all as cited in CCSP 2008b).

Fisheries

Although fisheries in cold freshwater regions are expected to be adversely affected, fisheries in warm freshwater regions could benefit from climate change. The effects of temperature increases have caused northward shifts of fisheries systems and this is expected to continue in the future (CCSP 2008b). According to IPCC, "many warm-water and cool-water species will shift their ranges northward or to higher altitudes" (Clark *et al.* 2001 and Mohseni *et al.* 2003, as cited in Field *et al.* 2007).

An example of negative impacts that result from large-scale species migration is the recent migration of two protozoan parasites from the Gulf of Mexico northward into the Delaware Bay. This parasitic incursion, possibly as a result of climate change, has led to a substantially increased mortality rate of oysters in the region (Hofmann *et al.* 2001, as cited in CCSP 2008b).

According to IPCC, the survival of brook trout in the United States is directly correlated to its preferred cold groundwater seeps habitat. As temperatures increase, mortality rates also increase for certain species of trout (CCSP 2008b). The salmonid species are likely also to be negatively affected by rising temperatures as they, too, are cold-water species (Gallagher and Wood 2003, as cited in Field *et al.* 2007). It is *likely* that other coldwater marine species could "disappear from all but the deeper lakes; cool-water species will be lost mainly from shallow lakes; and warm-water species will thrive, except in the far south, where temperatures in shallow lakes will exceed survival thresholds" (CCSP 2008b). Stocks of the river-spawning walleye will likely decline due to lower lake levels and climate change impacts in Lake Erie (Jones *et al.* 2006, as cited in Field *et al.* 2007). Coastal fisheries are also expected to experience the negative impacts of climate change, including coral reef bleaching, due to increased ocean temperatures (CCSP 2008b). In Alaska, the spawning and migration behaviors of commercially fished species could be affected and increasing temperatures might cause an increase in the cooling needs for storage and processing of catch (CIER 2007).

Adaptation

Motivation to engage in specific adaptation strategies because of the impacts of climate change on the forest, fiber, and food systems of the United States is expected. Adaptive practices in the forestry sector include cultivar selection, replanting tree species that are appropriate for the new climate regime, and utilizing dying timber (CCSP 2000). These and other potential strategies should be taken in the context of overall demand, population, and economic growth. Adaptive measures could be especially important to ensure the survival of forest, fisheries, and agriculture systems that are rich in biodiversity and productive value (CCSP 2000). It is possible that the current pace of climate change will make it difficult for many tree species to adapt as readily via migration as they have in previous periods of climate changes (Davis and Shaw 2001). It has been documented via pollen records that tree migration rates in the past have been roughly 20 to 40 km per century. In order to keep up with the projected climate changes in the future, tree migration rates would require migration patterns of roughly 300 to 500 km per century. Due to the projected pace of climate change, it is possible that “taxa that fail to adapt rapidly enough to tolerate these new and rapidly changing climate regimes will go extinct” (Davis and Shaw 2001). It is also possible that climate change could result in extinctions of many tree species (Davis and Shaw 2001).

4.5.6.2.2 Projected Global Impacts of Climate Change

Although the preceding section highlights anticipated climate change impacts in the United States, there are additional impacts that could affect forest and agriculture systems elsewhere in the world.

Crops

Globally, the agriculture and forest infrastructure will be affected by climate change. A recent Harvard report on Climate Change Futures states that a “changing climate will alter the hydrological regime, the timing of seasons, the arrival of pollinators and the prevalence, extent, and type of crop diseases and pests” (Anderson *et al.* 2005). Throughout the mid- to high-latitudinal regions, crop-specific productivity increases are projected for global mean temperature increases of 1 to 3 degrees Celsius. Beyond a 3-degrees Celsius increase in global mean temperature, crop productivity is expected to decrease in some regions (Easterling *et al.* 2007). Depending on the crop type, experiments on the effects of increased CO_2 concentrations, namely 550 parts per million as opposed to current levels of roughly 380 parts per million, suggest that crop yields could increase by 0 to 20 percent (Parry *et al.* 2007).

In a modest warming climate scenario, adaptive practices such as using various cultivars and altering planting and harvesting times might maintain cereal crop yields and possibly allow for an increase in productivity in the high latitudinal and temperate regions (Easterling *et al.* 2007). The adaptive practice in regions with 1 to 2 degrees Celsius increases in temperatures corresponds to an avoidance of a 10 to 15 percent reduction in yield for cereal crops (Parry *et al.* 2007). However, in the lower latitude dry regions, cereal crop productivity is projected to decrease for 1 to 2 degrees Celsius temperature increases, thereby exacerbating hunger issues for the population living in these regions (Parry *et al.* 2007).

According to IPCC the, “projected changes in the frequency and severity of extreme climate events will have more serious consequences for food and forestry production, and food insecurity, than will changes in projected means of temperature and precipitation” (Easterling *et al.* 2007). The low latitudinal regions might experience an increase in the frequency of extreme weather events like floods and droughts, which could adversely affect crop production, especially in the subsistence farming regions (Easterling *et al.* 2007). Extreme weather events, “reduce crop yield and livestock productivity beyond the impacts due to changes in mean variables alone, creating the possibility for surprises” (Parry *et al.* 2007). The reduced adaptive capacity of small-scale farmers such as subsistence and artisanal fisherfolk could result in increased vulnerability to extreme weather events, sea-level rise, and the spread of human disease, which could negatively affect agricultural and fish yields (Parry *et al.* 2007). Current climate change models do not yet include recent findings on precipitation extremes that are expected to impact agricultural production in areas such as southern Asia, northern Europe, and eastern Australia. These areas are expected to experience an impact on agricultural productivity as a result of projected increased precipitation extremes such as floods and droughts (Christensen *et al.* 2007, as cited in Easterling *et al.* 2007). Certain crops, such as wheat, are impacted by high precipitation events because wheat is, "susceptible to insects and diseases (especially fungal diseases) under rainy conditions" (Rosenzweig and Hillel 1998, as cited in Anderson *et al.* 2005). On the other hand, during droughts, certain fungi, such as *Aspergillus flavus*, are stimulated and will feed on drought-weakened crops (Anderson *et al.* 2005).

Decreases in crop and forest yields in moderate warming scenarios for the low latitudes will likely result in increased dependence on food imports in these typically the developing countries. As such, agricultural exports to lower latitude countries are likely to increase in the short term (Parry *et al.* 2007).

There could be a marginal increase in the population at risk of hunger due to climate change, but this would occur in the context of an overall decrease in the global population at risk of hunger as a result of anticipated economic development (Parry *et al.* 2007).

Forests

Globally, commercially grown forests for use in timber production are expected to increase modestly in the short term, depending on geographic region (Easterling *et al.* 2007). Large regional and local differences are anticipated as is a shift in terms of production increase from the lower latitudes to the higher latitudes (Parry *et al.* 2007). This poleward shift of forests and vegetation is estimated at roughly 500 km or more for the boreal zones for climate scenarios with CO_2 concentrations of double the current levels (Kirilenko and Sedjo 2007). In terms of distributional production, net benefits will accrue to regions experiencing increased forest production, whereas regions with declining activity will likely face net losses (Kirilenko and Sedjo 2007).

Due to increases in CO_2 concentration, there is potential for a carbon fertilization effect on the growth of trees with some experiments showing up to an 80 percent increase in wood production for orange trees (Kirilenko and Sedjo 2007). There is evidence to support elevated growth for young, immature forests in response to higher CO_2 concentration levels (Parry *et al.* 2007). However, free-air CO_2 enrichment experiments indicate that mature forests show no appreciable response to elevated CO_2 concentrations. However, young, immature forests show elevated growth in response to higher CO_2 concentrations (Parry *et al.* 2007). It should be noted that there has been only one feasibility study regarding forest free air CO_2 enrichment (FACE) of 100-year-old tree stands in which little to no stem growth was recorded, but that this lack of growth might be explained by the relative difficulty of controlling for constant CO_2 levels (Kirilenko and Sedjo 2007). Many GCMs have projected increases in forest production in certain geographic regions with notable exceptions. For example, the Terrestrial Ecosystem Model and the Center for International Trade in Forest Products Global Trade Model have simulated a future harvest increase of 2 to 11 percent in western North America, a 10 to 12 percent increase in New Zealand, a 10 to 13 percent increase in South America and a harvest decrease in Canada (Kirilenko and Sedjo 2007).

It is important to contrast these possible short term benefits with the negative implications of a warming climate since, "continued warming favors more fungal and insect of forests, and more harsh weather will further weaken tree defenses against pests" (Anderson *et al.* 2005) The ability of forests to continue to function as providers of agriculture and energy as well as sequester carbon will be affected by climate change (Anderson *et al.* 2005). Overall, the "effects of future drought and decreased soil moisture on agriculture and natural vegetation (such as forests) are uncertain and may, at least in part, be temporarily offset by fertilization effects of higher atmospheric concentrations of CO_2" (Triggs *et al.* 2004, as cited in CIER 2007). These extreme weather events, in concert with increased damage from insect and pathogen outbreaks and wildfires, might result in large-scale deforestation, as evidenced by recent trends in the Amazon basin (Kirilenko and Sedjo 2007). Climate-vegetation models have indicated that at CO_2 concentration levels of roughly three times current levels, the Amazon rainforests will eventually be lost due to climate change (Cox *et al.* 2004, as cited in Kirilenko and Sedjo 2007).

Fisheries

The aquaculture and fisheries sector are expected to incur negative development impacts as a result of the regional changes in the distribution and proliferation of various marine species (Easterling *et al.* 2007). As the distribution of certain fish species continues to be regionally rearranged, there is the potential for notable extinctions in the fisheries system, especially in freshwater species, in temperature ranges at the margin (Parry *et al.* 2007). Recent evidence indicates that the Meridional Overturning Circulation, which supplies nutrients to the upper layers of the Pacific and Atlantic Oceans, is slowing and thus adversely affecting regional production of primary food supply for fisheries systems (McPhaden and Zhang 2002, Curry and Mauritzen 2005, Gregg *et al.* 2003, Lehodey *et al.* 2003, all as cited in Easterling *et al.* 2007). In the North Sea, a shift in the distribution of warm water species such as zooplankton has resulted in a shift of fish species from whiting to sprat (Beaugrand 2004, as cited in CCSP 2008b).

The largest economic impacts associated with the fisheries sector as a result of climate change are expected to occur in coastal regions of Asia and South America (Allison *et al.* 2005, as cited in CCSP 2008b). Specifically, regional climate change could most affect species such as tuna and Peruvian anchovy (Barber 2001 and Lehodey *et al.* 2003, both as cited in CCSP 2008b).

Earlier spring ice melts in the Arctic and diminishing sea ice are affecting the distribution and productivity of marine species, particularly the upper-level sea organisms. In turn, fish harvests in the Arctic region are expected to change in the warming future. The freshwater species in the Arctic region are expected to be most affected by the increasing temperatures (Wrona *et al.* 2005, as cited in Field *et al.* 2007).

4.5.7 Industries, Settlements, and Society

This section defines these resources and describes the existing conditions and potential vulnerability of each to climate change impacts. In addition, this section briefly describes the potential vulnerability of cultural resources, including archaeological resources and buildings of historic significance to climate change impacts. The primary resource used in this section is the IPCC Fourth Assessment Report (Wilbanks *et al.* 2007); specifically, Chapter 7 for industry, settlement, and society.

The industries, settlements, and society sector encompasses resources and activities that describe how people produce and consume goods and services, deliver and receive public services, and live and relate to each other in society.

As defined by IPCC, this sector includes the following:

- Industry: manufacturing, transport, energy supply and demand, mining, construction, and related informal production activities (Wilbanks *et al.* 2007)
- Services: trade, retail, and commercial services, tourism, risk financing/insurance (IPCC 2007a)
- Utilities/Infrastructure: systems designed to meet relatively general human needs, often through largely or entirely public utility-type institutions (Wilbanks *et al.* 2007)

- Human Settlement: urbanization, urban design, planning, rural settlements (Wilbanks *et al.* 2007)
- Social Issues: demography, migration, employment, livelihood, and culture (Wilbanks *et al.* 2007)

4.5.7.1 Affected Environment

The industry, settlements, and society sector covers a very broad range of human institutions and systems, including the industrial and services sectors, large and small urban areas and rural communities, transportation systems, energy production, and financial, cultural, and social institutions.

A principal objective of human societies is to reduce their sensitivity to weather and climate. Recent experience with storms such as Hurricane Katrina reveals the limits to human control over climate-related impacts on industries, settlements, and society. Systems that are sensitive to climate change include air and water quality, linkage systems (transportation and transmission networks), building structures, resource supplies, social networks, and economic systems (Wilbanks *et al.* 2007).

This sector normally experiences and is generally resilient to variability in environmental conditions. Industries, settlements, and human society, however, can be vulnerable to extreme or persistent changes. Vulnerability increases when changes are unexpected or if resources or other factors inhibit the ability of this sector to respond to changes (Wilbanks *et al.* 2007).

Together, industry and economic services account for more than 95 percent of gross domestic product in highly developed economies and between 50 and 80 percent of gross domestic product in less developed economies (World Bank 2006, as cited in Wilbanks *et al.* 2007). Industrial activities are vulnerable to temperature and precipitation changes. For example, in Canada weather-related road accidents translate into annual losses of at least $1 billion Canadian annually, while more than a quarter of air travel delays in the United States are weather related (Andrey and Mills 2003, as cited in Wilbanks *et al.* 2007). Buildings, linking systems, and other infrastructure are often located in areas vulnerable to extreme weather events (flooding, drought, high winds). Trapp *et al.* (2007) found a net increase in the number of days in which severe thunderstorm environmental conditions could occur during the late 21st century using global and high-resolution regional climate models. The analysis suggests a future increase in these conditions of 100 percent or more in Atlanta, Georgia, and New York, New York. Such extreme events that can threaten linkage infrastructures such as bridges, roads, pipelines or transportation networks could cause industry to experience substantial economic losses (Wilbanks *et al.* 2007).

Institutional infrastructure is generally considered to be less vulnerable to weather and climate variation, as it embodies less fixed investment and is more readily adapted within the time scale of climate change. In some cases, experience with climatic variability can enhance the resilience of institutional infrastructure by triggering adaptive responses (Wilbanks *et al.* 2007).

Vulnerability to climate change impacts is determined by local geography and social context rather than large scale or aggregate factors (Wilbanks *et al.* 2007). Risk factors associated with local geography and social context are briefly described below.

4.5.7.1.1 Geography

Extreme weather events are more likely to pose risks to industry, settlements, and society than gradual climate change (Wilbanks *et al.* 2007). Resources and activities that are located in areas with higher susceptibility to extreme weather events (high temperatures, high winds, and flooding) are more vulnerable to the impacts of climate change. Extreme weather events can damage transportation routes and other infrastructure, damage property, dislocate settlement patterns, and disrupt economic activity. Gradual climate change can change patterns of consumption, decrease or increase the availability of inputs for production, and affect public health needs. Such impacts are experienced locally, but can be linked to impacts on national and global systems (Wilbanks *et al.* 2007).

Archaeological resources and buildings of historic significance are fixed in location and are therefore vulnerable to the effects of extreme weather events and gradual changes associated with local geography. Extreme weather events can expose archaeological resources and damage structures. Over time, gradual changes to weather patterns can also erode protective cover around archaeological resources and increase the rate of deterioration of historic buildings. Vulnerability of these resources to climate change impacts is tied to the susceptibility of location and local geography to extreme and gradual changes to weather.

4.5.7.1.2 Social Context

Worldwide, many of the places where people live are under pressure from a combination of growth, social inequity, jurisdictional fragmentation, fiscal shortfalls, and aging infrastructure. These stresses can include scarcity of water, poor sanitation, inadequate governance structures, unmet resource requirements, economic inequities, and political instability. While these types of stresses vary greatly across localities, they can combine with climate change impacts to result in substantial additional stress at local, national, and global levels (Wilbanks *et al.* 2007).

The social impacts associated with climate change will be mainly determined by how the changes interact with economic, social, and institutional processes to minimize or magnify the stresses. From an environmental justice perspective, the most vulnerable populations include the poor, the very old and very young, the disabled, and other populations that have limited resources and ability to adapt to changes (Wilbanks *et al.* 2007).

4.5.7.1.3 Urbanization

It is estimated that one third of the world's urban population (nearly 1 billion people) lives in overcrowded and unserviced slums, and 43 percent of the urban population is in developing countries. More generally, human settlements are often situated in risk-prone regions such as steep slopes, ravines, and coastal areas. These risk-prone settlements are expected to experience an increase in population, urbanized area, and economic activity. The population in the near-coastal zone (*i.e.*, within 330 feet elevation and 60 to 65 miles distance from the coast) has been estimated to be between 600 million and 1.2 billion, or 10 to 23 percent of the world's population (Adger *et al.* 2005, McGranahan *et al.* 2006, both as cited in Wilbanks *et al.* 2007). Migration from rural to urban areas is a common response to calamities such as floods and famines (Wilbanks *et al.* 2007).

4.5.7.2 Environmental Consequences

Key climate change impacts on this set of human systems are likely to vary widely and depend on a range of location-specific characteristics and circumstances. Moreover, potential climate change impacts on this sector could be particularly challenging to determine because effects tend to be indirect rather than direct, for example changes in temperature—a direct effect of climate change—affect air pollution concentrations in urban areas thereby affecting human health and health care systems, which are all indirect effects (Wilbanks *et al.* 2007).

The human institutions and systems that comprise the industry, settlements, and society sector tend to be quite resilient to fluctuations in environmental conditions that are within the range of normal occurrence. However, when environmental changes are more extreme or persistent, these systems can exhibit a range of vulnerabilities "especially if the changes are not foreseen and/or if capacities for adaptation are limited" (Wilbanks *et al.* 2007). For this reason industry, settlements, and society in developing countries are expected to be more vulnerable to direct and indirect climate change impacts than they are in industrialized countries (Wilbanks *et al.* 2007).

Climate change is expected to affect industry, settlements, and society via a range of physical effects, including the frequency and intensity of tropical cyclones and storms, extreme rainfall and floods, heat and cold waves, drought, temperature extremes, precipitation, and sea-level rise. Following the approach in Wilbanks *et al.* 2007, the categories of human systems addressed in this section include industry, services, utilities and infrastructure, settlements, and social issues. Each category is described below, and potential climate impacts on each category are discussed. Key systems within these categories that are expected to experience impacts associated with climate change are then discussed in greater detail in subsequent sections.

Industry includes manufacturing, transport, energy supply and demand, mining, construction, and related informal production activities (Wilbanks *et al.* 2007). These activities can be vulnerable to climate change when (a) facilities are located in climate-sensitive areas such as coasts and floodplains, (b) the sector is dependent on climate-sensitive inputs such as food processing, or (c) the sector has long-lived capital assets (Ruth *et al.* 2004, as cited in Wilbanks *et al.* 2007). For the energy sector, in addition to possible infrastructure damage or destruction from the effects of climate change (*e.g.*, as could happen due to extreme weather events) effects could also include climate-driven changes in demands for energy. For example, demand for heating could decline in winter months while demand for cooling could rise in summer months (CCSP 2008f).

Services include trade, retail and commercial services, tourism, and risk financing or insurance (Wilbanks *et al.* 2007). Possible climate change impacts on trade include impacts on transportation from extreme weather events like snow and ice storms that could impede the ability to transport goods, or impacts on comparative advantage of a region or country due to temperature shifts that affect production. Climate change impacts on transportation could also affect retail and commercial services. Retail and commercial services could also be affected by climatic conditions that affect prices of raw materials and by potential damage to infrastructure such as facilities existing in climate sensitive areas like coastal regions. Extreme events such as hurricanes can also affect tourism infrastructure. Tourism services could also be affected by climate change impacts through temperature shifts and changes that affect the natural landscape of tourist destinations. Potential indirect effects of climate change on tourism include changes in availability of water and energy prices. With respect to the insurance sector, climate change impacts could lead to increasing risk, which could trigger higher premiums and more conservative coverage. A reduction in availability of or ability to afford insurance could in turn lead to impacts on local and regional economies.

Utilities and infrastructure includes systems that are "designed to meet relatively general human needs, often through largely or entirely public utility-type institutions" (Wilbanks *et al.* 2007). This includes physical infrastructure such as water, transportation, energy, and communication systems, as well as institutional infrastructure such as shelters, public health care systems, and police, fire, and emergency services. "These infrastructures are vulnerable to climate change in different ways and to different degrees depending on their state of development, their resilience, and their adaptability" (Wilbanks *et al.* 2007). In general, institutional infrastructure tends to be less vulnerable to climate change than physical infrastructure because it typically involves less investment in fixed assets and is more flexible over timeframes that are relevant to climate change. There are numerous points where impacts on different infrastructures interact and the failure of one system can put pressure on others. At the same time, however, "this means that measures to protect one sector can also help to safeguard the others" (Wilbanks *et al.* 2007).

Human Settlement - Climate change interacts with other stresses in its impact on human settlements (Wilbanks *et al.* 2007). Potential impacts on human settlements could be experienced through several pathways. Sea-level rise threatens populations in coastal areas by accelerating the inundation of coastal wetlands, threatening vital infrastructure and water supplies, augmenting summertime energy demand, and affecting public health (Wilbanks *et al.* 2007). Changes in precipitation patterns could alter the availability of potable water while changes in temperature could affect air quality and contribute to an increase in incidents of heat stress and respiratory illnesses (Wilbanks *et al.* 2007). In urban areas, the Urban Heat Island effect (Wilbanks *et al.* 2007), which relates to the "degree to which built and paved areas are associated with higher temperatures than surrounding rural areas" (National Science and Technology Council 2008) might affect the manner in which climate change affects these areas.

Social Issues - Within human settlements, society could also experience a variety of effects associated with climate change. For example, communities could experience increasing stress on management and budget requirements for public services, if demands on public health care and disaster risk reduction grow (CCSP 2008f). There could be a loss of cultural and traditional groups of people, *e.g.* "indigenous societies in polar regions" (Wilbanks *et al.* 2007). Societal concerns that might be affected by the impacts of climate change include socioeconomic issues relating to developed versus developing areas and rich versus poor. Because the developing countries and poorer populations tend to have weaker infrastructure in place to begin with, their vulnerability to climate change effects is expected to be higher and their capacity to cope or adapt are expected to be lower than developed countries and wealthier populations (Wilbanks *et al.* 2007).

4.5.7.2.1 Projected Impacts of Climate Change for the United States

The research literature on climate impacts on United States industry, settlements, and society is relatively sparse. "At the current state of knowledge, vulnerabilities to possible impacts are easier to project than actual impacts because they estimate risks or opportunities associated with possible consequences rather than estimating the consequences themselves" (CCSP 2008f). In general, "climate change effects on human settlements in the United States are expected to occur as a result of interaction with other processes" (National Science and Technology Council 2008). These effects include those on health, water resources, physical infrastructure (notably transportation systems), energy systems, human settlements, and economic opportunities.

Impacts on human health and human health care systems are expected to arise because of temperature-related stress. Increases in cases of respiratory illness associated with high concentrations of ground-level ozone; water-, food-, and vector-borne diseases; and allergies related to higher concentrations of plant species are expected.

Effects on water are expected to include reductions in snowpack, river flows, and groundwater levels, saline intrusion in rivers and groundwater, an increase in water demand due to increasing temperatures, and impacts on sanitation, transportation, food and energy, and communication infrastructures from severe weather events.

The United States coastline, deltas, and coastal cities such as the Mississippi Delta and surrounding cities, are vulnerable to sea-level rise. "Rapid development, including an additional 25 million people in the coastal United States over the next 25 years will further reduce the resilience of coastal areas to rising sea levels and increase the economic resources and infrastructure vulnerable to impacts" (Field *et al.* 2007, as cited in National Science and Technology Council 2008).

Effects on other key human systems are discussed in greater detail below. Because this section deals with such a broad set of human systems, the potential impacts of climate change and potential adaptations available to key human systems are discussed together. Given the enormous range of human systems that could be affected by climate change, the discussion here is focused on a few key systems where impacts can best be characterized or supported by sufficient information.

Impacts on Transportation Infrastructure

Climate affects the design, construction, operation, safety, reliability, and maintenance of transportation infrastructure, services, and systems. The potential for climate change raises critical questions about how changes in temperature, precipitation, storm events, sea-level rise, and other climate variables could affect the system of roads, airports, rail, public transit, pipelines, ports, waterways, and other elements of the nation's and the world's complex transportation systems.

Climate changes anticipated during the next 50 to 100 years include higher temperatures, changes in precipitation patterns, increased storm frequency and intensity, and rising sea levels globally, resulting from the warming of the world's oceans and decline in polar ice sheets. These changes could affect the transportation system in a wide variety of ways. Those of greatest relevance for the United States are summarized below.

- *Increases in very hot days and heat waves.* It is very likely that heat extremes and heat waves will continue to become more frequent, more intense, and last longer in most regions during the 21st century. This could increase the cost of transportation construction, operations, and maintenance.

- *Increases in Arctic temperatures.* Arctic warming is virtually certain as temperature increases are expected to be greatest over land and at most high northern latitudes. As much as 90 percent of the upper layer of permafrost could thaw under more pessimistic emission scenarios.

- *Rising sea levels.* It is virtually certain that sea levels will continue to rise in the 21st century as a result of thermal expansion and loss of mass from ice sheets. This could make much of the existing transportation infrastructure in coastal areas prone to frequent, severe, and/or permanent inundation.

- *Increases in intense precipitation events.* It is very likely that intense precipitation events will continue to become more frequent in widespread areas of the United States. Transportation networks, safety, and reliability could be disrupted by visibility problems for drivers, and by flooding, which could result in substantial damage to the transportation system.

- *Increases in hurricane intensity.* Increased tropical storm intensities, with larger peak wind speeds and more intense precipitation are likely, which could result in increased travel disruption, impacts on the safety and reliability of transportation services and facilities, and increased costs for construction, maintenance, and repair (Transportation Research Board 2008).

Numerous studies have examined ways of mitigating the transportation sector's contribution to global warming from GHG emissions. However, far less attention has been paid to the potential impacts of climate change on United States transportation and on how transportation professionals can best adapt to climate changes that are already occurring, and will continue to occur into the foreseeable future even if drastic mitigation measures were taken today. Since GHGs have long life spans they continue to impact global climate change for decades (Transportation Research Board 2008).

Scientific evidence confirms that climate change is occurring, and that it will trigger new, extreme weather events and could possibly lead to surprises, such as more rapid than expected rises in sea levels or temperature changes. Every mode of transportation will be affected as climate change poses new and often unfamiliar challenges to infrastructure providers (Transportation Research Board 2008).

Consideration of climate change-related factors in transportation planning and investment decisions should lead to a more resilient, reliable, and cost-effective transportation system in the coming decades. When decisionmakers better understand the risks associated with climate change, they can make better decisions about potential adaptation strategies and the tradeoffs involved in planning, designing, constructing, operating, and maintaining transportation systems (Transportation Research Board 2008).

Projected climate changes have profound implications for transportation in the United States (Transportation Research Board 2008). Climate change is likely to increase costs for the construction and maintenance of transportation infrastructure, impact safety through reduced visibility during storms and destruction of elements of the transportation system during extreme weather events, disrupt transportation networks with flooding and visibility problems, inundate substantial portions of the transportation system in low lying coastal areas, increase the length and frequency of disruptions in transportation service, cause substantial damage and incur costly repairs to transportation infrastructure, and impact the overall safety and reliability of the nation's transportation system (Transportation Research Board 2008).

Transportation systems across the United States are projected to experience both positive and negative impacts from climate change over the next century; the degree of impacts will be determined, in part, by the geographic region (Transportation Research Board 2008). Coastal communities are especially vulnerable to impacts associated with sea-level rise, increased frequency or intensity of storms, and damage to the transportation system due to storm surges and flooding. The literature indicates that the intensity of major storms could increase by 10 percent or more, which could result in more frequent Category 3 (or higher) storms in the Gulf Coast and along the Atlantic coast (Transportation Research Board 2008).Warming temperatures might require changes in the kinds of materials used for construction of transportation facilities, and in the operation and maintenance of transportation facilities and services. Higher temperatures could require the development and use of more heat-tolerant materials (Transportation Research Board 2008). Restrictions on work rules could increase the time and costs for labor for construction and maintenance of transportation facilities. Rail lines could be affected by higher temperatures and more frequent rail buckling, which would affect service reliability, safety and overall system costs and performance. Costs could increase for ports, maintenance facilities, and transportation terminals if higher temperatures require an increase in refrigeration and cooling (Transportation Research Board 2008); and higher temperatures could affect aircraft performance and the runway lengths required for safe operation (Transportation Research Board 2008). On the positive side, higher temperatures might open up northern transportation routes for longer periods of time and allow more direct routing for marine transportation (Transportation Research Board 2008).

Changes in precipitation patterns could increase short-term flooding, resulting in decreased safety, disruptions in transportation services, and costly damage to transportation infrastructure. Hotter climates could exhibit reduced soil moisture and average runoff, which might require changes in the management and maintenance of publicly owned right-of-way. The potential increase in heavy rainfall might exceed the capacity of existing drainage systems, resulting in more frequent flooding and associated disruptions in transportation system reliability and service, increased costs for maintenance of existing facilities, and increased costs for construction of new facilities (Transportation Research Board 2008).

Relative sea-level rise might inundate existing transportation infrastructure and substantially increase the cost of provision of new transportation facilities and services. Some portions of the transportation infrastructure in coastal areas, or in areas prone to flooding, might have to be protected with dikes or levees – increasing the cost for construction and maintenance, and the potential for more serious flooding incidents associated with the failure of such dikes and levees (Transportation Research Board 2008).

Increased storm frequency and intensity might lead to greater transportation service disruption, and damage to transportation infrastructure in coastal and inland areas. Model results for the study of the Gulf Coast conservatively estimated a 22- to 24-foot potential surge for major hurricanes (Transportation Research Board 2008). During Hurricane Katrina (a Category 3 storm at landfall) surges exceeded these heights in some locations (Transportation Research Board 2008). While the specific location and strength of storm surges are difficult to predict due to the variation of the scale and trajectory of individual tropical storms, substantial portions of the coastal infrastructure across the United States are vulnerable to increased damage resulting from the impacts of climate change (Transportation Research Board 2008).

Disruptions in transportation system availability could result in substantial economic impacts associated with increased costs to construct or repair transportation infrastructure, and costs associated with disruptions in transportation for goods and services. Increasing fuel costs and delays in transportation service result in increased transport costs, which are then passed on to consumers. A substantial disruption in transportation (*e.g.,* destruction of a major transportation facility by hurricane, flood, or other extreme weather event) could affect the regional economy in many different ways. Communities are likely to require long periods of time to recover from these events, and some communities could be permanently affected (Transportation Research Board 2008).

The analysis to date raises clear cause for concern regarding the vulnerability of transportation infrastructure and services in coastal areas, and across the United States. Addressing the risks associated with a changing climate in the planning and design of transportation facilities and services can help public agencies and private investors to minimize disruptions to the smooth and safe provision of transportation services; and can protect the substantial investments made in the nation's transportation infrastructure now and in the future (Transportation Research Board 2008).

According to the USCCSP's *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure Report* (Transportation Research Board 2008), four key factors are critical to understanding how climate change might affect transportation:

- *Exposure.* What is the magnitude of stress associated with a climate factor (sea-level rise, temperature change, severe storms, and precipitation) and the probability that this stress will affect a transportation segment or facility?

- *Vulnerability.* Based on the structural strength and integrity of the infrastructure, what is the potential for damage and disruption in transportation services from this exposure?

- *Resilience.* What is the current capacity of a system to absorb disturbances and retain transportation performance?

- *Adaptation.* What response(s) can be taken to increase resilience at both the facility (e.g., a specific bridge) and system levels?

New approaches to address climate change factors in transportation planning and decisionmaking could include:

- *Extending planning timeframes.* To address the long timeframe over which climate changes and environmental processes occur, planning time frames might need to be extended beyond the typical 20- to 30-year planning horizon. The fact that transportation infrastructure can last for many decades (or even more than 100 years) argues for planning for much longer time frames to examine the potential impacts of climate change and other elements of the natural environment on the location, construction techniques, and costs for transportation infrastructure investments that are expected to last for many decades (Transportation Research Board 2008).

- *Conducting risk assessment analysis for transportation investments.* Transportation investments face many uncertainties, including the potential impacts of climate change on construction, operation, and maintenance. Planners and decisionmakers can use iterative risk management analysis to evaluate potential risks of all types, and to identify potential ways to minimize the risks and increase the resiliency of transportation infrastructure. Transportation structures and facilities can be hardened, raised, or even relocated if needed. Where it is critical to safety, reliability and mobility, redundant systems might be necessary for the most critical elements of the transportation system (Transportation Research Board 2008).

Impacts on Energy Systems

Although the energy sector has been seen as a driver of climate change, the energy sector is also subject to the effects of climate change (Wilbanks *et al.* 2007). All major energy sources are subject to a variety of climate change effects, including temperature, wind, humidity, precipitation, and extreme weather events (Bhatt *et al.* 2007). The most direct climate change impacts for fossil fuel and nuclear power plants, for example, are related to power plant cooling and water availability (Bhatt *et al.* 2007). Each kilowatt of electricity generated by thermoelectric generation requires about 25 gallons of water. Power plants rank only slightly behind irrigation in terms of freshwater withdrawals in the United States (USGS 2004, as cited in Bhatt *et al.* 2007). In addition, about 10 percent of all United States coal shipments were delivered by barge in 2003, and consequently low river flows can create shortfalls in coal supplies at power plants (Bhatt *et al.* 2007).

USCCSP identified potential effects of climate change on energy production and use in the United States, which are stated in terms of likelihood (Wilbanks *et al.* 2007). Principal impacts and their likelihood are listed below:

- Climate change will reduce total energy demand for space heating; effects will differ by region (*virtually certain*).

- Climate change will increase total energy demand for space cooling; effects will differ by region (*virtually certain*).

- Net effects on energy use will differ by region. Overall impacts will be affected by patterns of interregional migration – which are likely to be in the direction of net cooling load regions – and investments in new building stock (*virtually certain*).

- Temperature increases will increase peak demands for electricity (*very likely*).
- Changes in the distribution of water availability will affect power plants; in areas with decreased water availability, competition for water supplies between energy and other sectors will increase (*virtually certain*).
- Temperature increases will reduce overall thermoelectric power generation efficiency (*virtually certain*).
- In some regions, energy resource production and delivery systems will be vulnerable to the effects of sea-level rise and extreme weather events, especially the Gulf Coast and the East Coast (*virtually certain*).
- Hydropower production will be directly and substantially affected by climate change, especially in the West and Northwest (*very likely*).
- Climate change concerns will affect perceptions and practices related to risk management behavior in investment by energy institutions (*very likely*).
- Climate change concerns are almost certain to affect public and private sector energy technology research and development investments and energy resource and technology choices by energy institutions, along with associated emissions (*virtually certain*).

USCCSP concluded that there is very little literature on adaptation of the energy sector to effects of climate change, and their following discussion is therefore largely speculative (Wilbanks *et al.* 2007). Both energy users and providers are accustomed to changing conditions that affect their decisions. The energy sector is among the most resilient of all economic sectors in terms of responding to changes within the range of historical experience (Wilbanks *et al.* 2007). Adaptations to the effects of climate change on energy use could focus on increased demands and rising costs for space cooling; likely responses include investing in more efficient cooling equipment and building envelopes. Increased demands for both peak and average electricity demands could lead to contingency planning for load-leveling, more efficient and expanded generation capacity, expanded inter-ties, and increased storage capacity (Wilbanks *et al.* 2007).

In terms of energy production and supply, the most likely near-term adaptation is expected to be an increase in perceptions of uncertainty and risk in long-term strategic planning and investment; with investors seeking to reduce risks through such approaches as diversifying supply sources and technologies, and risk-sharing arrangements (Wilbanks *et al.* 2007).

Impacts on Human Settlements

The impacts of climate change on human settlements are expected to be substantial in a number of ways. "Settlements are important because they are where most of the [United States] population lives, often in concentrations that imply vulnerabilities to location-specific events and processes" (Wilbanks *et al.* 2007). Among the general effects of climate change are increased stress on human settlements due to higher summer temperatures and decreased stress associated with warmer winter weather. Changes in precipitation and water availability, rising sea levels in coastal regions, and greater risks from extreme weather events such as storms, flooding, and droughts are also expected to affect human settlements to various degrees. At the same time, stresses due to cold weather extreme events, such as blizzards and ice storms, are expected to decrease (Wilbanks et al 2007).

Predicting climate change impacts on United States settlements is difficult because climate change is not forecast on a scale that is appropriate for local decisionmaking, and because climate is not the only change that settlements are confronting. A key example is the continuing population shift, particularly among persons who have reached retirement, toward the Sun Belt and coastal areas. This means an ever larger elderly population could be at risk especially from extreme weather events such as tropical storms, as well as some types of vector-borne diseases and heat related illnesses (CCSP 2008f).

Anticipated human impacts include the following:

- Increased respiratory and cardiovascular problems (Patz and Baldus 2001, as cited in CCSP 2008f).
- Changes in mortality rates caused by temperature extremes (Rozenzweig and Solecki 2001, as cited in CCSP 2008f).
- Increased water demands associated with warming accompanied by changes in precipitation that alters access to water (Gleick 2000, Kirshen 2002, Ruth *et al.* 2007, all as cited in CCSP 2008f).
- Damages or disruptions to services associated with urban infrastructure such as sanitation systems, electricity transmission networks, communication systems, and the like could occur as a result of storms, floods, and fires (CCSP 2008f).
- Sea-level rise could jeopardize many of the 673 coastal counties and threaten population centers (Neumann *et al.* 2000, Kirshen *et al.* 2004, both as cited in CCSP 2008f).
- Vulnerable populations such as the poor, elderly, those in ill health, the disabled, persons living alone, and individuals with limited rights (*e.g.*, recent migrants) are expected to be at greater risk from climate change (CCSP 2008f).

As a specific example with respect to urban infrastructure, the New York City Department of Environmental Protection assessed potential climate change impacts on the city's drainage and wastewater collection systems, noting that if rainfall becomes more intense, sewer system capacities could be exceeded leading to street and basement flooding (NY City DEP 2008). Additionally, extreme precipitation events could lead to an inundation of the Water Pollution Control Plants' (WPCPs) influent wells. Sea-level rise could threaten hydraulic capacity of WPCP outfalls by making peak flow discharges more difficult and also increase the salinity of influent to the WPCP which would upset biological treatment processes and lead to corrosion of equipment (NY City DEP 2008).

The vulnerability of human settlements and infrastructure in coastal areas to natural disasters such as hurricanes and tropical storms was demonstrated through the damages incurred by Hurricanes Katrina and Rita in the Southeastern region of the United States After Hurricane Katrina struck, a total of 90,000 square miles was declared a Federal disaster area, 80 percent of New Orleans was flooded, more than 1,700 lives were lost, 850,791 housing units were damaged, 2,100 oil platforms and over 15,000 miles of pipeline were damaged (Petterson *et al.* 2006, as cited in CIER 2007).

There are various possible adaptation strategies for human settlements. Assuring effective governance, increasing the resilience of physical and linkage infrastructures, changing settlement locations over a period of time, changing settlement form, reducing heat-island effects, reducing emissions and industry effluents, improving waste handling, providing financial mechanisms for increasing resiliency, targeting assistance programs for especially impacted segments of the population, and adopting sustainable community development practices are some of them (Wilbanks *et al.* 2005, as cited in Wilbanks *et al.* 2007). Land use choices, specifically the discouragement of housing development in flood prone areas including areas below sea level and in deep flow plains, can help protect human settlements and preserve management flexibility for these areas (Isenberg *et al.*, 2008). The choice of strategies and policies for adaptation depend on their relationships with other social and ecological processes and level of economic development (O'Brien and Leichenko 2000, as cited in Wilbanks *et al.* 2007).

Impacts on Economic Opportunities and Risks

Communities or regions that are dependent on climate-sensitive resources or goods or whose comparative advantage could be affected are expected to be particularly vulnerable to climate change. The insurance sector is an example of an industry that could be highly vulnerable to climate impacts. If increasing trends of adverse weather events continue, claims made to private and public insurers are expected to climb (NAST 2001, as cited in CIER 2007). Overall risk exposure of insurers' has grown considerably, *e.g.*, the National Flood Insurance Program's exposure increased four-fold since 1980 to $1 trillion in 2005 and the Federal Crop Insurance Corporation's exposure grew up to $44 billion (U.S. GAO 2007, as cited in CIER 2007). To the extent that climate change increases costs for insurers or increases the difficulty in forecasting risks, the insurance sector might "withdraw (or make much more expensive) private insurance coverage from areas vulnerable to climate change impacts" (National Science and Technology Council 2008).

Trade, retail, and commercial services, and tourism are other economic areas that are expected to be affected by climate change impacts, largely as a result of impacts on the transportation and energy sectors. For example, impacts on transportation will affect distribution and receipt of goods for retail services. This could have a particular effect on the Midwest which is a heavy domestic freight and shipping route area. Approximately "$3.4 billion and 60,000 jobs rely on the movement of goods within the Great Lakes-St. Lawrence shipping route annually" (Easterling and Karl 2001, as cited in CIER 2007). A decline in water levels could jeopardize this mode of transporting manufacturing. In fact, "system connectivity is predicted to be come 25 percent impaired causing a loss of $850 million annually" (Easterling and Karl 2001, as cited in CIER 2007). Dredging 7.5 to 12.5 million cubic yards, costing $85-142 million, might be the only alternative to salvage this system if water levels decline substantially (Great Lakes Regional Assessment Group 2000, as cited in CIER 2007).

Tourism could be affected by "changes in the landscape of areas of tourist interest" as well as by changes in the availability of resources and energy costs (Wilbanks *et al.* 2007). In the United States, climate change impacts could affect winter recreation and tourism in the Northeast. Warmer winters would "shorten the average ski and snowboard seasons, increase snow making requirements, and drive up operating costs," possibly "prompting further closures and consolidation of ski areas northward toward the Canadian border" (Frumhoff *et al.* 2007).

Historical and Cultural Resources

A variety of cultural and historical resources are at risk from climate change. According to a recent study by UNESCO "The adverse impacts of climate change will have consequences for humanity as a whole including the products of human creativity...these consequences will be manifest in at least two principal ways: (1) the direct physical effects on the buildings or structures and (2) the effects on social structures and habitats" (Colette *et al.* 2007).

Alaska is the region expected to be most affected by climate change largely because of location (warming is more pronounced closer to the poles) and way of life (settlement and economic activities based around Arctic conditions) (CCSP 2008f). Indigenous communities in Alaska are facing major economic and cultural impacts because they depend for subsistence on various climate-sensitive animals such as polar bears, walruses, seals, and caribou (National Science and Technology Council 2008). "Changes in species' ranges and availability, access to these species, a perceived reduction in weather predictability, and travel safety in changing ice and weather conditions present serious challenges to human health and food security, and possibly even the survival of some cultures" (ACIA 2004, as cited in National Science and Technology Council 2008).

In discussing the impacts of climate change on historic cities and settlements around the world, Colette *et al.* 2007 lists the following potential threats associated with climate change:

- Increased salt mobilization with resulting damage to surfaces and decoration as a result of increasing rate of heavy rainfall
- Changes in the amplitude of temperature and humidity can cause splitting, cracking, flaking and other damage to exposed surfaces
- Organic building materials such as wood could be subject to increase infestation as a result of migration of pests
- An increase in flooding can directly damage structures and promote growth of damaging micro-organisms such as molds and fungi
- In arid regions, desertification, salt weathering and erosion could threaten cultural and historic sites

Climate change could also create pressures that result in migration of populations, which in turn could result in the breakdown of communities and the loss of "rituals and cultural memory" (Colette *et al.* 2007).

4.5.7.2.2 Projected Global Impacts of Climate Change

As the discussion above suggests, the three major ways in which industry, settlements, and society are vulnerable to climate change are through impacts on economics, infrastructure, and health. The magnitude of impacts on industry, settlements, and society largely depends on location and the level of development of the area or region. The discussion below highlights anticipated impacts on key human systems at the global level.

Global Energy Sector Impacts

In terms of energy production and use, the expected global impacts will likely be similar to those discussed above for the United States. When the climate warms, less heating will be needed for industrial, commercial, and residential buildings, with changes varying by region and by season (Wilbanks *et al.* 2007). Electricity is used in areas around the world for cooling; coal, oil, gas, biomass, and electricity provide energy for heating. Regions with substantial requirements for both cooling and heating could see net increases in electricity demands while demands for other energy sources decline (Hadley *et al.* 2006, as cited in Wilbanks *et al.* 2007).

According to one study, by 2100 the benefits (reduced heating) will be about 0.75 percent of gross domestic product, and impacts (increased cooling) will be approximately 0.45 percent (Tol 2002a, 2002b, both as cited in Wilbanks *et al.* 2007). These percentages could be affected by migration from heating-intensive regions to cooling-intensive regions (Wilbanks *et al.* 2007).

Climate change could also affect global energy production and distribution if extreme weather events become more frequent or intense; and in regions dependent upon water supplies for hydropower or thermoelectric generation if there are substantial changes in rainfall/snowfall locations and seasonality. Reduced stream flows are expected to jeopardize hydropower production in some areas, but higher precipitation rates resulting in greater or more sustained stream flows could be beneficial (Casola *et al.* 2005, Viosin *et al.* 2006, both as cited in Wilbanks *et al.* 2007). More frequent or intense extreme weather events could threaten coastal energy infrastructures including electricity transmission and distribution facilities (Bull *et al.* 2007).

Warming temperatures resulting in melting of permafrost threaten petroleum production facilities and pipelines, electrical transmission towers, and nuclear power plants in the Arctic region (Nelson *et al.* 2001, as cited in Wilbanks *et al.* 2007). As with Alaska's North Slope facilities, structural failures in transportation and industrial infrastructure are becoming more common in northern Russia due to melting permafrost (Wilbanks *et al.* 2007).

Global Transportation Sector Impacts

The IPCC concludes, with *very high confidence*, that data since 1970 have demonstrated anthropogenic temperature rises have visibly altered ecosystems (Parry *et al.* 2007). Other stressors on the built environment and the ability of cities and countries to adapt to a changing climate make it difficult to discern the exact impacts of climate change on transportation systems around the world. Additional factors, such as projected population growth, are expected to exacerbate the effects of climate change. Development typically occurs in the coastal regions, especially in the newly developing third world countries. These areas are particularly vulnerable to the impacts of projected increases in extreme weather events such as hurricanes, cyclones, unusually heavy precipitation, and flooding. In addition these developing countries are less able to adapt to expected changes due to their limited resources and other pressing needs (Wilbanks *et al.* 2007).

Transportation system vulnerabilities in more developed countries often focus on physical assets and infrastructures and their economic value and replacement costs, along with linkages to global markets. Vulnerabilities in less developed countries often focus on human populations and institutions that are likely to have very different transportation needs and resources (Wilbanks *et al.* 2007). A warmer, drier climate could exacerbate many of the problems of developing countries, including drought and decreases in food production in areas of Africa and Asia (Wilbanks *et al.* 2007).

At a national scale, industrialized countries such as the United Kingdom and Norway can cope with most kinds of gradual climate change, but localized differences can show considerable variability in stresses and capacities to adapt (Environment Canada 1997; Kates and Wilbanks 2003, as cited in National Science and Technology Council 2008; London Climate Change Partnership 2004; O'Brien *et al.* 2004; Kirshen *et al.* 2006).

The impacts on the United States transportation systems described above apply in other countries as well. Based on information developed by the Transportation Research Board (2008) the potential impacts of climate change on transportation fall into the two major categories described below.

- Climate change will affect transportation primarily through increases in several types of weather and climate extremes, such as very hot days, intense precipitation events, intense hurricanes, drought, and rising sea levels, coupled with storm surges and land subsidence.

The impacts will vary by mode of transportation and region, but they will be widespread and costly in both human and economic terms and will require substantial changes in the planning, design, construction, operation, and maintenance of transportation systems.

- Potentially, the greatest impact of climate change on global transportation systems will be flooding of coastal roads, railways, transit systems, and runways because of rising sea levels coupled with storm surges, and exacerbated in some locations by land subsidence (National Science and Technology Council 2008).

Given the global nature of the impacts of climate change and the world economy, coordination within and among nations will become increasingly important (Wilbanks *et al.* 2007). Strong and complex global linkages and interactions occur throughout the world today and are likely to increase in the future. Climate-change effects cascade through interlinked systems for international trade, migration, and communication patterns producing a variety of direct and indirect effects. Some of these impacts might be anticipated. However, many might not, especially if the globalized economy becomes less resilient and more interdependent (Wilbanks *et al.* 2007).

The impacts of an extreme weather event in one location (*e.g.*, Hurricane Katrina in Louisiana) causes ripple effects throughout the transportation system in the United States and in areas around the world linked to the United States through the ports in the affected area (Transportation Research Board 2008).

There are now incidences in Europe, North America, and Japan, of new transportation infrastructure being designed and constructed with potential climate change in mind. For example, bridges and other infrastructure designed at higher elevations in anticipation of sea-level rise over the life span of these transportation system elements (Wilbanks *et al.* 2007).

Global Human Settlements Impacts

Human settlements are vulnerable to the effects of climate change in three major ways: (1) through economic sectors affected by changes in input resource productivity or market demands for goods and services; (2) through impacts on certain physical infrastructure; and (3) through impacts of weather and extreme events on the health of populations. The degree of vulnerability tends to be a function of the location (coastal and riverine areas are most at risk), economy (economies most dependent on weather-related sectors are at the highest risk), and size (larger settlements are at a greater aggregate risk, but they likely have greater resources to prevent the impacts of climate change and respond to events that result from climate changes such as hurricanes, floods, or other extreme weather events) (Wilbanks *et al.* 2007).

Shifts in precipitation patterns might affect already stressed environments. For example, mean precipitation in all four seasons of the year has tended to decrease in all main arid and semi-arid regions of the world, *e.g.*, northern Chile and northeast Brazil, West Africa, and Ethiopia, drier parts of southern Africa, and western China (Folland *et al.* 2001, as cited in Wilbanks *et al.* 2007). Increasing temperature could aggravate ozone pollution in many cities, which could affect quickly growing urban areas that, especially those in developing countries, are experiencing more air pollution problems (Wilbanks *et al.* 2007). Extreme weather events affect settlements and society in developing countries just as they do developed countries, through damage and destruction of infrastructure and loss of human life, although perhaps in slightly different ways. For example, in some urban areas of developing countries, informal settlements develop. These informal settlements are especially vulnerable as they tend to be built on hazardous sites and susceptible to floods, landslides, and other climate-related disasters (Cross 2001, UN-Habitat 2003, both as cited in Wilbanks *et al.* 2007). Another example is how "[i]n developing countries, a common cause of death associated with extreme weather events in urban areas is electrocution by fallen power cables" (Few *et al.* 2004, as cited in Wilbanks *et al.* 2007).

Generally, low-income and other vulnerable populations would experience the same impacts from climate change as populations in comparable geographic areas described in this section, as well as sections 4.5.6, Food, Fiber, and Forest Products and 4.5.8, Human Health. However, as with environmental justice populations in the United States, climate change impacts would likely be differentially experienced by vulnerable populations. The magnitude of climate change impacts on residents of developing countries would be expected to be greater. For example, IPCC notes that the continent of Africa's "major economic sectors are vulnerable to current climate sensitivity, with huge economic impacts, and this vulnerability is exacerbated by existing developmental challenges such as endemic poverty, complex governance and institutional dimensions; limited access to capital, including markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts. These in turn have contributed to Africa's weak adaptive capacity, increasing the continent's vulnerability to projected climate change" (Wilbanks *et al.* 2007).

As discussed in this section, the danger to human health from climate change will differentially affect developing countries. The IPCC states that "Adverse health impacts will be greatest in low-income countries. Those at greater risk include, in all countries, the urban poor, the elderly and children, traditional societies, subsistence farmers, and coastal populations" (Wilbanks *et al.* 2007). Section 4.5.8 describes in detail the potential health effects from climate change on developing countries; these impacts include:

- Increases in malnutrition, and related health impacts, in developing regions of the world due to declining crop yields
- Potential increases in water-related diseases, such as diarrhea-causing pathogens, due to higher temperatures
- Potential for continuation of upward trends in certain vector-borne diseases, such as malaria in Africa, which have been attributed to temperature increases
- Increases in temperature leading to increased ozone and air pollution levels in large cities with vulnerable populations

Section 4.5.6 and this section describe the effects of climate change on developing countries that would differ or be substantially more severe than similar effects experienced by developed nations. Because the developing world tends to depend more on small-scale farming and subsistence economic activities, individuals in these areas would be disproportionately affected by climate change impacts on agricultural and subsistence resources. In particular, these impacts could include:

- Decreases in precipitation in developing parts of the world, such as southern Africa and northern South America, leading to decreases in agricultural production and increased food insecurity
- Substantial potential for impacts on small-scale subsistence farmers resulting from increases in extreme weather events projected under global climate change, reducing agricultural production in some areas of the globe
- Changes in the range of fish and animals and species extinctions, affecting populations in developing nations that depend economically on these resources

- Declines in tourism, especially to coastal and tropical areas heavily affected by sea-level rise, with severe economic consequences for smaller, developing nations

- Sea-level rise and severe weather-related events affecting the long-term habitability of atolls (low coral reef-formed islands) (Barnett and Adger 2003)

Global Impacts on Economic Opportunities and Risks

Impacts vary by region and locality and cannot be generalized for all nations. Although impacts are expected to vary, a factor that developed countries have in common is that their access to material and financial resources provides them opportunities to adapt to the effects of a changing climate. By contrast, developing countries are expected to be less able to adapt to climate change because they lack both the physical and financial resources needed to bolster their resilience to the same extent that is possible in industrialized countries.

In developing countries "industry includes a greater proportion of enterprises that are small-scale, traditional, and informally organized…Impacts of climate change on these businesses are likely to depend on… location in vulnerable areas, dependence on inputs sensitive to climate, and access to resources to support adaptive actions" (Wilbanks *et al.* 2007). One specific industry that could become more vulnerable to direct and indirect impacts of climate change is the tourism industry. Impacts on this industry can be "especially significant for smaller, tourist-oriented countries often in the developing world" (Wilbanks *et al.* 2007). It seems "likely that tourism based on natural environments will see the most substantial changes due to climate change… Tropical island nations and low-lying coastal areas may be especially vulnerable as they may be affected by sea-level rise, changes in storm tracks and intensities, changes in perceived climate-related risks, and changes in transport costs…" (Wilbanks *et al.* 2007). The implications are most notable for areas in which tourism is a relatively large share of the local or regional economy, and those for which adaptation would represent a relatively substantial need and a relatively substantial cost (Wilbanks *et al.* 2007). Trade is another industry that could be affected by extreme weather events that temporarily close ports or transport routes and damage infrastructure critical to trade, both domestic and international. There could be "linkages between climate change scenarios and international trade scenarios, such as a number of regional and sub-regional free trade agreements" (Wilbanks *et al.* 2007). However, research on this topic is lacking.

4.5.7.2.3 Adaptation

People and societies have adapted to changing conditions in every phase of human history, and human societies have generally been highly adaptable (Ausubel and Landford 1977). Adaptation can be anticipatory or reactive, self-induced and decentralized, or dependent on centrally initiated policy changes and social collaboration. Adaptation measures can be gradual, occurring over long periods of time; or evolutionary based on reactions to abrupt changes in settlement patterns or economic activity, or in response to extreme weather events (Wilbanks *et al.* 2007).

Adaptation strategies vary widely depending on the exposure of a place or sector to dimensions of climate change, its sensitivity to such changes, and its capacities to cope with the changes. Some of the strategies are multisectoral, such as improving climate and weather forecasting at local and regional levels, emergency preparedness, and public education (Wilbanks *et al.* 2007). These strategies are likely to be more prominent in more fully developed countries, but are important tools to facilitate adaptation in all countries. Awareness, capabilities, and access to resources that facilitate adaptation to climate change are likely to be much less widely available in less developed countries, where industrial production and residential population often locate in areas vulnerable to flooding, coastal erosion, and extreme weather events (Wilbanks *et al.* 2007).

New warning systems and evacuation procedures are important adaptation strategies. New warning systems in areas prone to extreme weather events such as hurricanes, cyclones, tornados, and flooding can help to prevent weather-related deaths; and minimize damage to community infrastructure, including the transportation system. Adaptation strategies tend to be context-specific, within larger global markets and policy structures, although it generally takes place within the larger context of globalization (Benson and Clay 2003; Sperling and Szekely 2005).

"Adaptation strategies vary widely depending on the exposure of a place or sector to dimensions of climate change, its sensitivity to such changes, and its capacities to cope with the changes" (Wilbanks *et al.* 2007). In general, uncertainty about the distribution and timing of climate-change impacts at the local level makes judgments about the scale and timing of adaptation actions very difficult (Wilbanks *et al.* 2007).

4.5.8 Human Health

4.5.8.1 Affected Environment

Climate change has contributed to human mortality and morbidity (*very high* confidence; IPCC 2007b) with further projected increases. Climate change could increase the risk of flooding; increase incidence of heat waves; change the severity, duration, and location of extreme weather; increase surface temperature; and alter precipitation intensity and frequency. These events can affect human health either directly through temperature and weather or indirectly though changes in water, air, food quality, vector ecology, ecosystems, agriculture, industry, and settlements. Climate change can also affect health through social and economic disruption. Malnutrition, death, and disease brought on by climate-change are projected to affect millions of people (Confalonieri *et al.* 2007).

4.5.8.2 Environmental Consequences

4.5.8.2.1 Heat Waves

A heat wave is a period of abnormally high temperatures that can be accompanied by unusual humidity. This weather phenomenon is not formally specified by a time period or temperature reading. Conventionally, a heat wave lasts several days to several weeks, though a one-day event can qualify as a heat wave. The temperature to qualify as a heat wave is dependent upon what is considered unusually hot for that region, as increases in mortality can occur below temperatures considered extremely hot (Ebi *et al.* 2008). IPCC has found the number of hot days, hot nights, and heat-waves to have increased (Confalonieri *et al.*. 2007). Global warming has increased intensity of heat waves (Houghton *et al.* 2001, as cited in Epstein *et al.* 2006), due in part to the disproportionate warming at night (Easterling *et al.*1997, as cited in Epstein *et al.* 2006). Heat-wave events can trigger poor air quality and forest fires, leading to further increases in human mortality and morbidity (Bates *et al.* 2005, Goodman *et al.* 2004, Keatinge and Donaldson 2001, O'Neill *et al.* 2005a, Ren *et al.* 2006 all as cited in Ebi *et al.* 2008).

The impact of a heat wave on the affected population depends on the current health and economic status. In South Asia, those most sensitive to heat waves include the rural population, elderly, outdoor workers, very young, city-dwellers, those with less education, socially isolated, medicated people, mentally ill, and those without available air conditioning (Chaudhury et al 2000, as cited in Confalonieri *et al.*. 2007; Diaz *et al.* 2002, Klinenberg 2002, McGeehin and Mirabelli 2001, Semenza *et al.* 1996, Whitman *et al.* 1997, Basu *et al.* 2005, Gouveia *et al.* 2003, Greenberg *et al.* 1983, O'Neill *et al.* 2003a, Schwartz 2005, Jones *et al.* 1982, Kovats *et al.* 2004, Schwartz et al 2004a, Semenza *et al.* 1999, Watkins *et al.* 2001 all as cited in Ebi 2008). People in developed areas can be impacted substantially by heat waves as well. Existing electricity grids in the United States would be severely stressed by a major heat wave, leading to brownouts and blackouts further contributing to increased heat-related illnesses (Epstein *et al.*, 2006).

The urban heat island effect could increase temperatures experienced in cities by 2 to 10 degrees Fahrenheit compared to neighboring rural and suburban areas (EPA 2005 as cited in Ebi *et al.* 2008). This increase in temperature occurs, in part, as the city pavement and buildings absorb a greater amount of incoming solar radiation compared to vegetation and trees; in addition, heat is also emitted from buildings and transportation (EPA 2005, Pinho and Orgaz 2000, Vose *et al.* 2004, Xu and Chen 2004, all as cited in Ebi *et al.* 2008). However, it has been demonstrated that during a heat wave, not all urban areas experience greater heat-related mortality than the surrounding rural and suburban areas (Sheridan and Dolney, 2003, as cited in Ebi *et al.* 2008).

4.5.8.2.2 Cold Waves

Human mortality and morbidity can also be caused by cold waves. Cold waves affect human health through death, hypothermia, frostbite, damage to organs such as kidney, pancreas, and liver, with greatest risk to infants and the elderly (NOAA 2001). Cold waves can cause further complications of heavy snow, ice, coastal flooding, and stranded motorists. As with a heat wave, the classification of a cold wave varies by region, with no formal definition for the minimum temperature reached, the rate of temperature fall, or the duration of the event. Populations in temperate countries tend to be more sensitive to cold weather (Honda *et al.* 1998, as cited in Confalonieri *et al.*. 2007). The human health reaction of a population to a cold wave can vary depending on the income, (Healy 2003, as cited in Ebi *et al.* 2008), age, topography, climate, (Curriero *et al.* 2002, Hajat 2006, both as cited in Confalonieri *et al.* 2007), race, (Fallico *et al.* 2005. as cited in Ebi *et al.* 2008), sex, (Wilkinson *et al.* 2004, as cited in Ebi *et al.* 2008), health, (Wilkinson *et al.* 2004, as cited in Ebi *et al.* 2008), dress, (Donaldson *et al.* 2001, as cited in Ebi *et al.* 2008), and fuel access (Healy 2003, as cited in Ebi *et al.* 2008). Cold days, cold nights, and frost days have become less common (IPCC 2007b) with the winter season projected to continue to decrease in duration and intensity (Alley *et al.* 2007, as cited in Ebi *et al.* 2008). This could lead to a decrease in cold-related health impacts, notwithstanding external factors, such as influenza outbreaks (Ebi *et al.* 2008).

4.5.8.2.3 Extreme Weather Events

Climate change is anticipated to affect the number, severity, and duration of extreme weather events (Fowler and Hennessey 1995, as cited in Sussman *et al.* 2008). Extreme weather events include floods, tropical and extra-tropical cyclones, tornadoes, windstorms, and drought. Extreme weather can further trigger additional extreme events such as wildfires, negatively affecting infrastructure, including sanitation, human mortality and morbidity, and mental health (Confalonieri *et al.* 2007). The loss of shelter, large-scale population displacement, damage to community sanitation and health care, and reduction in food availability can extend the level of mortality and morbidity beyond the actual event (Curriero *et al.* 2001b, as cited in Sussman *et al.* 2008). Factors that influence population vulnerability to extreme weather include location, population density, land use, age, income, education, health, health care response, and disaster preparedness (Blaikie *et al.* 1994, Menne 2000, Olmos 2001, Adger *et al.* 2005, Few and Matthies 2006, all as cited in Confalonieri *et al.* 2007).

Adverse weather conditions create safety hazards and delays in the Nation's transportation systems, especially on the nation's highways. The Federal Highway Administration (FHWA) estimates that about 25 percent of highway crashes occur during adverse weather resulting in about 17 percent of highway fatalities (AMS, 2004), while the Federal Motor Carrier Safety Administration (FMCSA) found that the factor "environmental conditions" was the critical reason[22] for 3 percent of large truck crashes (FMCSA, 2007). Extreme weather events that increase adverse weather conditions on the nation's highways could potentially affect highway safety.

Floods occur with the greatest frequency compared to other extreme weather events (EM-DAT 2006, as cited in Confalonieri *et al.* 2007). The intensity of a flood is dependent on rainfall, surface runoff, evaporation, wind, sea level, and local topography (Confalonieri *et al.* 2007). Health impacts related to flood events include deaths and injuries sustained during a flood event; increased transmission and prevalence of infectious diseases; and toxic contamination of supplies and food (Greenough *et al.* 2001, Ahren *et al.* 2005, both as cited in Confalonieri *et al.* 2007; Hajat et al 2003, Kalashnikov *et al.* 2003, Tuffs and Bosch 2002 (all as cited in Epstein *et al.* 2006)).

Drought is an abnormal period of dry weather that has led to substantial decrease in water availability for a given location (Huschke 1959). The health impacts associated with a drought include mortality, malnutrition, infectious diseases, and respiratory diseases (Menne and Bertollini 2000, as cited in Confalonieri *et al.* 2007). Aggravating this situation, malnutrition increases the susceptibility of contracting an infectious disease (Confalonieri *et al.* 2007) and drought-related population displacement can reduce access to adequate and safe water, food, and shelter, leading to increased malnutrition and infectious diseases. Further health impacts can spiral, such as a change in the transmission of mosquito-borne diseases during and after the drought event (Confalonieri *et al.* 2007). Impacts on the agricultural productivity affect health through risk of under- and malnutrition (Epstein *et al.* 2006), and increased dust storm activity and frequency of forest fires. Drought conditions weaken trees' defenses against pests and can result in increased threats to human health from forest fires (Mattson and Haack 1987, Boyer 1995, Holsten *et al.*, 2000, all as cited in Epstein *et al.* 2006).

4.5.8.2.4 Air Quality

Climate change can affect air quality through altering local weather patterns and/or pollution concentrations. Ground-level ozone, particulate matter, and airborne allergens contribute to poor air quality, leading to respiratory ailments and premature mortality. Increasing exposure to these pollutants would have substantial negative health impacts (Confalonieri *et al.* 2007).

Ground-level ozone contributes to urban smog, and occurs both naturally and as a secondary pollutant formed through photochemical reactions of nitrogen oxides and volatile organic compounds.[23] These reactions are accelerated with increasing sunlight and temperatures; thus ozone concentrations tend to peak during late afternoon and early evening in the warmer season; however, some locations demonstrate no such seasonality in ozone concentration (Bates 2005, as cited in Confalonieri *et al.* 2007). The concentration of ground-level ozone for a particular location varies as a function of temperature, wind, solar radiation, atmospheric moisture, atmospheric mixing, and cloud cover. Studies have found increasing levels of ground-level ozone in most regions (Wu and Chan 2001, Chen *et al.* 2004, both as cited in Confalonieri *et al.* 2007). A recent study found increases in CO_2 concentrations lead to increases in water vapor and temperatures. These lead to higher ozone concentrations in polluted areas, resulting in

[22] FMCSA conducted the Large Truck Crash Causation Study (LTCCS) sample of 963 crashes involved 1,123 large trucks and 959 motor vehicles that were not large trucks between 2001 and 2003. The LTCCS defines the Critical Reason as the immediate reason for the critical event (*i.e.*, the failure leading to the critical event). The critical reason is assigned to the vehicle coded with the critical event in the crash. It can be coded as a driver error, vehicle failure, or environmental condition (roadway or weather). Other causal coding includes a Critical Event and Associated Factors.

[23] Nitrogen oxides are emitted, in part, through the burning of fossil fuels. Volatile organic compounds are emitted from varying sources including burning of fossil fuels, transpiration, evaporation from stored fuels, solvents and other chemicals.

an increase in ozone-related deaths by 40 percent (Jacobson 2008). Climate change is anticipated to increase ozone-related diseases (Sussman *et al.* 2008).

Ozone exposure is associated with respiratory ailments such as pneumonia, chronic obstructive pulmonary disease, asthma, allergic rhinitis, chest pain, shortness of breath, and premature mortality (Mudway and Kelly 2000, Gryparis *et al.* 2004, Bell *et al.* 2005, 2006, Ito *et al.* 2005, Levy *et al.* 2005, all as cited in Confalonieri *et al.* 2007,; American Lung Association, 2008). Asthmatics are considered a sensitive population (Ebi *et al.* 2008). Long-term exposure to elevated amounts of ozone has been shown to affect lung efficiency (Ebi et al 2008; American Lung Association 2008).

Particulate matter comprises solid and liquid particles suspended in the atmosphere varying in both chemical composition and origin. Concentrations of particulate matter are affected by emission rates and local weather conditions such as atmospheric stability, wind, and topography. Some particulates display seasonal variability directly linked to seasonal weather patterns (Alvarez *et al.* 2000, Kassomenos *et al.* 2001, Hazenkamp-von Arx *et al.* 2003, Nagendra and Khare 2003, Eiguren-Fernandez *et al.* 2004, all as cited in Confalonieri *et al.* 2007). In Mexico City and Los Angeles, local weather conditions can create a stagnant air mass, restricting dispersion of pollution. Seasonal weather patterns can further enhance the chemical reactions of emissions, thereby increasing secondary particulate matter (Rappengluck *et al.* 2000, Kossmann and Sturman 2004, both as cited in Confalonieri *et al.* 2007).

Breathing particulate matter can cause respiratory ailments, heart attack, and arrhythmias (Dockery *et al.* 1993, Samet *et al.* 2000, Pope *et al.* 1995, 2002, 2004, Pope and Dockery 2006, Dominici *et al.* 2006, Laden *et al.* 2006, all as cited in Ebi *et al.* 2008). Populations at greatest risk could include children, the elderly, and those with heart and lung disease, diabetes (Ebi *et al.* 2008), and high blood pressure (Künzli *et al.* 2005, as cited in Ebi *et al.* 2008). Chronic exposure to PM could decrease lifespan by 1 to 3 years (Pope 2000, as cited in American Lung Association 2008). Increasing PM concentrations will have a measurable adverse impact on human health (Confalonieri *et al.* 2007).

Forest fires contribute to poor air quality conditions. During the 5th largest United States wildfire in 1999, medical visits at the Hoopa Valley National Indian Reservation increased by 52 percent with symptoms affecting lower respiratory tract and preexisting cardiopulmonary conditions (Mott *et al.* 1999). Human health ailments associated with forest fires include burns, smoke inhalation, mortality, eye illnesses, and respiratory illnesses (Confalonieri *et al.* 2007; Ebi *et al.* 2008). Certain regions are anticipated to experience an increase in frequency and intensity of fire events with projected changes in temperature and precipitation. Pollution from forest fires along with other pollutants, such as carbon monoxide, ozone, desert dust, mould spores and pesticides, can be transported thousands of kilometers on time scales of 4 to 6 days affecting populations far from the sources (Gangoiti *et al.* 2001, Stohl *et al.* 2001, Buchanan *et al.* 2002, Chan *et al.* 2002, Martin *et al.* 2002, Ryall *et al.* 2002, Ansmann *et al.* 2003, He *et al.* 2003, Helmis *et al.* 2003, Moore *et al.* 2003, Shinn *et al.* 2003, Unsworth *et al.* 2003, Kato *et al.* 2004, Liang *et al.* 2004, Tu *et al.* 2004, all as cited in Confalonieri *et al.* 2007).

4.5.8.2.5 Water-borne and Food-borne Diseases

Substantial morbidity and childhood mortality has been linked to water- and food-borne diseases. Climate change is projected to alter temperature and the hydrologic cycle through changes in precipitation, evaporation, transpiration, and water storage. These changes, in turn, potentially affect water-borne and food-borne diseases, such as salmonellosis, campylobacter, leptospirosis, and pathogenic species of vibrio. They also have a direct impact on surface water availability and water quality. It has been estimated that over 1 billion people in 2002 did not have access to adequate clean water (McMichael *et al.* 2003, as cited in Epstein *et al.* 2006). Increased temperatures, greater evaporation, and heavy rain events have been associated with adverse impacts on drinking water through increased waterborne diseases, algal blooms, and toxins (Chorus and Bartram 1999, Levin *et al.* 2002, Johnson and Murphy 2004 (all cited in Epstein *et al.* 2006)). In the United States, 68 percent of all waterborne diseases between 1948 and 1994 happened after heavy rainfall events (Curriero *et al.* 2001a, as cited in Epstein *et al.*, 2006). Climate change could further impact a pathogen by directly affecting its life cycle (Ebi *et al.* 2008). The global increase in the frequency, intensity, and duration of red tides could be linked to local impacts already associated with climate change (Harvell *et al.* 1999, as cited in Epstein *et al.* 2006); toxins associated with red tide directly affect the nervous system (Epstein *et al.* 2006).

Many people do not report or seek medical attention for their ailments of water-borne or food-borne diseases; hence, the number of actual cases with these diseases is greater than clinical records demonstrate (Mead et al 1999, as cited in Ebi *et al.* 2008). Many of the gastrointestinal diseases associated with water-borne and food-borne diseases can be self-limiting; however, vulnerable populations include young children, those with a compromised immune system, and the elderly.

4.5.8.2.6 Vector-borne Diseases

Infections can be spread by the bite of an infected arthropod (termed vector-borne), such as mosquitoes, ticks, sandflies, and blackflies, or through non-human vertebrates such as rodents, canids, and other mammals. Such diseases include typhus, malaria, yellow fever, dengue fever, West Nile virus, Western Equine encephalitis, Eastern Equine encephalitis, Bluetongue virus, and lyme disease. Increased insect density has been correlated with milder seasonal variability (Confalonieri *et al.* 2007) and tick distributions tend to expand with higher minimum temperatures (Ebi *et al.* 2008). In general, climate and weather are important constraints on the range of transmission for vector-borne diseases. For example, temperature and flooding are key constraints on the range of mosquitoes, which serve as a primary vector for malaria and other diseases (Epstein *et al.* 2006). Changes in seasonal duration and increases in weather variability reduce/eliminate these constraints (Epstein *et al.* 2006). In southern Mozambique a the number of malaria cases increased four to five times over long-term averages in the days and weeks following a severe flooding event in 2000 (Epstein *et al.* 2006). Temperature and the availability of water can both play key roles in regulating population size as well. For the deer tick, the disease vector for Lyme disease, off-host survival is strongly affected by these two variables, and thus climate is the primary factor determining size and distribution of deer tick populations (Needham and Teel 1991, Bertrand and Wilson 1996, both as cited in Epstein *et al.* 2006). Changes in land use practice or to the habitat and behavior of wildlife hosts of the insect can also impact latitudinal or altitudinal shifts in the disease carrying species (Confalonieri *et al.* 2007).

4.5.8.3 Projected Health Impacts of Climate Change on the United States

Human health is projected to be adversely affected by rising temperatures, increasing ground-level ozone concentrations, changes in extreme weather events, and increasing food and water-borne pathogens. The impact of the varying health-related event is dependent on location. The United States is anticipated to sustain fewer cases of illness and death associated with climate change compared with the developing world (CCSP 2008f). The current health infrastructure along with the United States government's disaster planning and emergency response systems are key assets to enable the United States to meet changing health effect demands associated with climate change. These health impacts will vary in scope across the United States.

In the United States, there have been 20,000 heat and solar-related deaths from 1936 to 1975, with the heat wave of 1980 accounting for over 1,250 deaths (NOAA 2005). There could be a rise in heat-related morbidity and mortality in the coming decades (CCSP 2008f) due, in part, to an aging population. By 2010, 13 percent of the population of the United States is projected to be over the age of 65, and 20 percent by 2030 (Day 1996, as cited in Ebi *et al.* 2008). Studies have shown a decline in heat-related mortality over the past decades, possibly due to increased air conditioning usage and improved health care (Davis *et al.* 2002, Davis *et al.* 2003a, Davis *et al.* 2003b, Carson *et al.* 2006 (all cited in Ebi *et al.* 2008)). Heat waves are anticipated to increase in severity, frequency and duration, particularly in the Midwest and Northeast sections of the country (CCSP 2008f; Frumkin 2008).

The northern latitudes of the United States are likely to experience the greatest increases in average temperature and concentrations of many of the airborne pollutants (CCSP 2008f). In particular, urban centers in the West, Southwest, Mid-Atlantic and Northeast regions are projected to incur the largest increases in average temperatures (Frumkin 2008). A regional climate simulation projected air quality to worsen in Texas but to improve in the Midwest in 2045 to 2055 compared with 1995 to 2005 (Leung and Gustafson 2005, as cited in Ebi *et al.* 2008). In urban areas, ground-level ozone concentrations are anticipated to increase in response to higher temperatures and increases in water vapor concentration (CCSP 2008f; Jacobson 2008). Climate change could further cause stagnant air masses that increase pollution concentrations of ground-level ozone and PM in populated areas. For example, one study projected an increase in the upper Midwest stagnant air between 2000 and 2052 (Mickley *et al.* 2004, as cited in Ebi *et al.* 2008). Further, Frumkin (2008) found that climate change is likely to alter the air pollution contribution from natural sources and increase the creation of secondary pollutants; however, an alternative study found an increase in evaporative losses from nitrate particles reduces PM levels (Aw and Kleeman 2003, as cited in Ebi *et al.* 2008). A recent study concluded that continuous local outdoor CO_2 emissions can increase the respective CO_2 concentration for that area, thereby increasing ozone levels (Jacobson 2008).

The spring pollen season has been shown to begin earlier than usual in the Northern Hemisphere (D'Amato *et al.* 2002, Weber 2002, Beggs 2004 all cited in Confalonieri *et al.* 2007). There is further evidence suggesting a lengthening of the pollen season for some plant species (Confalonieri *et al.* 2007). A recent study determined that the density of air-borne pollen for some species has increased, however, it is not understood what the allergenic content of this additional pollen is (Huynen and Menne 2003, Beggs and Bambrick 2005, both as cited in Confalonieri *et al.* 2007). Additionally, climate change could alter the pollen concentration of a given plant species as the species reacts to increased concentration of CO_2. Current findings demonstrate that ragweed pollen production and the length of the ragweed pollen season increase with rising CO_2 concentrations and temperatures (Wan *et al.* 2002, Wayne *et al.* 2002, Singer *et al.* 2005, Ziska *et al.* 2005, Rogers *et al.* 2006a all cited in Confalonieri *et al.* 2007). Invasive plant species with high allergenic content such as ragweed and poison ivy have been found to be spreading in particular locations around the world, increasing potential health risks (Rybnicek and Jaeger 2001, Huynen and Menne 2003, Taramarcaz *et al.* 2005, Cecchi *et al.* 2006 all cited in Confalonieri *et al.* 2007).

Extreme weather events are likely to be altered by climate change, though there is uncertainty predicting the frequency and severity of events. Some regions in the United States might experience drought conditions due to the reduction in rainfall, while other sections of the country are likely to experience increased frequency of heavy rainfall events, leading to potential flood risk (Frumkin 2008). On the west coast, water quality could be adversely affected as water supplies reduce with decreases in regional precipitation and depletion of mountain snowpacks (Frumkin 2008). It is considered *very likely* (greater than 90 percent certainty) that over the course of this century there will be an increase in the frequency of extreme precipitation (IPCC 2007a). The Southeast, Intermountain West and West are likely to experience an increase in frequency, severity and duration of forest fires (CCSP 2008f, Brown *et al.* 2004, Fried *et al.* 2004 (all cited in Ebi *et al.* 2008)). Impacts to respective vulnerable populations could change in the future as shifts occur in population, suburban development, and community preparedness. It is very likely that a large portion of the projected growth of the United States population will occur in areas considered to be at risk for future extreme weather events (Ebi *et al.* 2008). Hence, even if the rate of health impacts were to decrease, the growth in population in risk areas will still cause an increase in the total number of people affected.

Pathogen transmission depends on many climate-related factors such as temperature, precipitation, humidity, water salinity, extreme weather events, and ecological shifts, and could display seasonal shifts (Ebi *et al.* 2008). Few studies have projected the health impact of vector-borne diseases. Vector-borne illnesses are likely to shift or expand northward and to higher elevations with the possible introduction of new vector-borne diseases (CCSP 2008f, Frumkin 2008), while decreasing the range of tick-borne encephalitis in low latitudes and elevation (Randolph and Rogers 2000, as cited in Ebi *et al.* 2008). Malaria and dengue fever in the United States are unlikely to be affected by climate change variables given the housing quality, land use patterns, and vector control (Frumkin 2008).

Overall, populations within certain regions of the United States regions could experience climate change-induced health impacts from a number of pathways simultaneously. For instance, populations in coastal communities could experience an extreme weather event, such as a tropical cyclone and flooding, adding to health burdens associated with sea-level rise or coastal erosion.

4.5.8.3.1 Adaptation

The United States has a number of organizations and activities that identify and plan for the prevention of adverse health impacts associated with weather and climate although recent experiences following extreme weather and vector-borne disease outbreaks have demonstrated there is a need for improvement (Confalonieri *et al.* 2007, as cited in Ebi *et al.* 2008). The regions where there is an anticipated increase in the health impacts of climate change are very likely to have a greater proportion of poor, elderly, disabled, and uninsured residents. In addition, the American Academy of Pediatrics has determined children are a vulnerable population, recommending the United States government give children particular attention when developing emergency management and disaster response systems (American Academy of Pediatrics 2007; McMichael and Githek 2001; U.S. Department of Health and Human Services 2007, as cited in American Academy of Pediatrics 2007).

The public health sector has divided the activities associated with preventing diseases into one of three classifications: primary, secondary and tertiary. Primary prevention protects the unaffected population from contracting diseases. Secondary prevention focuses on the response action that starts at the onset of a disease. Tertiary prevention deals with an existing disease and focuses on reducing suffering and long-term health difficulties. Primary prevention tends to be the most effective and least costly compared to secondary or tertiary prevention (Ebi *et al.* 2008).

Adaptation policies and measures to address impacts to human health due to climate change should be continually managed as climate change is dynamic. Such adaptation might include the:

- Support and maintenance of the public health infrastructure (Frumkin 2008)
- Improvement and dissemination of preventive care in the public health infrastructure (Frumkin 2008)
- Continued use of nationwide surveillance as a tool to identify, track and map vector-borne diseases (Frumkin 2008)
- Utilization of preparedness tools to identify and assist vulnerable populations during extreme weather events (Frumkin 2008)
- Strengthening of infrastructure to withstand extreme weather events

4.5.8.4 Projected Global Health Impacts of Climate Change

Globally, climate change is anticipated to contribute to both adverse and beneficial health impacts. Projected adverse health impacts include malnutrition leading to disease susceptibility (*high confidence*); increased heat-wave, flood, storm and fire-induced mortality (*high confidence*); decrease in cold-related deaths (*high confidence*); increased diarrheal disease burden (*medium confidence*); increased levels of ground-level ozone (*high confidence*); and altered geographic distribution of some infectious disease vectors (*high confidence*) (Confalonieri *et al.* 2007). A decrease in cold-related mortality and some pollutant-related mortality, increased crop yields in certain areas, and restriction of certain diseases in certain areas (if temperatures or precipitation rises above the critical threshold for vector or parasite survival) are examples of projected beneficial health impacts (Confalonieri *et al.* 2007). The adverse impacts, however, greatly outweigh the beneficial impacts, particularly after the mid-century mark (Confalonieri *et al.* 2007).

Regionally, the impact on human health will vary. Some Asian countries could experience increasing malnutrition by 2030 with crop yields decreasing later in the century, rendering the population in the region particularly vulnerable to malnutrition-associated diseases and disorders (Confalonieri *et al.* 2007). Certain coastal areas will experience flooding by 2030 impacting human mortality (Confalonieri *et al.* 2007). By 2080, lyme disease is projected to have moved northward into Canada, due to a two- to four-fold increase in tick abundance (Confalonieri *et al.* 2007). By 2085, climate change is projected to increase the population at risk to dengue fever to a total of 3.5 billion people (Confalonieri *et al.* 2007).

Heat waves have been experienced globally: thousands of deaths incurred in India over the eighteen heat-waves recorded between 1980 and 1998 (De and Mukhopadhyay 1998, Mohanty and Panda 2003, De *et al.* 2004 all cited in Confalonieri *et al.* 2007). In August 2003, approximately 35,000 deaths were linked to a heat-wave experienced in Europe, with France alone incurring over 14,800 deaths (Hemon and Jougla 2004, Martinez-Navarro *et al.* 2004, Michelozzi *et al.* 2004, Vandentorren *et al.* 2004, Conti *et al.* 2005, Grize *et al.* 2005, Johnson *et al.* 2005 all cited in Confalonieri *et al.* 2007). Around 60 percent of the heat-wave related deaths in France were people at or over 75 years of age (Hemon and Jougla, 2004, as cited in Confalonieri *et al.* 2007). Overall, studies have linked high temperatures to about 0.5-2 percent of annual mortality in the elderly European population (Pattenden *et al.* 2003, Hajat *et al.* 2006, both as cited in Confalonieri *et al.* 2007).

In 2003, floods in China affected 130 million people (EM-DAT 2006, as cited in Confalonieri *et al.*2007). In 1999, storms with floods and landslides in Venezuela killed 30,000 people (Confalonieri *et al.* 2007).

The World Health Organization (WHO) estimates that a high proportion of those in dry regions (approximately 2 billion) experience malnutrition, infant mortality, and water-related diseases (WHO 2005, as cited in Confalonieri *et al.* 2007). Children in low-income countries are particularly vulnerable to loss of life due to diarrhea. The transmission of the enteric pathogen appears to increase during the rainy season for children in the sub-Saharan Africa (Nchito *et al.* 1998, Kang *et al.* 2001, both as cited in Confalonieri *et al.* 2007). In Peru, higher temperatures have been linked to periods of increased diarrhea incidence experienced by adults and children (Checkley *et al.* 2000, Speelmon *et al.* 2000, Checkley *et al.* 2004, Lama *et al.* 2004, all as cited in Confalonieri *et al.* 2007).

Cholera outbreaks associated with floods can occur in areas of poor sanitation. A study in Sea surface temperatures in the Bay of Bengal demonstrated a bimodal seasonal pattern that translated to increased plankton activity leading to increases in cholera in nearby Bangladesh (Colwell 1996, Bouma and Pascual 2001, both cited in Confalonieri *et al.* 2007).

Dengue is considered the most important vector-borne viral disease (Confalonieri *et al.* 2007). A strong correlation exists between climate-based factors such as temperature, rainfall and cloud cover with the observed disease distribution in Colombia, Haiti, Honduras, Indonesia, Thailand and Vietnam (Hopp and Foley 2003, as cited in Confalonieri *et al.* 2007). Favorable climate conditions for dengue exist to about one-third of the world's population (Hales *et al.* 2002, Rogers *et al.* 2006b, both as cited in Confalonieri *et al.* 2007).

Malaria is a vector-borne disease spread by mosquitoes. Depending on location, malaria outbreaks could be influenced by rainfall amounts and sea-surface temperatures in southern Asia, Botswana, and South America (Kovats *et al.* 2003, Thomson *et al.* 2005, DaSilva *et al.* 2004, all as cited in Confalonieri *et al.* 2007). A recent study of malaria in East Africa found that the measurable warming trend the area has experienced since the 1970s can be correlated with the potential of disease transmission. (Pascual *et al.* 2006, as cited in Confalonieri *et al.* 2007) However, southern Africa was not shown to exhibit the same trend (Craig *et al.* 2004, as cited in Confalonieri *et al.* 2007). External factors are also influencing the number of cases of the disease in Africa, such as drug-resistant malaria, and parasite and HIV infection. Studies did not provide clear evidence that malaria in South America or the continental regions of the Russian Federation have been affected by climate change (Benitez *et al.* 2004, Semenov *et al.* 2002, both as cited in Confalonieri *et al.* 2007). In general, however, higher temperatures and more frequent extreme weather occurrences (such as floods and droughts) are predicted to have a stronger influence on the wider spread of malaria with increasing climate change (McMichael *et al.* 1996, as cited in Epstein *et al.* 2006).

Temperature has been shown to affect food-borne and water-borne diseases. Several studies have found increases in salmonellosis cases (food poisoning) within 1 to 6 weeks of the high-temperature peaks (controlled by season). This could be due, in part, to the processing of food products and the population varying its eating habits during warmer months (Fleury *et al.* 2006, Naumova *et al.* 2006, Kovats *et al.* 2004, D'Souza *et al.* 2004, all as cited in Ebi *et al.* 2008). High temperatures have been shown to increase common types of food poisoning (D'Souza *et al.* 2004, Kovats *et al.* 2004, Fleury *et al.* 2006, all as cited in Confalonieri *et al.* 2007). Increasing global temperatures could contribute to a rise in salmonellosis cases (Ebi *et al.* 2008). There is further concern that projected increasing temperatures from climate change will also increase leptospirosis cases, a disease that is resurging in the United States.

The effects of climate change on air quality are expected to adversely impact people suffering from asthma and other respiratory ailments. Increases in temperature, humidity, the prevalence and frequency of wildfires, and other factors are expected to result in more smog, dust, and particulates that exacerbate asthma. Widespread respiratory distress throughout many regions of the world is a possible result of climate change. Current asthma treatment and management plans might be overwhelmed, leading to major increases in asthma-related morbidity and mortality (Epstein *et al.* 2006).

Warm climates are more apt to support the growth of the pathogenic species of Vibrio, leading to shell-fish related death and morbidity that might affect the United States, Japan and South-East Asia (Janda *et al.* 1988, Lipp *et al.* 2002, both as cited in Ebi *et al.* 2008, 2-10; Wittmann and Flick 1995, Tuyet *et al.* 2002, both as cited in Confalonieri *et al.* 2007). If temperatures increase, the geographic range and concentration of the Vibrio species could expand. For example, as the waters of the northern Atlantic have warmed, the concentration of Vibrio species has also (Thompson *et al.* 2004, as cited in Ebi *et al.* 2008). Future ocean warming might also lead to the proliferation of harmful algal blooms, releasing toxins that contaminate shellfish and lead to food-borne diseases (Confalonieri *et al.* 2007). Algal blooms such as red tide can also increase if fecal bacteria concentrations and nutrient loading increases from storm water runoff during heavy precipitation events (Frumkin 2008).

In 2000, WHO estimated that climate change has caused the loss of more than 150,000 lives (Campbell-Lendrum *et al.* 2003, Ezzati *et al.* 2004, McMichael 2004 (as cited in Confalonieri *et al.* 2007)). The projected risks in 2030 described by the WHO study vary by health outcome and region; most of the increase in disease is due to diarrhea and malnutrition. More cases of malaria are predicted in those countries that are situated at the edge of the current distribution. The projected health impact associated with malaria is mixed, with some regions demonstrating increased burden and others exhibiting decreased burden.

4.5.8.4.1 Adaptation

Climate change is considered to pose a risk to the health of both the United States and global populations (Ebi *et al.* 2008). Developed societies such as the United States are more likely to implement effective adaptation measures reducing the magnitude of severe health impacts. For example, the risk and impact of floods on a population can be reduced with changes in water management practices, improved infrastructure, and land use practices (EEA 2005, as cited in Confalonieri *et al.* 2007). Unblocking drains also helps to reduce the transmission of enteric pathogens (Parkinson and Butler 2005, as cited in Confalonieri *et al.* 2007). However, improvements world-wide in adaptive capacity are needed (*high confidence*; Confalonieri *et al.* 2007). Many governments have increased their efforts to cope with extreme climate events moving from disaster relief to risk management. Efforts in Portugal, Spain, France, UK, Italy and Hungary focus on short-term events such as heat waves (Pascal *et al.* 2006, Simón *et al.* 2005, Nogueira 2005, Michelozzi *et al.* 2005, NHS 2006, Kosatsky and Menne 2005, all as cited in Confalonieri *et al.* 2007) while other efforts have undertaken long-term strategies addressing policies for agriculture, energy, forestry and transport (Confalonieri *et al.* 2007).

4.6 ENVIRONMENTAL JUSTICE

4.6.1 Affected Environment

Executive Order (EO) 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations*, directs federal agencies to "promote nondiscrimination in federal programs substantially affecting human health and the environment, and provide minority and low income communities access to public information on, and an opportunity for public participation in, matters relating to human health or the environment." EO 12898 also directs agencies to identify and consider disproportionately high and adverse human health or environmental effects of their actions on minority and low-income communities, and provide opportunities for community input in the NEPA process, including input on potential effects and mitigation measures. CEQ, the entity responsible for compliance with EO 12898, has provided agencies with general guidance on how to meet the requirements of the EO as it relates to NEPA in *Environmental Justice Guidance Under the National Environmental Policy Act*. This guidance document also defines the terms "minority" and "low-income community" in the context of environmental justice analysis. Members of a minority are defined as: American Indians or Alaskan Natives, Asian or Pacific Islanders, Blacks, and Hispanics. Low-income communities are defined as those below the poverty thresholds from the U.S. Census Bureau.

In compliance with EO 12898, NHTSA provides in this FEIS a qualitative analysis of the cumulative effects of the proposed action with climate change and other identified relevant actions on these populations.

Environmental justice populations tend to be concentrated in areas with a higher risk of climate-related impacts. USCCSP notes that this geographic placement might put these communities at higher risk, "from climate variability and climate-related extreme events such as heat waves, hurricanes, and tropical and riverine flooding" (CCSP 2008f).

4.6.2 Environmental Consequences

4.6.2.1 Non-climate Change Effects

With consideration of the reasonably foreseeable increase in CAFE standards for MY 2016-2020, the minimum threshold for which has already been established by Congress as 35 mpg, a further decrease in oil consumption and production is predicted. These changes would further the trends affecting environmental justice populations described in Section 3.5.

NHTSA predicts that oil refining would decrease as a result of the reductions predicted to result from the MY 2011-2015 CAFE standards, which could cause a decrease in related air pollutant discharges and a local improvement in air quality for residents near oil refineries. This improvement could represent a small positive impact on environmental justice populations near these facilities.

All six criteria air pollutants regulated by EPA under the Clean Air Act and all but one of vehicle emission toxic air pollutants would decrease overall with adoption of any of the action alternatives and the foreseeable MY 2011-2015 standards (see Section 4.3). However, increases in VMT due to the rebound effect are still projected to cause increases in some criteria and toxic air pollutants in some air quality nonattainment areas. The large size of each nonattainment area, the uniform distribution of increases in VMT, and the minor emissions increases in affected nonattainment and other areas make it unlikely that there would be disproportionate effects to environmental justice populations.

4.6.2.2 Effects of Climate Change in the United States

Environmental justice populations in the United States, as defined by EO 12898, would experience the same general impacts as a result of global climate change felt by the U.S. population as a whole and described in Sections 4.5.6, Food, Fiber, and Forest Products; 4.5.7, Industries, Settlements, and Society; and 4.5.8, Human Health. However, the USCCCP notes that the general climate change impacts to the U.S. population might be differentially experienced by environmental justice populations, explaining that "[e]conomic disadvantage, lower human capital, limited access to social and political resources, and residential choices are social and economic reasons that contribute to observed differences in disaster vulnerability by race/ethnicity and economic status" (CCSP 2008f). A general description of the potential impacts of climate change on the population of the United States is provided below. These impacts are similar to those that would be experienced globally, although the severity of impacts experienced by developing countries would likely be disproportionately larger than those experienced in developed nations, such as the United States. The most likely anthropogenic climate change impacts include:

- *Human Health* – increased mortality and morbidity due to excessive heat, increases in respiratory conditions due to poor air quality, increases in water- and food-borne diseases and changes to the seasonal patterns of vector-borne diseases, increases in malnutrition (*see* Section 4.5.7 for details)

- *Services* – disruption of ability to transport goods and services, shifts in the location of certain crops, disaster-related damage to transportation infrastructure (roads, rail, ports), tourism location shifts, insurance premium increases (*see* Section 4.5.6 for details)

- *Utilities and Infrastructure* – more frequent droughts and increases in demand for irrigation or drinking water, flood-related impacts on sewage systems with potential water quality impacts, and disaster-related damage to transportation, power, and communications systems (*see* Section 4.5.6 for details)

- *Human Settlement* – synergistic effects with existing resource scarcities (energy and water), inundation of inhabited coastal areas due to sea-level rise, urban temperature increases (*see* Section 4.5.6 for details)

- *Social Issues* – increased stress on public services and disruptions to traditional cultures (*see* Section 4.5.6 for details)

- *Agriculture* – changes in crop yields, more intense droughts and floods, changes in the length of growing seasons (*see* Section 4.5.6 for details)

- *Forest and Ecosystem Services* – increased risk of forest fires, redistribution and extinction of economically or culturally important wildlife species, expanded ranges for pests and invasive species (*see* Section 4.5.6 for details)

Environmental justice populations would likely be disproportionately affected by some of these potential impacts. The rest of this section discusses, qualitatively, the most substantial areas of potential disproportionate impact for these populations in the United States.

4.6.2.2.1 Human Health

Low-income and minority communities exposed to the direct effects of extremes in climatic conditions might also experience synergistic effects with pre-existing health risk factors, such as limited availability of preventative medical care and inadequate nutrition (CCSP 2008f).

As stated in Section 4.5.7, increases in heat-related morbidity and mortality as a result of higher overall and extreme temperatures is likely to disproportionately affect minority and low-income populations, partially as a result of limited access to air conditioning and high energy costs (CCSP 2008f, O'Neill *et al.* 2005a). Urban areas, which often have relatively large environmental justice populations, would likely experience the most substantial temperature increase due to the urban "heat island" effect and could be particularly vulnerable to this type of health impact (CCSP 2008f, Knowlton *et al.* 2007).

Increasing temperatures could also lead to expanded ranges for a number of diseases (CCSP 2008f). As described in Section 4.5.8, the number and severity of outbreaks for vector-borne illnesses, such as the West Nile Virus, could become more frequent and severe. Because the vectors of these diseases (such as mosquitoes) are more likely to come into contact with environmental justice populations, disproportionate impacts might occur. For example, an outbreak of the mosquito-borne dengue fever in Texas primarily affected low-income Mexican immigrants living in lower quality housing without air conditioning, leading a team researching the outbreak to conclude that the low prevalence of dengue in the United States is primarily due to economic, rather than climatic, factors (Reiter *et al.* 2003).

4.6.2.2.2 Land Use

In the United States, two primary types of geographical environmental justice communities are likely to be affected by global climate change: urban areas, because of their relatively high concentrations of low-income and minority residents, and indigenous communities. Environmental justice communities in urban areas, because of previously mentioned heat exposure and health issues, are likely to experience climate change impacts more acutely. Additionally, environmental justice populations in coastal urban areas (vulnerable to increases in flooding as a result of projected sea-level rise, larger storm surges, and human settlement in floodplains) are less likely to have the means to quickly evacuate in the event of a natural disaster (CCSP 2008f, National Science and Technology Council 2008). USCCSP, as an example, notes that flooding in Louisiana following the 2005 Hurricane Katrina primarily killed poor and elderly residents having no means to flee (National Science and Technology Council 2008). As stated in Section 4.5.7, indigenous communities in the United States, particularly Alaska, could face major impacts on their subsistence economies from climate change. These impacts would result from their partial reliance on arctic animals, such as seals and caribou, for food and the potential destruction of transportation infrastructure due to ground thaw.

In coastal and floodplain areas prone to flooding because of larger storm surges and generally more extreme weather, increases in flood insurance premiums could disproportionately affect environmental justice populations unable to absorb the additional cost. Lack of sufficient insurance coverage might render these populations more financially vulnerable to severe weather events.

Potential food insecurity as a result of global climate change, particularly among low-income populations in the United States and abroad, is an often mentioned concern (Wilbanks *et al.* 2007, CCSP 2008f). Climate change is likely to affect agriculture by changing the growing season, limiting rainfall and water availability, or increasing the prevalence of agricultural pests (*see* Section 4.5.6 for more information). In the United States, the most vulnerable segment of the population to food insecurity is likely to be low-income children (Cook and Frank 2007, as cited in CCSP 2008f).

4.7 NON-CLIMATE CUMULATIVE IMPACTS OF CO_2

4.7.1 Affected Environment

In addition to its role as a GHG in the atmosphere, CO_2 is exchanged from the air to water, plants, and soil. CO_2 dissolves easily in water and more easily in salt water such as oceans. In water, CO_2 combines with water molecules to form carbonic acid. The amount of CO_2 dissolved in oceans is related to its concentrations in the air. This process reduces the amount of CO_2 in the atmosphere as a GHG, but also increases the acidity of the ocean. Increasing levels of CO_2 are having a global effect on the oceans. By 2100, ocean pH could drop 0.5 units from pH levels of the 1900s (Hall-Spencer *et al.* 2008).

Plants remove CO_2 from the air through photosynthesis and use the carbon for plant growth. This uptake by plants can influence annual fluctuations of CO_2 on the order of 3 percent from growing season to non-growing season (Schneider and Londer 1984, as cited in Perry 1994). Increased levels of CO_2 essentially act as a fertilizer influencing normal annual plant growth.

In addition, CO_2 concentrations affect soil microorganisms. Only recently have the relationships between above-ground ecosystems and below-ground components of ecosystems been considered significant; there is increasing awareness of the fact that feedbacks between the above-ground/below-ground components play a fundamental role in controlling ecosystems processes. For example, the organic carbon required for below-ground decomposition is provided by plants. Plants also provide the resources for root-associated microorganisms (Wardle *et al.* 2004). The "decomposer subsystem in turn breaks down dead plant material and indirectly regulates plant growth and community composition by determining the supply of available root nutrients" (Wardle *et al.* 2004).

Specific plant species, depending on the quantity and quality of resources provided to below-ground components, might have greater impacts on soil biota and the processes regulated by those biota than do other plants. Variation in the quality of forest litter produced by co-existing species of trees, for instance, "explains the patchy distribution of soil organisms and process rates that result from 'single tree' effects" (Wardle *et al.* 2004). The composition of plant communities has a consistent and substantial impact on the composition of root-associated microbes; however, the effects of plant community composition on decomposer systems are apparently context-dependent. In one example cited, manipulating the composition of plant communities in five sites in Europe produced distinctive effects on decomposer microbes, while root-related soil microbes experienced no clear effect (Wardle *et al.* 2004).

The amount of carbon stored in soils of temperate and boreal forests is about four times greater than the carbon that is stored by vegetation and is "33 percent higher than total carbon storage in tropical forests" (Heath *et al.* 2005). Terrestrial communities contain as much carbon as the atmosphere. Forest soils are also the longest-lived carbon pools in terrestrial ecosystems (King *et al.* 2004). Several experiments involving increases of atmospheric CO_2 resulted in increasing carbon mass in trees, but a reduction of carbon sequestration in soils. This is associated with increasing soil microorganism respiration (Heath *et al.* 2005, Black 2008); respiration is associated with "root herbivory, predation, consumption of root exudates, and the decomposition of root and leaf litter" (King *et al.* 2004). In future real-world scenarios, however, the reduction of soil carbon via increased soil respiration could be countered by an increase in litter on the forest floor.

4.7.2 Environmental Consequences

4.7.2.1 Ocean Acidification

One of the large-scale non-climatic effects of an increase in CO_2 emissions is the potential for ocean acidification. The ocean exchanges huge quantities of CO_2 with the atmosphere, and when atmospheric concentrations rise (due to anthropogenic emissions), there is a net flux from the atmosphere to the oceans. This lowers the pH of the oceans (the water becomes more acidic), which reduces the ability of shell-forming organisms to produce their shells. Most shells are made of calcium carbonate, which dissolves under acidic conditions (Hall-Spencer *et al.* 2008, Kleypas *et al.* 2006). According to Kleypas *et al.* (2006), under increasing atmospheric CO_2, "A variety of evidence indicates that calcification rates will decrease, and carbonate dissolution rates increase, as $CaCO_3$ (calcium carbonate) saturation state decreases." Studies have also shown that long-term ocean acidification, such as a pH drop of 0.7 units, has negative effects on fish through reduction in metabolic rates, reproductive dysfunction, growth reduction and survivorship reduction (Michaelidis *et al.* 2005, Shirayama and Thronton 2005, Pane and Barry 2007, all as cited in Keller *et al.* 2008).

In conjunction with rapid climate change, ocean acidification could pose severe threats to coral reef ecosystems. Reef building and reef dissolution are always occurring, but dissolution of coral reefs is expected to increase, and surpass reef building, as anthropogenic CO_2 in the atmosphere increases. If the water column above reefs becomes saturated with the CO_2 from the atmosphere, the water could be less able to hold the CO_2 respired by microorganisms in the reef environment. Although the interactions are complex and difficult to project, a possible scenario is that the excess CO_2 in the reef environment could prevent reef-building. Thresholds for calcium carbonate dissolution exceeding calcification varies for different reef systems (Kleypas *et al.* 2006).

A recent study found that one-third of the 704 zooxanthellate reef-building coral species assessed are at risk of extinction (Carpenter *et al.* 2008). This number has increased dramatically in recent decades due to bleaching and diseases driven by elevated sea surface temperatures. Because NHTSA cannot quantify the impacts of this rulemaking action on threatened species or critical habitat, a Section 7 consultation is not possible. NHTSA discussed this issue with the U.S. Fish and Wildlife Service as part of the development of the FEIS.

4.7.2.2 Plant Growth and Soil Microorganisms

In contrast to its potential adverse effect on the productivity of marine ecosystems, higher CO_2 concentrations in the atmosphere could increase the productivity of terrestrial systems. Plants use CO_2 as an input to photosynthesis. The IPCC Fourth Assessment Report (IPCC 2007a) states that "On physiological grounds, almost all models predict stimulation of carbon assimilation and sequestration in response to rising CO_2, referred to as 'CO_2 fertilization'" (Denman *et al.* 2007).

Under bench-scale and field-scale experimental conditions, several investigators have found that higher concentrations have a fertilizing effect on plant growth (*e.g.,* Long *et al.* 2006, Schimel *et al.* 2000). IPCC reviewed and synthesized field and chamber studies, finding that:

> There is a large range of responses, with woody plants consistently showing net primary productivity (NPP) increases of 23 to 25 percent (Norby *et al.* 2005), but much smaller increases for grain crops (Ainsworth and Long 2005). Overall, about two-thirds of the experiments show positive response to increased CO_2 (Ainsworth and Long 2005, Luo *et al.* 2005). Since saturation of CO_2 stimulation due to nutrient or other limitations is

common (Dukes *et al.* 2005, Köerner *et al.* 2005), the magnitude, and effect of the CO_2 fertilization is not yet clear.

The CO_2 fertilization effect could mitigate some of the increase in atmospheric CO_2 concentrations by resulting in more storage of carbon in biota.

The current annual exchange in CO_2 between the atmosphere and terrestrial ecosystems is estimated at nine to ten times greater than annual emissions produced as a result of burning fossil fuels. Even a small shift in the magnitude of this exchange could have a measurable impact on atmospheric CO_2 concentration (Heath *et al.* 2005). The above-ground/below-ground processes and components in terrestrial ecosystems typically sequester carbon. Studies are now confirming that variations in atmospheric CO_2 have impacts not only on the above-ground plant components, but also on the below-ground microbial components of these systems.

In one study, CO_2 levels were artificially elevated in a forest for the purpose of studying the effect of atmospheric CO_2 on soil communities. An *indirect* impact of the increased CO_2 was that distinct changes in the composition of soil microbe communities occurred as a result of increased plant detritus (BNL 2007, Science Daily 2007). In another study, an increase in CO_2 *directly* resulted in increased soil microbial respiration. However, after 4 to 5 years of increased exposure to CO_2, "the degree of stimulation declined" to only a 10- to 20-percent increase in respiration over the base rate (King *et al.* 2004). Additionally, the degree of stimulation was linked to variability in seasonal and interannual weather (King *et al.* 2004).

The increase in microbe respiration could, therefore, diminish the carbon sequestration role of terrestrial ecosystems. Upon reaching a certain level of CO_2 in the atmosphere, carbon sinks in soils could become net carbon emitters (Heath *et al.* 2005, Black 2008). Because of the number of factors involved in determining soil respiration and carbon sequestration, the threshold for substantial changes in these activities varies spatially and temporally (King *et al.* 2004).

As with the climatic effects of CO_2, the changes in non-climatic impacts associated with the alternatives is difficult to assess quantitatively. In the Reference Case, atmospheric CO_2 concentrations increase from current levels of about 380 ppm to as much as 800 ppm in 2100 (Kleypas *et al.* 2006). Whether the distinction in concentrations is substantial across alternatives is not clear because the damage functions and potential existence of thresholds for CO_2 concentration are not known. However, what is clear is that a reduction in the rate of increase in atmospheric CO_2 would reduce the ocean acidification effect and the CO_2 fertilization effect.

Chapter 5 Mitigation

Council on Environmental Quality (CEQ) regulations for implementing the procedural requirements of the National Environmental Policy Act (NEPA) require that the discussion of alternatives in an Environmental Impact Statement (EIS) "[i]nclude appropriate mitigation measures not already included in the proposed action or alternatives" (40 CFR § 1502.14(f)). In particular, an EIS must discuss the "[m]eans to mitigate adverse environmental impacts" (40 CFR § 1502.16(h)). As defined in the CEQ regulations (40 CFR § 1508.20), mitigation includes:

(a) Avoiding the impact altogether by not taking a certain action or parts of an action.

(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

(e) Compensating for the impact by replacing or providing substitute resources or environments.

The National Highway Traffic Safety Administration's (NHTSA's) proposed action is to implement Corporate Average Fuel Economy (CAFE) standards for model years (MY) 2011-2015, as required by the Energy Independence and Security Act of 2007 (EISA). The cumulative impacts analysis (*see* Chapter 4) considers the implementation of CAFE standards for MY 2011-2015 and for MY 2016-2020.[1] Under Alternative 1, No Action, NHTSA would take no action to implement the MY 2011-2015 CAFE standards. The No Action Alternative assumes that average fuel economy levels in the absence of CAFE standards beyond 2010 would equal the higher of a manufacturer's product plans or the manufacturer's required level of average fuel economy for MY 2010. Compared to the No Action Alternative, each of the six action alternatives (Alternatives 2 through 7) would result in a decrease in carbon dioxide (CO_2) emissions and associated climate-change effects, and a decrease in energy consumption. This is true regardless of the Input Scenario employed (Reference Case and Mid-1, Mid-2 and High Scenarios).

Under the No Action Alternative, CO_2 emissions and energy consumption would continue to increase; by reducing these increases, as would occur under any of the six action alternatives, the CAFE standards will have a beneficial effect that does not require mitigation.

Emissions from criteria air pollutants and mobile source air toxics (MSATs) are generally anticipated to decline as well. According to the analyses described in Sections 3.3 and 4.3, some emissions would increase under some alternatives and for some analysis years, while most demonstrate uniform declines. Health costs and impacts are estimated to be reduced under all alternatives for the Reference Case and the High Scenario as a first approximation.

Oxides of nitrogen (NO_x), particulate matter ($PM_{2.5}$), oxides of sulfur (SO_x), volatile organic compounds (VOCs), benzene, 1,3-butadiene, and diesel particulate matter (DPM) exhibit decreases in emissions for all alternatives and input scenarios and for all analysis years under both the Reference Case and the High Scenario. Therefore, any negative health impacts associated with these emissions are similarly expected to be reduced, and no mitigation would be required.

[1] Although NHTSA will set CAFE standards for MY 2016-2020 in a future rulemaking, this NEPA analysis makes assumptions about the MY 2016-2020 standards based on the MY 2011-2015 standards and EISA requirements.

According to NHTSA's analysis, emissions of carbon monoxide (CO), acetaldehyde, acrolein, and formaldehyde could increase under certain alternatives or input scenarios, which requires further examination regarding the need for mitigation. Note that NEPA does not require that an agency adopt mitigation measures. The potential for harm depends on the selection of the final standards, the magnitude of the increases, and other factors. In all cases, the increases are approximately 1 percent or less over the No Action Alternative.

The analysis for acrolein emissions is incomplete because upstream emissions factors are not available. Upstream emissions demonstrate decreases due to fuel savings and reduced emissions from fuel refining and transportation. If upstream emissions of acrolein were included in the analysis, total acrolein emissions would show smaller increases or might decrease. Thus, the acrolein emissions reported in the FEIS represent an upper bound.

It should be noted that even if CO emissions show some level of increase, the associated harm might not increase concomitantly. There have been no violations of the CO standards for several years after a long downward trend, owing to the success of regulations governing fuel composition and vehicle emissions.

Two further considerations are relevant to these potential emissions increases. First, the choice of technologies to meet new CAFE standards is left to the vehicle manufacturers. Some of their choices have higher or lower impacts for these emissions. Second, EPA regulates these emissions under the Clean Air Act, which could result in future reductions as EPA promulgates new regulations. Nevertheless, there is the potential that some air pollutant emissions will increase in some years for some alternatives.

Beyond these considerations at the national level, there could also be localized increases in criteria and toxic air pollutant emissions in some nonattainment areas as a result of implementation of the CAFE standards under the action alternatives. These localized increases would represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act standards.

Federal transportation funds administered by the Federal Highway Administration (FHWA) might be available to assist in funding projects to reduce any increases. FHWA provides funding to states and localities specifically to improve air quality under the Congestion Mitigation and Air Quality Improvement (CMAQ) Program. FHWA and FTA also provide funding to states and localities under other programs that have multiple objectives including air quality improvement. As state and local agencies recognize the need to reduce emissions of CO, acetaldehyde, acrolein, or formaldehyde – or other emissions eligible under the CMAQ Program, including the criteria pollutants and MSATs analyzed for this FEIS – they have the ability to apply CMAQ funding to reduce impacts in most areas. Further, the EPA has the authority to continue to improve vehicle emissions standards.

Chapter 6 Unavoidable Adverse Impacts; Short-term Uses and Long-term Productivity; Irreversible and Irretrievable Commitment of Resources

6.1 UNAVOIDABLE ADVERSE IMPACTS

The National Highway Traffic Safety Administration (NHTSA) proposed action is to implement Corporate Average Fuel Economy (CAFE) standards for model years (MY) 2011-2015. The cumulative impacts analysis (*see* Chapter 4) considers implementation of CAFE standards for MY 2011-2015 and implementation of CAFE standards for MY 2016-2020.[1] Under Alternative 1 (No Action), NHTSA would not take action to implement the MY 2011-2015 CAFE standards. The six action alternatives (Alternatives 2 through 7) would result in a decrease in carbon dioxide (CO_2) emissions and associated climate change effects and a decrease in energy consumption as compared to the No Action Alternative.

Based on NHTSA's current understanding of global climate change, certain effects are likely to occur due to total greenhouse gas (GHG) emissions to the atmosphere. Neither the proposed action nor its alternatives would prevent these effects. As described in Sections 4.4 and 4.5, the action alternatives could diminish the effects of climate change and contribute to global GHG reductions.

Oxides of nitrogen (NO_x), particulate matter ($PM_{2.5}$), oxides of sulfur (SO_x), volatile organic compounds (VOCs), benzene, 1,3-butadiene, and diesel particulate matter (DPM) exhibit decreases in emissions for all alternatives and input scenarios and for all analysis years under both the Reference Case and the High Scenario. Any negative health impacts associated with these emissions are expected to be similarly reduced, and there would be no unavoidable negative impacts of these emissions.

According to NHTSA's analysis, emissions of carbon monoxide (CO), acetaldehyde, acrolein, and formaldehyde could increase under certain alternatives or input scenarios. Thus, the potential for unavoidable impacts depends on the selection of the final standards. In all cases, the increases are approximately 1 percent or less over the No Action Alternative. In addition, as noted in Chapter 5, the acrolein emissions reported in the FEIS represent an upper bound, and thus potential unavoidable impacts of acrolein emissions might be less.

Localized increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the CAFE standards under the action alternatives, largely due to increases in vehicle miles traveled. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act standards.

6.2 THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The six action alternatives (Alternatives 2 through 7) would result in a decrease in energy (crude oil) consumption and reductions in CO_2 emissions and associated climate change impacts compared to those of Alternative 1, No Action. Manufacturers would need to apply various technologies to the production of passenger cars and light trucks to meet the MY 2011-2015 CAFE standards under the six

[1] Although NHTSA will set CAFE standards for MY 2016-2020 in a future rulemaking action, NHTSA's National Environmental Policy Act analysis makes assumptions about the MY 2016-2020 standards based on the MY 2011-2015 standards and the EISA requirements.

action alternatives. NHTSA cannot predict which specific technologies manufacturers would apply to meet the CAFE standards under any of the six action alternatives; however, existing technologies and existing vehicle production facilities can be applied to meet the standards under the six action alternatives. Some vehicle manufacturers might need to commit additional resources to existing, redeveloped, or new production facilities to meet the CAFE standards. Such short-term uses of resources by vehicle manufacturers to meet the CAFE standards would enable the long-term reduction of national energy consumption and would enhance long-term national productivity.

6.3 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES UNDER THE ACTION ALTERNATIVES

Energy consumption in the United States would decrease under all the action alternatives compared to the No Action Alternative. Tables 3.2-2 and 3.2-3 (*see* Section 3.2 of this FEIS) summarize fuel consumption for the Reference Case under each alternative for passenger cars and light trucks, respectively, and Tables 3.2-4 and 3.2-5 summarize fuel consumption for the High Scenario under each alternative for passenger cars and light trucks, respectively. For the Optimized Alternative (Alternative 3) the Reference Case fuel savings[2] over the No Action Alternative in 2060 would be 4.3 billion gallons for passenger cars and another 4.3 billion gallons for light trucks. The Optimized Alternative High Scenario fuel savings over the No Action Alternative in 2060 would be 9.6 billion gallons for passenger cars and 11.0 billion gallons for light trucks.

As discussed in Section 6.2, manufacturers would need to apply various technologies to the production of passenger cars and light trucks to meet the MY 2011-2015 CAFE standards under the six action alternatives. NHTSA cannot predict which specific technologies manufacturers would apply to meet the CAFE standards under any of the six action alternatives. Existing technologies and existing vehicle production facilities can be applied to meet the CAFE standards under the six action alternatives. However, some vehicle manufacturers might need to commit additional resources to existing, redeveloped, or new production facilities to meet the standards. The specific amounts and types of irretrievable resources (such as electricity and other energy consumption) manufacturers would expend in meeting the CAFE standards would depend on the specific methods and technologies manufacturers choose to implement. Commitment of resources for manufacturers to comply with the CAFE standards would tend to be offset by the fuel savings from implementing the standards.

[2] Fuel savings are expressed as the sum of the number of gallons of diesel fuel and gasoline without adjustment for the energy content per gallon of each fuel.

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Chapter 9 Distribution List

National Environmental Policy Act implementing regulations (40 Code of Federal Regulations 1501.19) specify requirements for circulating an Environmental Impact Statement (EIS). In accordance with those requirements, the National Highway Transportation Safety Administration is mailing this Final EIS to the agencies, officials, and other interested persons listed in this chapter.

9.1 FEDERAL AGENCIES

- Advisory Council on Historic Preservation
- Centers for Disease Control and Prevention
- Council on Environmental Quality
- Delaware River Basin Commission
- Denali Commission
- Environmental Protection Agency
- International Boundary and Water Commission, Environmental Management Division
- Marine Mammal Commission
- National Capital Planning Commission, Office of Urban Design and Plan Review
- National Oceanic and Atmospheric Administration
- National Park Service
- National Science Foundation, Office of General Counsel
- Office of Science and Technology Policy, National Science and Technology Council
- Presidio Trust
- Susquehanna River Basin Commission
- Tennessee Valley Authority
- U.S. Agency for International Development, Bureau for Economic Growth, Agriculture and Trade
- U.S. Department of Agriculture, Agricultural Research Service
- U.S. Department of Agriculture, Animal and Plant health Inspection Service
- U.S. Department of Agriculture, Cooperative State Research, Education and Extension Service
- U.S. Department of Agriculture, Farm Service Agency
- U.S. Department of Agriculture, Natural Resources Conservation Service
- U.S. Department of Agriculture, Rural Business-Cooperative Service
- U.S. Department of Agriculture, Rural Housing Service
- U.S. Department of Agriculture, Rural Utilities Service
- U.S. Department of Agriculture, U.S. Forest Service
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration
- U.S. Department of Commerce, Economic Development Administration
- U.S. Department of Commerce, National Marine Fisheries Service
- U.S. Department of Defense
- U.S. Department of Defense, Army Corps of Engineers
- U.S. Department of Energy, Office of NEPA Policy and Compliance
- U.S. Department of Energy, Office of Climate Change Policy
- U.S. Department of Health and Human Services, Office of the Secretary
- U.S. Department of Health and Human Services, Centers for Disease Control and Prevention
- U.S. Department of Health and Human Services, Food and Drug Administration (FDA)
- U.S. Department of Health and Human Services, FDA, Center for Food Safety and Applied Nutrition

- U.S. Department of Health and Human Services, Health Resources and Services Administration
- U.S. Department of Health and Human Services, Indian Health Service
- U.S. Department of Health and Human Services, National Institutes of Health
- U.S. Department of Homeland Security, Office of Safety and Environment
- U.S. Department of Homeland Security, Federal Emergency Management Agency
- U.S. Department of Homeland Security, U.S. Coast Guard
- U.S. Department of Housing and Urban Development
- U.S. Department of Interior, Office of Environmental Policy and Compliance
- U.S. Department of Justice, Environment and Natural Resources Division
- U.S. Department of Labor, Mine Safety and Health Administration
- U.S. Department of Labor, Occupational Safety and Health Administration
- U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs
- U.S. Department of Transportation, Secretary for Policy
- U.S. Department of Transportation, Federal Aviation Administration
- U.S. Department of Transportation, Federal Highway Administration
- U.S. Department of Transportation, Federal Motor Carrier Safety Administration
- U.S. Department of Transportation, Federal Railroad Administration
- U.S. Department of Transportation, Maritime Administration
- U.S. Department of Transportation, Federal Transit Administration
- U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration
- U.S. Department of Transportation, Research and Innovative Technology Administration
- U.S. Department of Transportation, Saint Lawrence Seaway Development Corporation
- U.S. Department of Transportation, Surface Transportation Board
- U.S. Environmental Protection Agency, Office of Federal Activities
- U.S. Environmental Protection Agency, NEPA Compliance Division
- U.S. Federal Energy Regulatory Commission, Office of Energy Projects
- U.S. Federal Energy Regulatory Commission, Division of Hydropower, Environment and Engineering
- U.S. Federal Energy Regulatory Commission, Division of Gas – Environmental and Engineering
- U.S. Federal Transit Administration
- U.S. Fish and Wildlife Service
- U.S. Forest Service
- U.S. Institute for Environmental Conflict Resolution
- Valles Caldera Trust

9.2 STATE AGENCIES

- Alabama Department of Environmental Management
- California Office of Attorney General
- Connecticut Office of Attorney General
- Florida Department of Environmental Protection
- Florida Department of Transportation
- Florida Energy Office
- Hawaii Department of Transportation
- Maryland Department of the Environment
- Maryland Historical Trust
- Massachusetts Office of Attorney General
- Minnesota Pollution Control Agency

- Missouri Department of Natural Resources
- Montana Department of Transportation
- New Jersey Department of Environmental Protection
- New Jersey Office of Attorney General
- New Mexico Department of Attorney General
- New York City Corporation Council
- New York State Department of Transportation
- New York State Environmental Law Division
- New York State Office of Attorney General
- Nevada Department of Transportation
- Nevada Division of Environmental Protection
- Oregon Department of Attorney General
- Oregon Department of Environmental Quality
- Pennsylvania Department of Environmental Protection
- Rhode Island Department of Attorney General
- Rhode Island Department of Environmental Management
- South Carolina Department of Transportation
- South Dakota Department of Environmental & Natural Resources
- Tennessee Department of Transportation
- Vermont Agency of Natural Resources
- Vermont Office of Attorney General
- Washington State Department of Ecology
- Washington State Department of Transportation

9.3 ELECTED OFFICIALS

- The Honorable Sarah Palin, Governor of Alaska
- The Honorable Togiola T.A. Tulafono, Governor of American Samoa
- The Honorable Janet Napolitano, Governor of Arizona
- The Honorable Mike Beebe, Governor of Arkansas
- The Honorable Bill Ritter, Governor of Colorado
- The Honorable Ruth Ann Minner, Governor of Delaware
- The Honorable Sonny Perdue, Governor of Georgia
- The Honorable Felix P. Camacho, Governor of Guam
- The Honorable C.L. “Butch” Otter, Governor of Idaho
- The Honorable Rod R. Blagojevich, Governor of Illinois
- The Honorable Mitchell E. Daniels, Governor of Indiana
- The Honorable Chet Culver, Governor of Iowa
- The Honorable Kathleen Sebelius, Governor of Kansas
- The Honorable Steve Beshear, Governor of Kentucky
- The Honorable Bobby Jindal, Governor of Louisiana
- The Honorable John E. Baldacci, Governor of Maine
- The Honorable Martin O’Malley, Governor of Maryland
- The Honorable Jennifer M. Granholm, Governor of Michigan
- The Honorable Tim Pawlenty, Governor of Minnesota
- The Honorable Haley Barbour, Governor of Mississippi
- The Honorable Dave Heineman, Governor of Nebraska
- The Honorable John Lynch, Governor of New Hampshire
- The Honorable Bill Richardson, Governor of New Mexico
- The Honorable Michael F. Easley, Governor of North Carolina
- The Honorable John Hoeven, Governor of North Dakota

- The Honorable Benigno R. Fitial, Governor of the Commonwealth of the Northern Mariana Islands
- The Honorable Ted Strickland, Governor of Ohio
- The Honorable Brad Henry, Governor of Oklahoma
- The Honorable Edward G. Rendell, Governor of Pennsylvania
- The Honorable Aníbal Acevedo-Vilá, Governor of Puerto Rico
- The Honorable Rick Perry, Governor of Texas
- The Honorable Jon Huntsman, Jr., Governor of Utah
- The Honorable John P. deJongh, Jr., Governor of the United States Virgin Islands
- The Honorable Timothy M. Kaine, Governor of Virginia
- The Honorable Joe Manchin III, Governor of West Virginia
- The Honorable Jim Doyle, Governor of Wisconsin
- The Honorable Dave Freudenthal, Governor of Wyoming

9.4 NATIVE AMERICAN TRIBES

- Atmautlauk Traditional Council
- Big Pine Paiute Tribe of the Owens Valley
- Bois Forte Band of Chippewa
- Buckland Fuel Project
- Chalkyitsik Village Council
- Chickasaw Nation
- Enterprise Rancheria
- Flandreau Santee Sioux Tribe
- Fond du Lac Reservation
- Goshute Business Council
- Greenville Rancheria
- Holy Cross Village
- Jena Band of Choctaw Indians
- Kaibab Paiute Tribe
- Kokhanok Village Council
- Leech Lake Band Ojibwe
- Leisnoi Village aka Woody Island Tribal Council
- Lime Village Traditional
- Louden Tribal Council
- Miami Tribe of Oklahoma
- Mille Lacs Band of Ojibwe
- Minto Village Council
- Modoc Tribe
- Native Village of Atka
- Native Village of Buckland
- Native Village of Savoonga
- Native Village of Wales
- Nightmate Traditional Council
- Pinoleville Domo Nation
- Pueblo de San Illdefonso
- Red Cliff Tribe
- Skagway Traditional Council
- Swinomish Indian Tribal Community
- Tatitlek Village IRA Council

- Wiyot Tribe
- Yakutat Tlingit Tribe

9.5 COUNTY/LOCAL GOVERNMENTS

- Knox County, TN Department of Air Quality Management
- City of New York Environmental Law Division

9.6 STAKEHOLDERS

- Akiak EPA IGAP
- AkPIRG
- Alina Fortson
- Alliance of Automobile Manufacturers
- Allison Forbes
- American Association of Blacks in Energy
- American Council for an Energy-Efficient Economy
- American International Automobile Dealers Association
- American Jewish Committee
- Annie Chau
- Arizona Consumers Council
- Arizona PIRG
- BG Automotive Group, Ltd.
- BMW (US) Holding Corp.
- California Air Pollution Control Officers Association
- CALPIRG
- Carl Henne
- Caroline Keicher
- Catherine Easton
- Center for Biological Diversity
- Ceribon
- Charles C. Yoder
- Christina Marie Yagjian
- Chrysler, LLC
- Citizens' Utility Board of Oregon
- Columban Justice, Peace and Integrity of Creation Office (USA)
- Conservation Law Foundation
- Consumer Action
- Consumer Assistance Council of Cape Cod
- Consumer Federation of America
- Consumer Federation of the Southeast
- Consumers for Auto Reliability and Safety
- Consumers Union
- Daimler
- Dale Olson
- Democratic Process Center
- Doug Molof
- Eliza Berry
- Elizabeth R. McGurk
- Emanuel Figueroa
- Emily Spear

- Empire State Consumer Association
- Environment America
- Environmental Council of the States
- Environmental Defense Fund
- Evangelical Lutheran Church in America
- Florida Consumer Action Network
- Florida PIRG
- Ford Motor Co.
- Fred Dobb
- Fred Marshall
- Fred T. Teal, Jr.
- Friends Committee on National Legislation
- Fuji Heavy Industries USA/Subaru
- General Motors Corporation
- Gibson, Dunn & Crutcher LLP
- Greater Washington Interfaith Power and Light
- Heather Moyer
- Illinois PIRG
- Insurance Institute for Highway Safety
- Jaafar Rizvi
- James Adcock
- James Farrelly
- Jazzlin Allen
- Jewish Community Relations Council of Greater Washington
- Jewish Council of Public Affairs
- Jim Derzon
- Jim Pierobon
- Joan Claybrook
- John Schieber
- Joseph Frewer
- Julie Locascio
- Kirkland & Ellis LLP
- Lake Michigan Air Directors Consortium
- Lake Michigan Air Directors Consortium
- Lee Auto Malls
- Marissa Knodel
- Mary Hamilton
- Maryknoll Office of Global Concerns
- Maryland Consumer Rights Coalition
- Maryland PIRG
- Massachusetts Consumers Council
- Matt Dernoga
- Matt Kirby
- Matthew Du Pont
- Michael A. Kirchner
- Mike Koerber
- Nancy Miller
- National Automobile Dealers Association
- National Council of Churches USA
- National Tribal Environmental Council
- Natural Resources Canada

- Natural Resources Defense Council
- New Jersey Citizen Action
- New Mexico PIRG
- Nissan North America, Inc.
- Northeast States for Coordinated Air Use Management
- NYPIRG
- Pamela Woodward
- Peggy Gilges
- Presbyterian Church (USA) Washington Office
- Public Citizen
- Robert Burchard
- Robert Dawes
- Sam Blodgett
- Sarah Karlin
- Sarah Larsen
- Sierra Club
- The Consumer Alliance
- The Episcopal Church
- The United Methodist Church General Board of Church and Society
- Union for Reform Judaism
- Union of Concerned Scientists
- United Church of Christ
- United Church of Christ Justice and Witness Ministries
- University of Colorado School of Law
- US Public Interest Research Group
- Utility Consumers Action Network
- Vice Admiral Dennis McGinn, USN, Retired
- Victims Committee for Recall of Defective Vehicles
- Virginia Citizens Consumer Council
- Volkswagen Group of American
- VPIRG
- Western Regional Air Partnership
- Wisconsin Consumers League
- Yuli & Susan Chew

Chapter 10 Responses to Public Comments

On June 26, 2008, the National Highway Traffic Safety Administration (NHTSA) submitted to the U.S. Environmental Protection Agency (EPA) a draft Environmental Impact Statement (DEIS) to disclose and analyze the potential environmental impacts of the new Corporate Average Fuel Economy (CAFE) standards for MY 2011-2015 and reasonable alternative standards in the context of NHTSA's CAFE Program pursuant to National Environmental Policy Act (NEPA) implementing regulations issued by Council of Environmental Quality (CEQ), U.S. Department of Transportation (DOT) Order 5610.1C, and NHTSA regulations. On July 2, 2008, NHTSA published a *Federal Register* Notice of Availability of its DEIS. NHTSA's Notice of Availability also made public the date and location of a public hearing, and invited the public to participate at the hearing on August 4, 2008, in Washington, DC. On July 3, 2008, the EPA issued its Notice of Availability of the DEIS, triggering the 45-day public comment period. In accordance with CEQ NEPA implementing regulations, the public was invited to submit written comments on the DEIS until August 18, 2008.

NHTSA mailed approximately 200 copies of the DEIS to interested parties, including federal, state, and local officials and agencies; elected officials, environmental and public interest groups; Native American tribes; and other interested individuals, as listed in Chapter 9 of the DEIS. NHTSA held a public hearing on the DEIS at the National Transportation Safety Board Conference Center in Washington, DC, on August 4, 2008.

NHTSA received 66 written comments from interested stakeholders, including the EPA, the Centers for Disease Control (CDC), state and local agencies, elected officials, automobile trade associations, organizations, and individuals. In addition, NHTSA received one petition with 10,540 signatures expressing support for more stringent CAFE standards and the use of higher gas prices in the Volpe model. *See* Document ID No. NHTSA-2008-0060-0599.1. During the public comment hearing in Washington, DC, 44 people provided oral statements. In this chapter of the final Environmental Impact Statement (FEIS), NHTSA has quoted excerpts from and responded to the comments received.

NHTSA considered and evaluated all written and oral comments received during the public comment period in the preparation of this FEIS. NHTSA changed the EIS, in part, to respond to comments on the DEIS. We also changed the EIS as a result of updated information that became available after issuance of the DEIS.

We appreciate the comments provided during development of the EIS. The transcript from the public hearing and written comments submitted to NHTSA are part of the administrative record, and are available on the Federal Docket, which can be found on the Web at http://www.regulations.gov, Reference Docket No. NHTSA-2008-0060. Written comments and the public hearing transcript can also be viewed in their entirety in Appendix D of this FEIS. Sections 10.1 through 10.4 provide comments on the DEIS and NHTSA's responses to those comments. Table 10-1 lists the topics addressed in this chapter. Table 10-2 is an index of the comments from individuals, federal and state agencies, and private industry and the location in this chapter of NHTSA's responses to those comments.

Table 10-1

Outline of Issues Raised in Public Comments on the DEIS

10.1	**PURPOSE AND NEED**
10.1.1	NEPA Process
10.1.2	Timing of NEPA Process/Public Participation
10.1.3	Document Structure/Readability
10.1.4	NHTSA's Decision to Prepare an EIS
10.1.5	Functional Equivalence Doctrine
10.1.6	Transboundary Effects
10.2	**PROPOSED ACTION AND ALTERNATIVES**
10.2.1	General Context Comments
10.2.1.1	Clarifying Comparative Reduction Plans
10.2.1.2	Effects on Other Countries' Standards
10.2.2	Volpe Model
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10.2.2.2	Rebound Effect
10.2.2.3	Social Cost of Carbon
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10.2.2.6	Consumer Demand/Behavior
10.2.2.7	Fleet Composition Assumption
10.2.2.8	Discount Rate
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10.2.2.10	Military/National Security
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10.2.3.2	Different Economic Inputs to Volpe Model
10.2.3.3	Alternative 1 (No Action)
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10.2.3.5	Alternative 6 (Total Costs Equal Total Benefits)
10.2.3.6	Alternative 7 (Technology Exhaustion)
10.2.3.7	New Alternatives
10.2.3.8	Alternatives Relationship to Maximum Feasible Fuel Economy Standards
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10.3	**AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES**
10.3.1	Introduction
10.3.1.1	Approach to Scientific Uncertainty and Incomplete Information
10.3.1.2	Modeling After 2020
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10.3.2.1	Affected Environment
10.3.2.2	Methodology
10.3.2.3	Consequences
10.3.2.4	Health
10.3.3	Climate
10.3.3.1	Methodology
10.3.3.2	MAGICC Model
10.3.3.3	IPCC Scenarios
10.3.3.4	Non-CO2 GHGs
10.3.3.5	Consequences
10.3.3.6	Sea-Level Rise

Table 10-1 (cont'd)

Outline of Issues Raised in Public Comments on the DEIS

Table 10-2

Index of Comments from Individuals, Federal and State Agencies, and Private Industry

Commenter	Document ID Number a/	Location of Comment Excerpts and NHTSA's Responses
Federal Agencies		
Centers for Disease Control and Prevention	0600	10.2.2.2, 10.3.2.4, 10.3.3.1, 10.3.4.3, 10.3.6.3, 10.3.6.4, 10.4.1, 10.4.2
Susan Bromm, Environmental Protection Agency	0596	10.2.2.1, 10.2.2.3, 10.2.2.8, 10.3.1, 10.3.2, 10.3.2.1, 10.3.2.2, 10.3.2.3, 10.3.2.4, 10.3.3, 10.3.3.2, 10.3.3.3, 10.3.3.4, 10.3.6.2, 10.3.6.3, 10.3.6.5, 10.4.3
Industry		
Adam Lee, Lee Auto Malls	TRANS-02	10.2.2.1, 10.2.2.6
Organizations		
Julie Becker, Alliance of Automobile Manufacturers	0574	10.1.1, 10.1.4, 10.1.5, 10.1.6, 10.2.2, 10.2.2.5, 10.2.3.3, 10.2.3.6, 10.4.3,
Julie Becker, Alliance of Automobile Manufacturers	TRANS-01	10.1.4, 10.1.5, 10.1.6, 10.2.2.5, 10.2.3.3, 10.4.5.3
Barry Bernsten, BG Automotive Group	TRANS-17	10.3.2.4
Center for Biological Diversity	0572	10.1.2, 10.2.1, 10.2.2, 10.2.2.1, 10.2.2.3, 10.2.2.4, 10.2.2.6, 10.2.2.8, 10.2.3.1, 10.2.3.2, 10.2.3.3, 10.2.3.4, 10.2.3.6, 10.2.3.7, 10.2.3.8, 10.2.3.10, 10.3.1.1, 10.3.1.2, 10.3.2.2, 10.3.3, 10.3.3.2, 10.3.3.3, 10.3.3.4, 10.3.3.6, 10.3.5.1, 10.3.6.1, 10.3.6.4, 10.4.1, 10.4.4, 10.4.5.1, 10.4.5.4
Ami Greener, American Jewish Committee	TRANS-39	10.2.2.1, 10.2.2.4, 10.2.3.8, 10.2.3.10, 10.3.1.2
Eli Hopson, Union of Concerned Scientists	TRANS-19	10.2.1, 10.2.2.3, 10.2.2.4, 10.2.3.8, 10.2.3.10
James Keck, Environmental Defense Fund	TRANS-32	10.2.1, 10.2.3.8, 10.2.3.10, 10.3.2.4, 10.3.4.3, 10.3.7
Debbie Linick, Jewish Community Relations Council	TRANS-30	10.2.2.1
Elizabeth McGurk, National Counsel of Churches and Christ	TRANS-42	10.2.3.10
Ann Mesnikoff, Sierra Club	TRANS-08	10.2.1, 10.2.2.1, 10.2.2.3, 10.2.2.4, 10.2.3.10, 10.3.1.2
Ben Schreiber, Environment America	TRANS-38	10.2.2.1
David Westcott, NADA	TRANS-04	10.1.4, 10.2.2.2, 10.2.2.6
Consumer Federation of America (and others)	0564	10.1, 10.2.1, 10.2.2.1, 10.2.2.2, 10.2.2.6, 10.2.2.8, 10.2.2.10, 10.2.3.1, 10.2.3.5, 10.2.3.8, 10.2.3.9
Environmental Defense Fund	0596	10.1.2, 10.2.1, 10.2.3.8, 10.3.1.2, 10.3.2.4, 10.3.3.5, 10.3.4.3, 10.4.2
Natural Resources Defense Council	0557	10.2.1, 10.2.2.1, 10.2.2.3, 10.2.2.4, 10.2.2.8, 10.2.2.10, 10.2.3.8, 10.2.3.10
Joan Claybrook, Public Citizen	0576	10.1.1, 10.1.3, 10.2.1, 10.2.2, 10.2.2.1, 10.2.2.2, 10.2.2.3, 10.2.2.4, 10.2.2.6, 10.2.2.9, 10.2.2.10, 10.2.3.1, 10.2.3.3, 10.2.3.4, 10.2.3.8, 10.2.3.10, 10.3.1.2, 10.3.6.4, 10.4.5.4
Caroline Keicher, Sierra Club	0598	10.2.1, 10.2.2.1, 10.2.2.3, 10.2.2.4, 10.2.3.8, 10.2.3.10, 10.3.1.2

Table 10-2 (cont'd)

Index of Comments from Individuals, Federal and State Agencies, and Private Industry

Commenter	Document ID Number a/	Location of Comment Excerpts and NHTSA's Responses
Organizations (cont'd)		
Union of Concerned Scientists	0575	10.1.3, 10.2.1, 10.2.2, 10.2.2.1, 10.2.2.2, 10.2.2.3, 10.2.2.4, 10.2.2.6, 10.2.2.7, 10.2.2.8, 10.2.2.9, 10.2.2.10, 10.2.3.5, 10.2.3.8, 10.4.4, 10.4.5.1, 10.4.5.2, 10.4.5.4
Mari Castellanos, United Church of Christ	TRANS-26	10.2.3.10
Mark Cooper, Consumer Federation of America	TRANS-05	10.1, 10.1.2, 10.2.1, 10.2.2.6, 10.2.2.10, 10.2.3.1, 10.2.3.8
Private Citizens		
James Adcock	0554	10.1, 10.2.1, 10.2.1.2, 10.2.2.1, 10.2.2.4, 10.3.6.4, 10.4.4, 10.4.5.1, 10.4.5.2
Matthew DuPont	TRANS-16	10.1.3
Catherine Easton	TRANS-41	10.2.1, 10.2.2.6
James Farrelly	0535	10.2.2.1
Emanuel Figueroa	TRANS-25	10.2.2.1, 10.2.3.10
Allison Forbes	TRANS-29	10.2.2.1
Alina Fortson	TRANS-35	10.2.1, 10.2.2.1, 10.2.3.8
Joseph Frewer	TRANS-13	10.2.1, 10.2.2.1
Peggy Gilges	0534	10.2.3.10
Carl Henne	0548	10.2.3.10
Sarah Karlin	TRANS-27	10.2.1
Jazzlin Allen	TRANS-11	10.2.3.10
Caroline Keicher	TRANS-20	10.2.1, 10.2.2.4, 10.2.3.10
Matt Kirby	TRANS-36	10.2.1, 10.2.2.1, 10.3.1.2
Michael Kirchner	0544	10.2.3.10
Marissa Knodel	TRANS-15	10.2.2.4, 10.2.3.10, 10.3.6.6
Sarah Larsen	0550	10.2.1, 10.2.2.4, 10.2.3.10, 10.3.1.2
Julie Locascio	TRANS-22	10.2.2.1
Fred Marshall	0547	10.2.3.10,
Dennis McGinn	TRANS-03	10.2.2.10,
Nancy Miller	0549	10.2.2.1,
Doug Molof	TRANS-09	10.2.1, 10.2.2.1,
Eliza Berry	TRANS-07	10.2.1, 10.2.3.10,
Tara Morrow	TRANS-23	10.2.2.1, 10.2.2.2i, 10.2.2.6, 10.2.3.10
Heather Moyer	TRANS-24	10.2.2.1, 10.2.1, 10.2.3.7, 10.2.3.10
Dale Olson	0530	10.3.3, 10.3.6.4
Jim Pierobon	TRANS-28	10.2.2.1, 10.2.2.4
Mary Hamilton	0545	10.2.3.10
Lena Pons	TRANS-06	10.1, 2.A, 10.2.2.4, 10.2.3.1, 10.2.3.3, 10.2.3.7, 10.2.3.10,

Table 10-2 (cont'd)

Index of Comments from Individuals, Federal and State Agencies, and Private Industry

Commenter	Document ID Number a/	Location of Comment Excerpts and NHTSA's Responses
Private Citizens (cont'd)		
Jim Derzon	0551	10.2.2.1,
Jaafar Rizvi	TRANS-37	10.2.1, 10.2.3.8, 10.2.3.10, 10.3.4.2
John Scheiber	0539	10.2.3.10,
Emily Spear	TRANS-44	10.2.1, 10.2.2.10, 10.2.3.10,
Fred Teal, Jr.	TRANS-34	10.2.2.1, 10.2.2.4, 10.2.3.10,
Pamela Woodward	TRANS-18	10.2.2.1, 10.2.2.6
Sam Blodgett	TRANS-12	10.2.2.1, 10.2.3.8, 10.2.3.10
Christina Marie Yagjian	TRANS-21	10.2.1, 10.2.3.10, 10.3.1.2
Charles Yoder	TRANS-43	10.2.2.10
Ceribon	0536	10.2.3.10
Robert Burchard	0533	10.2.3.10
Annie Chau	TRANS-14	10.1, 10.2.2.1, 10.2.3.9, 10.2.3.10,
Robert Dawes	TRANS-40	10.2.3.10
Matt Dernoga	TRANS-10	10.2.2.1, 10.2.3.10
Fred Dobb	TRANS-33	10.2.2.1, 10.3.4.1
State Agencies		
Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York and Oregon; Pennsylvania Department of Environmental Protection; New York City Corporation Counsel	0585	10.1.3, 10.2.1, 10.2.1.1, 10.2.3.8, 10.2.3.9, 10.3.1.2, 10.3.3, 10.3.3.1, 10.3.3.3, 10.3.3.5, 10.1.3,
Stanley Gee, New York Department of Transportation	0588	10.2.2.1, 10.2.2.2, 10.2.2.3, 10.2.2.4, 10.2.2.8, 10.2.3.6, 10.2.3.10, 10.3.2.1, 10.3.2.3
The Northeast States for Coordinated Air Use Management	0559	10.1.2, 10.2.1, 10.2.2.1, 10.2.2.4, 10.2.2.8, 10.2.3.4, 10.2.3.10, 10.3.1.2

a/ Document Identification Numbers in this column are truncated; comment documents on the Federal Docket contain the EIS docket number (NHTSA-2008-0060) in front of the numbers listed in this column.

10.1 PURPOSE AND NEED

Comments

Comment Number: 0554-10
Organization: Individual
Commenter: James Adcock

Given the uncertainty in future gas prices, as evidenced by the disparity between the EIA [Energy Information Administration] values NHTSA [National Highway Transportation Safety Administration] has used vs. recent gas prices, and recent large decreases in the estimated GHG [greenhouse gas] concentrations necessary to reach tipping point [http://www.columbia.edu/~jehl] NHTSA should reduce the numbers of years its proposed regulations extend forward. The farther one projects into the future, the greater the error in these projections. Given the rapid changes in our understanding of Global Warming and GHG, and the rapid changes in gas prices, it would be rational to extend the regulations forward for fewer years, allowing NHTSA to respond more appropriately once better understanding of these issues have been reached.

Comment Number: 0564-15
Organization: Consumer Federation of America
Commenter: Mark Cooper

Throughout its analysis, NHTSA indicates that certain assumptions were made with incomplete data and without critically important information about the auto market. Nevertheless, for no apparent reason, NHTSA set this low standard for the maximum period allowable under the law. NHTSA excuses the failure to obtain complete and accurate data for its assumptions with a claim that it must promulgate a standard for model year 2011 by mid-2009 in order to give automakers proper advanced notice. While that is correct, there was no need to rush to promulgate standards for later model years, certainly not 2013 through 2015. With numerous important issues still under study, it was incredibly irresponsible for NHTSA to write rules for years that do not require an expedited process, when additional time would afford a much more informed rulemaking. Critical information missing from NHTSA's analysis includes:

- The effectiveness of available technologies for improving fuel economy;
- The cost of technologies for improving fuel economy;
- Market shares of various models in the vehicle fleet; and
- The value of reduced emissions of greenhouse gases.

Unbelievably, NHTSA fully recognized that it did not have reliable and accurate information in these areas and would obtain that information only after the rule was promulgated. Additional and critical information missing from the Administration's analysis resulted in NHTSA making projections that were way ahead of the data available to them. This is, however, data that could be obtained, which would provide a much firmer basis for developing a rule that applies to 2013 vehicles and beyond. Without this critical data, NHTSA's conclusions:

- Relied on old sales data and projections in a time of rapid change in the industry;
- Failed to consider the impact of vehicle mix on safety;
- Did not incorporate technology adoption strategies ("pull ahead") that speed penetration of fuel-saving technology into the vehicle fleet;

- Ignored recent changes in fuel economy and the practices of automakers in adopting fuel economy technologies; and
- Overlooked changes in vehicle usage patterns across time.

Some underlying data used by NHTSA is suspect and would benefit greatly from even a small amount of further research and disclosure by the automakers, including:

- The production plans of automakers;
- Market share and price data;
- The validity of the speed of adoption of technology (phase-in caps) in light of dramatic changes in auto market behavior; and
- Assumptions about the compliance strategies of auto manufacturers.

There is no question that NHTSA needed to get the rulemaking started for 2011, and perhaps 2012, so it could complete the process eighteen months before the model year, as mandated by the new statute, but going beyond that, in light of the incredible importance of this regulation and the woeful lack of knowledge of critical aspects of the analysis, was irresponsible. NHTSA certainly could have moved forward with this rulemaking in light of these uncertainties by providing the minimum notice necessary, thereby keeping its options open for writing fuel economy standards for later years based on better information.

By rushing ahead with imperfect knowledge, faulty assumptions and a bias against fuel savings, NHTSA's approach denies the critical benefits of reduced gasoline and oil consumption to individual consumers and the nation as a whole. Therefore, it was unreasonable for NHTSA to set standards that run so far ahead of its knowledge. Adopting proposed standards for 2013 to 2015 based on such faulty data is arbitrary and capricious and leads to standards that are unreasonable.

The damage of NHTSA's proposed rule goes beyond the immediate impact of lost savings. By relying on a flawed analytic framework and flawed empirical specifications, this rulemaking undermines future rulemakings in two ways.

- First, procedurally, once this framework is set, it will be difficult to change. Inertia and judicial deference make it difficult to reverse agency decisions.
- Second, setting a low standard makes it far more difficult for the industry to meet higher future standards. Requiring large jumps in improvements is always more expensive than gradual improvements toward a goal, so fixing the mistakes later is harder because the industry is farther behind.

Because of the enormous importance of this particular rulemaking, it is critical for NHTSA to get the fundamental framework correct from the start and to set the standard at a reasonable and achievable level.

Comment Number: TRANS-05-4
Organization: Consumer Federation of America
Commenter: Mark Cooper

Our recommendation that you increase the level of the standards for 2011 and 2012, and that you withdraw the 2013 through 2015 proposals so that you can fix the fundamentally analytic flaws in the analytic framework and the erroneous economic assumptions is all the more compelling in light of the mounting evidence that the rule NHTSA has proposed fails to be a reasonable standard that comports with the act.

Comment Number: TRANS-06-9
Organization: Public Citizen
Commenter: Lena Pons

NHTSA has not presented a regulatory alternative that would result in actually reducing greenhouse gas emissions from motor vehicles. This is unacceptable. NHTSA has the responsibility to use its expertise to pose a theory wherein there is a regulatory alternative that could result in producing impacts that actually reduce greenhouse gas emissions from the motor vehicle sector.

And considering again that there is leeway for the agency to consider impacts that are the result of regulations that are outside of the lead agency's jurisdiction, then it could look at things that would address vehicle miles traveled reductions, or other types of policies that might, as a whole, result in reductions that will result in improving the situation in terms of global warming, which again goes to the issue of context.

Comment Number: TRANS-14-3
Organization: U.S. Public Interest Research Group
Commenter: Annie Chau

[NHTSA should rescind] the 2013 to 2015 standards, which are based on incomplete information.

Response

Commenters suggested that NHTSA set model year (MY) 2011-2012 standards in this current rulemaking and postpone the setting of MY 2013-2015 standards until the agency receives additional information. Although we appreciate the commenters' suggestion, we have concluded that the best approach for achieving at least the 35-mile-per-gallon (mpg) level specified in the Energy Policy and Conservation Act of 1975 (EPCA) is to set standards 5 years in advance, a regulatory option Congress has explicitly provided NHTSA in that statute. By doing so, NHTSA also promotes regulatory stability and allows manufacturers appropriate lead time to implement approaches to comply with more ambitious Corporate Average Fuel Economy (CAFE) standards.

NHTSA acknowledges that the amount of information concerning a future model year steadily increases as time passes. If NHTSA waits the maximum amount of time permissible under EPCA (that is, until just 18 months before a model year) to set standards for that model year, NHTSA would have little ability to require the manufacturers to make more than relatively minor improvements to the product plans they would already have established for that year. Changing plans requires lead time. Due to the nature of automobile production, manufacturers generally set production and supply contracts years in advance. While minor changes can be made in 18 months, substantial changes would be economically impracticable in such a short time.

For both the Notice of Proposed Rulemaking (NPRM) and for the alternatives described in this Final Environmental Impact Statement (FEIS), NHTSA used the best available information it could gather, including all the comments it received on its NPRM, and consulted with various experts, inside and outside the Federal Government, to derive the estimates it is using in the Volpe model. Waiting several years to set MY 2013-2015 CAFE standards might enable NHTSA to obtain additional and more up-to-date information regarding, for example, available technologies, product plans and market share, among other Volpe model components and inputs. However, in deciding whether to wait, NHTSA would also have to weigh the fact that the loss of several years of lead time before MY 2013-2015 would mean that, on balance, NHTSA would have to set lower standards than we could set now. The longer NHTSA waited to set the standards, the less ability it would have to require manufacturers to depart from their product plans for those model years, while still satisfying the EPCA factors of technological feasibility and economic practicability. More lead time allows manufacturers to structure their production cycles to meet more aggressive future standards.

Congress has already considered whether it is appropriate to set standards for up to 5 model years. In enacting the Energy Independence and Security Act of 2007 (EISA), Congress granted NHTSA the discretion to set CAFE standards anywhere from 1 model year to 5 model years at a time. See 49 United States Code (U.S.C.) § 32902(b)(3)(B). Further, Congress provided a process in EPCA by which NHTSA may amend previously promulgated CAFE standards if it determines that a different level would be the maximum feasible level for that model year. See 49 U.S.C. § 32902(c). Hence, there is a process to refine the CAFE standards if new information concerning the maximum feasible level becomes available after CAFE standards are initially set. Taking into account these available regulatory strategies in light of the comments raised, NHTSA believes that the best approach is to set CAFE standards for 5 model years. This will provide useful and important lead time information to the manufacturers, while preserving a regulatory tool to make adjustments to CAFE standards if new information should so warrant.

As explained in the NPRM, NHTSA will work with the National Academy of Sciences to update the list of fuel-saving technologies and their associated costs and effectiveness numbers on a 5-year interval, as required by EISA. To ensure that the combined passenger-car and light-truck fleets meet the statutorily mandated floor of 35 mpg in 2020, NHTSA will continue to request product plan updates from manufacturers during the 5 years covered by this rulemaking to assess whether the industry is on track and whether any changes to the standards are needed.

The comment that NHTSA must look at regulatory options that would reduce vehicle miles traveled (VMT) or GHG emissions goes beyond NHTSA's statutory authority. As explained in the NPRM and the Draft Environmental Impact Statement (DEIS), EPCA (as amended by EISA) requires NHTSA to set average fuel economy standards at "the maximum feasible average fuel economy level that [NHTSA] decides the manufacturers can achieve in that model year." VMT is related to fuel economy in that increases in VMT due, for example, to increases in the vehicle population, will increase fuel consumption and carbon dioxide (CO_2) emissions. More stringent standards will generally increase VMT (because they decrease the per-mile cost of fuel). This is known as the "rebound effect" and is considered by the Volpe model. Similarly, increasing fuel prices will generally decrease VMT. Thus, although CAFE standards indirectly affect VMT, NHTSA cannot control the growth of VMT.

10.1.1 NEPA Process

Comments

Comment Number: 0574-1
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

Moreover, as the Alliance [of Automobile Manufacturers] noted in its NEPA [National Environmental Policy Act] scoping comments, to the extent NEPA applies at all to the process of setting fuel economy standards under EPCA and EISA, it is a supplementary tool designed to provide additional information to NHTSA decisionmakers. It cannot be allowed to overtake or misshape the careful balancing of factors mandated by Congress in EPCA and refined in the Reform CAFE approach under EISA. Under bedrock NEPA precedent, the statute is purely procedural in nature and cannot be used to require an agency to act in any particular way. Numerous individuals or organizations testifying at the August 4 public hearing appeared to suggest otherwise. As it proceeds, NHTSA should be careful to maintain a clear distinction between its substantive obligations under EISA and its procedural obligations under NEPA.

Comment Number: 0576-36
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA has not completed this draft EIS [Environmental Impact Statement] in accordance with the requirements under the National Environmental Policy Act (NEPA) [42 U.S.C. § 4321 et seq., Pub. L. 91-190 (Jan. 1, 1970)]. This document does not put the potential impacts of fuel economy standards in a context that allows for a meaningful comparison of alternatives, which unfairly biases judgment in favor of NHTSA's preferred action. The purpose of the EIS process is to provide an analysis of the environmental impacts that allows decisionmakers to consider whether the preferred action is also the action that produces the greatest environmental benefits.

Comment Number: 0574-16
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

Sierra is flexible about the process NHTSA could employ to answer these questions [regarding clarification of the benefit estimates that NHTSA is assuming for specific technologies]. They could be resolved by way of a written response, or, more profitably, they could be answered by way of a telephonic conference call in which any relevant staff from NHTSA or the Volpe Center [Volpe National Transportation Systems Center] are made available so that Sierra's consultants could have an interactive conversation with them. The Alliance's [Alliance of Automobile Manufacturers's] only interest is that the questions be answered, and that they be answered as expeditiously as possible. Sierra may have additional questions as it continues its analysis, and so I would also suggest that NHTSA establish a means for resolving those questions that will not require further letter-writing.

In sum, consistent with its obligations under the law and with the diligence and thoroughness for which the agency is known, NHTSA should quickly initiate a process with Sierra to resolve Sierra's serious questions, and bring such a process to a conclusion as soon as is practicable. Please let me know expeditiously if for some reason NHTSA disagrees with the need to resolve Sierra's questions.

Response

NHTSA understands the balancing process required under EPCA, as amended by EISA, and the essentially procedural nature of NEPA. However, NEPA independently requires decisionmakers to integrate its requirements into agency decisions to inform them of the potential environmental impacts of these decisions and to present alternatives for consideration. Accordingly, NHTSA has analyzed the environmental impacts of a wide range of alternatives, some of which might weigh one or more of the four EPCA statutory factors (technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need of the Nation to conserve energy) in a manner that NHTSA might not ultimately accept, as it applies its discretion to determining the "maximum feasible" level for CAFE standards. See 49 U.S.C. 32902(f).

NHTSA believes that we have fully met our responsibilities under NEPA and its implementing regulations. NHTSA has completed a comprehensive analysis of the environmental impacts of seven alternatives ranging from the No Action Alternative to the Technology Exhaustion Alternative. In response to comments, NHTSA has expanded the analysis to account for a variety of different input assumptions. NHTSA's results, first set forth in its DEIS and now in this FEIS, are being used to inform the agency of the range of reasonably foreseeable environmental impacts of setting the final CAFE standards for MY 2011-2015.

Regarding the Sierra Research, Inc. letter to which the Alliance of Automobile Manufacturers (AAM) refers, see responses in Section 10.2.2 (Volpe model) of this chapter.

10.1.2 Timing of NEPA Process/Public Participation

Comments

Comment Number: TRANS-05-1
Organization: Consumer Federation of America
Commenter: Mark Cooper

We urge the administration to hold hearings all across the country, not just here in Washington in the dead of August, so the public can weigh in on the issue of fuel economy, which is vital not only to consumer pocketbooks, but also to national security and the environment.

Consumer attitudes and behavior toward fuel economy play a vital role in NHTSA's market model and analysis, and as we show in our comments, NHTSA has completely misjudged the consumer. There would be no better way for NHTSA to correct this flaw than to hear directly, in person, from the people who it has failed to comprehend in its analysis.

Comment Number: 0559-1
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

In our previous comments, we noted that the Proposed Rule was published on May 2, 2008 with a deadline for comments of July 1, 2008, but NHTSA did not release the DEIS until June 24, 2008. Consequently, there was little opportunity to consider the DEIS while reviewing and developing comments on the Proposed Rule. The applicable federal regulations state, "NEPA procedures must insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken." [Footnote: 40 CFR [Code of Federal Regulations] 1500.1 & 1500.2.] Further, these regulations require federal agencies to "[i]ntegrate the requirements of NEPA with other planning and environmental review procedures…so that all such procedures run concurrently rather than consecutively." In so doing, the effect is to "[e]ncourage and facilitate public involvement in decisions which affect the quality of the human environment." Unfortunately, by separating the review periods for these two actions, the public involvement processes, both for the Proposed Rule and for the DEIS, were not well served.

Comment Number: 0559-10
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

In the context of these stated purposes of NEPA, we take note of the fact that the notice of proposed rulemaking [NPRM] was published on May 2, 2008 with a deadline for comments of July 1, 2008. However, NHTSA did not release the Draft Environmental Impact Statement until June 24, 2008, and NESCAUM did not receive a copy of the DEIS from NHTSA until June 30, 2008, which is only one day before the rulemaking comment deadline. Consequently, NESCAUM and other public commentators have essentially no opportunity to consider the environmental impacts, as stated by NHTSA, while reviewing and developing comments on the proposed rule. To be consistent with legislative intent and regulations implementing NEPA, NHTSA should provide an additional comment period on the proposed rule after the DEIS becomes final.

NHTSA's selection of the $7 per ton value for the social cost of carbon emissions is one example of how the absence of concurrent processes hinders efforts to provide fully informed comments and make better informed decisions. It would have been beneficial to have had the DEIS in hand while assessing the appropriateness of this figure. Considering the late release of the DEIS relative to the comment period for the proposed rule, there simply is not enough time to adequately formulate a comment in this regard.

Comment Number: 0572-2
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The NHTSA has also violated NEPA because the NEPA analysis has not informed the EPCA balancing and the Volpe model – rather, the NHTSA has done a post-hoc EIS on the "black box" number from the Volpe model. The federal NEPA regulations are clear on the order in which decision-making must proceed:

The statement shall be prepared early enough so that it can serve practically as an important contribution to the decision-making process and will not be used to rationalize or justify decisions already made (§§ 1500.2(c), 1501.2, and 1502.2). For instance: … (d) For informal rulemaking the draft environmental impact statement shall normally accompany the proposed rule. 40 C.F.R. § 1502.5. See also, *Pit River Tribe v. U.S. Forest Service*, 469 F.3d 768, 785 (9th Cir. 2006) (reviewing relevant statutes and holding that a post-hoc EIS does not cure failure to complete an EIS before lease extensions were granted; "The purpose of an EIS is to apprise decisionmakers of the disruptive environmental effects that may flow from their decisions at a time when they retain a maximum range of options").

Comment Number: 0596-8
Organization: Environmental Defense Fund
Commenter: Martha Roberts

Although the EIS assesses a range of CAFE alternatives, NHTSA selected a preferred alternative (the "optimized" alternative) a priori to the environmental analysis. Nowhere does NHTSA provide a reasoned argument for why the findings of the EIS should not alter the choice of the preferred alternative.

This blatantly contravenes the purpose that "[e]nvironmental impact statements shall serve as the means of assessing the environmental impact of proposed agency actions, rather than justifying decisions already made." [Footnote: CEQ [Council on Environmental Quality] 40 CFR Sec. 1502.2 (g).]

Response

NHTSA recognizes the importance of public input in the NEPA process and has provided ample opportunity for interested parties to be heard. In March and in April 2008, NHTSA informed the public through notices in the Federal Register regarding its plans to prepare an EIS. First, on March 28, 2008, NHTSA published a notice announcing its intent to prepare an EIS and requesting scoping comments. See 73 Federal Register (FR) 16615. One month later, on April 28, 2008, NHTSA published a supplemental notice of public scoping providing additional information about the standards, the alternatives NHTSA expected to consider, and inviting further comments. See 73 FR 22913. On May 2, 2008, NHTSA published a notice of proposed rulemaking proposing standards for MY 2011-2015 passenger cars and light trucks, informing the public that an EIS process was underway, and seeking comments on the proposed rule. See 73 FR 24352. On July 3, 2008, EPA published a Notice of Availability of the DEIS, which reflected our careful review and consideration of public scoping comments and the studies suggested by the commenters. See 73 FR 38204. After issuing the DEIS, NHTSA provided a 45-day public-comment period, which closed on August 18, 2008. On August 4, 2008, well before the close of the comment period, NHTSA held a public hearing on the DEIS in Washington, DC, during which interested parties were invited to testify. Forty-four persons and entities testified at that hearing. Sixty-six persons and entities submitted written comments to the DEIS public docket. NHTSA is confident that it has received full and extensive public input and that it has satisfied the public participation requirements of NEPA and the CEQ NEPA implementing regulations.

An agency may formulate a proposal or even identify a preferred course of action prior to completing work on an EIS. See Association of Public Agency Customer, Inc. v. Bonneville Power Administration, 126 F.3d 1158, 1184 (9th Cir. 1997) (citing Natural Resources Defense Council v. Hodel, 624 F. Supp. 1045 (D. Nev. 1985)). NHTSA has carefully considered, individually and collectively, all comments on the DEIS, and our final action will be fully informed by the environmental review process and analysis of alternatives encompassed in this FEIS.

10.1.3 Document Structure/Readability

Comments

Comment Number: 0575-25
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

One of the overarching challenges with commenting on NHTSA's analysis is the opaqueness of its economic practicability analysis. Because of the complexity of the Volpe model, its use of confidential product plans, limited agency explanations of computer model behavior, and general opaqueness of the agency's measurement process in determining economic practicability, a shadow is cast on the credibility of NHTSA's analysis. While UCS [Union of Concerned Scientists] appreciates the great deal of effort put into providing the information in the NPRM and PRIA [Preliminary Regulatory Impact Analysis], more explicit information is necessary to effectively and fully comment on the proposed rule.

The mere *appearance* of wrongdoing by either automakers or the agency can undermine the value of this work. As future fuel economy regulations are set, mechanisms must be instituted to improve transparency of the process. Such options could include, for example, improved documentation and on-site, third-party access to NHTSA-supplied confidential product plan information. (Signed non-disclosure agreements would be required.)

Comment Number: 0576-28
Organization: Public Citizen
Commenter: Joan Claybrook

Another serious problem with the Volpe Model is that it is not transparent, which significantly undermines the ability of public commenters to provide an opinion as to whether NHTSA has set standards at the maximum feasible level that maximizes public good. Automakers provide the inputs for the Volpe Model through product plans, which are closed from public view as confidential business information. This significantly biases the standards in favor of industry by shutting the public out of the process. NHTSA does not establish what is technological feasible and economically practicable based on an independent assessment of the current vehicle fleet and the available technology to improve the fleet, but rather accepts industry inputs, which are run through the black box of the Volpe Model, and a variety of "optimization" factors, which are tied to maximizing industry-wide benefits (73 *FR* 24416). In the past, rulemaking NHTSA has done its own research and evaluation of these factors which was more transparent.

Thus, the public is foreclosed from real participation in this system. There is intense public interest in new fuel economy standards. These upgrades are the first for passenger cars in over twenty years, and they will dictate the level of fuel economy new vehicles will get until 2015, which affects the new car market and will skew purchase decisions. High gas prices and concern about global warming contribute to increased consumer interest in fuel economy; however, the agency's scheme for setting fuel economy standards leaves them largely in the dark. Consumers must essentially trust that NHTSA has set standards in their interest using information provided by industry.

Comment Number: 0585-2
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary Of The Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

In order to fulfill NEPA's goal of informing the public of the environmental impacts of the agency's decision, the EIS must "be written in plain language and may use appropriate graphics so that decisionmakers and the public can readily understand them" (40 C.F.R. 1502.8). Further, the EIS "must be organized and written so as to be readily understandable by governmental decisionmakers and by interested non-professional laypersons likely to be affected by actions taken under the [FEIS]." *Earth Island Institute v. U.S. Forest Service*, 442 F.3d 1147, 1160 (9th Cir. 2006) (quoting *Oregon Environmental Council v. Kunzman*, 817 F.2d 484, 494 (9th Cir. 1987). The DEIS fails to meet this standard.

Comment Number: TRANS-16-5
Organization: Individual
Commenter: Matthew Du Pont

You have a duty to make that EIS report transparent to the public … it's currently failing to do so.

And this leads to the conclusion that simply by throwing on a very accessible, readable, lower level two to three page summary in addition to what you already have in this report, you can make this much more accessible to the public who demand this information.

So first of all, I think it's not too controversial that people find this issue important, after all this directly impacts global warming which according to a March 2006 *Time* [Magazine] poll, 88 percent of Americans find relevant for future generations.

But more importantly for our purposes here, 49 percent of Americans think that this is one of the issues that is very important to them, one of the issues that they are going out of their way to actually find out information about, instead of just reading it in the papers. So we know it's important, we know it's important to Americans.

And secondly, it's very non-controversial that the EIS is supposed to inform the public, not just policy makers. People look to the CEQ regulations governing the EIS creation, which cite a purpose of the EIS as "to encourage and facilitate public involvement in decisions which affect the quality of the human environment." And there are also several clarity and brevity requirements meant to make them more accessible to the public.

So we've got this demand for information. We've got this EIS with a burden to show the public how that information is being used. It sounds pretty good. But in reality right now, this particular environmental impact statement is failing to make itself accessible to the public.

I mean, first of all there is the length. Now, the CEQ guidelines say that reports should be less than 150 pages in most cases, in very special cases under 300. So if I, as an average citizen who is not getting paid to deal with these issues, am confronted with this 414 page monstrosity, it's highly likely I'm not going to read more than the summary, if I read anything at all.

But this brings us to the second problem. Even if I got to that summary, the very first sentence in the forward, I am confronted with no less than nine acronyms, probably six of which I don't know. It's just not very encouraging for me as an average person trying to vote correctly, to advocate policy, to be able to read this report, although maybe it's applicable to policy makers. But I, you know, as just a regular citizen, it's hard for me to get through.

So, and it doesn't get much better from there on in because the summary assumes knowledge of a lot of things. It assumes that I know why rising sea levels are bad, which admittedly is explained in the report, but I'm probably not going to go to page 270 or wherever that's explained, if I'm not grabbed in the beginning. And so we have this inaccessibility, and I think it's a huge problem. The citizens who are interested but don't have a career as a nonprofit policy wonk or an auto industry lobbyist are simply not going to read a 414 page report, or even a 25 page summary.

And this brings me to the point of my speech, something you could do very easily. It's not a solution, but it's certainly a step in the right direction. By simply providing a short jargon free summary, say just two to three pages long, in addition to what's already in the report, specifically labeled, for average citizens who don't know as much about the issue, you can allow people to make meaningful conclusions from this EIS, to be able to read it and perhaps talk to their neighbor about it, or talk to their Congress person.

Response

A number of commenters asserted that the DEIS failed to inform the public because it lacked transparency, particularly regarding the use of confidential manufacturer product plans and the Volpe *model. NHTSA believes that the least-speculative approach to assessing the costs and benefits of setting CAFE standards entails the use of the product plans of vehicle manufacturers for the periods at issue. These plans enable NHTSA to create standards that are tied to realistic production goals. The Volpe model is a tool we use to apply technologies and assess costs and benefits given a range of input assumptions, including product plan information, technology costs and effectiveness, and economic externalities. NHTSA selects the input assumptions based on the best available information and data at the time of the rulemaking. NHTSA recognizes that some of the assumptions could change over time, and updates these assumptions as new and more-up-to-date information becomes available.*

With the exception of manufactures' confidential product plans, which are a crucial part of the process and subject to confidentiality under federal regulation, NHTSA provides interested parties and the public with all relevant data and information used in the Volpe model and the rationale for selecting those inputs. See 5 U.S.C. § 552(b)(4); 18 U.S.C. § 1905; 49 U.S.C. § 30167(a); 49 CFR Part 512; Critical Mass Energy Project v. Nuclear Regulatory Comm'n, 975 F.2d 871 (D.C. Cir. 1992); FEIS Section 3.1.4 (detailing Volpe model inputs); NPRM, 73 FR 24352, 24391 (May 2, 2008); CAFE Compliance and Effects Modeling System Documentation, Docket No. NHTSA-2008-0089-0047; How to Obtain Volpe Model Installation Files, Docket No. NHTSA-2008-0089-0048; PRIA, Docket No. NHTSA-2008-0089-0003.1, pp. V1-V141. In an effort to provide further clarification, Chapter 2 and Section 10.2.2 provide more information about how the Volpe model works.

NHTSA has made every effort to make this FEIS as accessible and reader-friendly as possible. However, the extreme complexity and uncertainty surrounding climate-change science and the difficulty associated with measuring emissions and impacts warrant detailed and technical discussion. Readers should turn to the FEIS Summary, which provides a short, plain-language discussion of the analysis and findings described in the FEIS chapters and appendices.

10.1.4 NHTSA's Decision to Prepare an EIS

Comment

Comment Number: 0574-14
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

For the foregoing reasons [functional equivalence doctrine, NHTSA's pending en banc petition, the Ninth Circuit's en banc *McNair* decision, unlawful consideration of transboundary effects], NHTSA should either determine not to proceed with a NEPA EIS or, alternatively, announce its desire to do so only on a voluntary basis, producing in the alternative an EA/FONSI [Environmental Assessment/Finding of No Significant Impact]. In addition, NHTSA must address the other comments on the DEIS advanced by the Alliance herein and in its scoping comments filed June 2, 2008.

Comment Number: 0574-3
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

"[P]rojected differences among the CAFE alternatives are small — i.e., CO_2 concentrations as of 2100 are within 1.7 to 3.2 parts per million across alternatives . . . — regardless of reference scenario and climate sensitivity." 73 Fed. Reg. at 37,926. NHTSA's analysis of the effects on rainfall and sea level rise are similar. See DEIS 2-17 to 2-18. See also 73 Fed. Reg. at 37,926 (predicting sea level rise by the year 2100 by 0.1 centimeters). All of these impacts are sufficiently small that they fully vindicate NHTSA's decision in prior CAFE rulemakings to perform environmental assessments ("EAs") in lieu of performing full-blown EIS-level analyses.

Comment Number: 0574-9
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

On February 6, 2008, with the permission of the Solicitor General, NHTSA petitioned for en banc [in full court] review of the Ninth Circuit's decision concerning NHTSA's MY 2008-2011 light truck CAFE rules in *Center for Biological Diversity* [*Center for Biological Diversity v. NHTSA*, 508 F.3d 508 (9th Cir. 2007)]. NHTSA argued that it could not be ordered to complete an EIS, but instead, consistent with limitations on remedies under the Administrative Procedure Act (which provides the only basis for enforcing NEPA in court), NHTSA had to be allowed the choice to exercise its discretion on remand as to whether to prepare an EIS or an EA. That en banc petition remains pending.

It is wholly inconsistent for NHTSA to voluntarily perform an EIS in this CAFE rulemaking while its en banc petition is pending in the Ninth Circuit, absent some explanation of independent reasons for doing so. NHTSA's present course of action risks mooting the en banc petition. (The Alliance points out this issue for NHTSA's consideration without conceding that the voluntary preparation by NHTSA of an EIS in this rulemaking would moot the pending en banc petition. Clearly, the agency would have good arguments that even the voluntary preparation of an EIS on remand would not moot the case.) In order to maintain consistency with the position taken in the Ninth Circuit, NHTSA should issue, in the alternative, an EA/FONSI form of NEPA compliance document. The evidence NHTSA has developed in the DEIS amply supports a conclusion that environmental impacts are minimal. Doing so would ensure that the pending en banc petition in *Center for Biological Diversity* remains unaffected.

In its en banc decision in *Lands Council, Inc. v. McNair*, --- F.3d ---, 2008 WL264001 (9th Cir. July 2, 2008), the Ninth Circuit took a major step to bring its NEPA jurisprudence into greater harmony with the NEPA case law of other Circuits. In *McNair*, the Ninth Circuit overruled a number of its prior panel opinions in the NEPA area. The decision should be carefully considered by NHTSA in connection with finalizing its NEPA analysis for this rulemaking. (In directing NHTSA's attention to the McNair decision, which as mentioned brings the Ninth Circuit more in line with other Circuits, we also note that even if a future final rule emerging from these proceedings were to be challenged, it is not a foregone conclusion that such a challenge would occur in the Ninth Circuit.) One aspect of the decision that NHTSA should particularly note, which is consistent with its approach in the DEIS (but inconsistent with the approach of many in the August 4 public hearing) is the following: "[T]o require the Forest Service to affirmatively present every uncertainty in its EIS would be an onerous requirement, given that experts in every scientific field routinely disagree; such a requirement might inadvertently prevent the Forest Service from acting due to the burden it would impose." (*Lands Council, Inc. v. McNair*, --- F.3d ---, 2008 WL264001 (9th Cir. July 2, 2008) at *17)

Comment Number: TRANS-01-2
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

The next issue relates to NHTSA's ability to defend its position in ongoing or future litigation. Let me explain. NHTSA petitioned the Ninth Circuit to review en banc the *Center for Biological Diversity* decision. One question before the en banc panel would be whether the reviewing Courts lack the power to order the preparation of an EIS as opposed to ordering the agency to reconsider whether an EIS is appropriate.

The en banc petition has not yet been acted upon. Since the position NHTSA took there was sanctioned by the solicitor general, it would seem that NHTSA needs to reserve its right not to perform an EIS at all.

In order to preserve that right, NHTSA should also produce an environmental assessment, a finding of no significant impact for the current rulemaking. If NHTSA decides to proceed in any other manner, it risks wounding its own en banc petition. So it is critical for NHTSA to take this approach.

Comment Number: TRANS-04-2
Organization: National Automobile Dealers Association
Commenter: David Westcott

In the past, NHTSA has consistently and adequately assessed and accounted for the potential environmental impacts of its proposed CAFE standards. NADA [National Automobile Dealers Association] therefore disagrees with the 2007 Ninth Circuit Court of Appeals decision in *Center for Biological Diversity v. NHTSA* which reviewed NHTSA's '06 reform light truck standards, and suggests that it is incumbent upon NHTSA to conduct a formal EIS in conjunction with its model year 2011-2015 proposal, CAFE proposal.

Response

NHTSA agrees that NEPA does not require an agency to evaluate every possible uncertainty. NHTSA disagrees that the proper course is for NHTSA to publish both an EA and an EIS, regardless of circumstances. Such an approach would confuse the analysis. In any case, on August 18, 2008, the Ninth Circuit vacated and withdrew its decision in Center for Biological Diversity v. NHTSA, 508 F.3d 508 (9th Cir. 2007). See Center for Biological Diversity v. NHTSA, 2008 WL 3822966 (9th Cir. 2008). Specifically, the Ninth Circuit vacated its opinion requiring NHTSA to prepare an EIS in connection with its CAFE rulemaking, and remanded to NHTSA to prepare either a revised EA or an EIS, as appropriate. In so doing, the Ninth Circuit denied as moot NHTSA's petition for rehearing with suggestion for rehearing en banc. NHTSA has decided that it is appropriate to prepare an EIS.

10.1.5 Functional Equivalence Doctrine

Comments

Comment Number: 0574-17
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

NHTSA includes several paragraphs in its DEIS arguing that the functional equivalence doctrine does not apply to CAFE standard-setting under EPCA or EISA. See DEIS at 1-16 to 1-17. This attempted rebuttal does not adequately address the Alliance's NEPA scoping comments for several reasons. First, NHTSA does not consider the cases cited by the Alliance and the point made there that the functional equivalence doctrine has been applied by courts to statutes other than the Clean Air Act and Clean Water Act and in favor of agencies other than the EPA [U.S. Environmental Protection Agency]. NHTSA's rebuttal effectively continues to assert that the functional equivalence doctrine applies only in such highly limited situations, without addressing the other authorities brought to its attention.

Second, NHTSA's rebuttal does not attempt to compare the procedures mandated in statutory contexts where the courts have found the functional equivalence doctrine to apply with the statutory procedures created in EPCA and EISA. Without such a comparison, it is empty for NHTSA to simply declare that the functional equivalence doctrine is only narrowly drawn. Moreover, NHTSA's attempted rebuttal avoids addressing cases like *Portland Cement Ass'n v. Ruckelshaus*, 486 F.3d 375, 384 (D.C. Cir. 1973), *cert. denied*, 417 U.S. 921 (1974) which interprets a vague provision of the Clean Air Act (requiring EPA only to impose "the best system of emission reduction") as requiring the functional equivalent of NEPA analysis.

Third, NHTSA's argument is illogical, because it would render the functional equivalence doctrine useless. Under NHTSA's reasoning, a statute would have to specify a set of procedures that is essentially identical to NEPA (plus the great detail in NEPA's regulations) before it would serve to require the functional equivalent of NEPA analysis. But if that were the case, then the doctrine would serve no purpose at all and would fail to relieve agencies of any kind of compliance burden. Instead, as *Portland Cement* explains, functional equivalence exists whenever a "workable balance is struck between some of the advantages and disadvantages of full application of NEPA." *Portland Cement.* Compare *Center for Biological Diversity v. NHTSA*, 508 F.3d 508, 527-28 (9th Cir. 2007). (EPCA creates a "reasonable" balancing of multiple variables for courts to review deferentially.)

Fourth, NHTSA provides no response at all to subsection III.A.2 of the Alliance's NEPA scoping comments. That subsection makes the point that the passage of EISA and the various directives it gives to NHTSA to consider environmental matters, as well as EISA's legislative history, indicates that environmental issues were in the foreground of Congress's mind in adopting that statute, and on that basis the functional equivalence doctrine can be applied.

Finally, even if NHTSA decides not to rely solely on the functional equivalence doctrine, it should recognize that its invocation in the alternative would help to protect its rulemaking against challenges asserting that the NEPA analysis being performed is defective or insufficient. NHTSA's analysis can be read to suggest that the agency agrees the defense is colorable, but is merely choosing not to invoke it as a discretionary matter. NHTSA should reconsider at least adopting the defense in the alternative, which would permit a court to pass on the issue. There is no downside to the agency acting in that fashion.

Comment Number: 0574-4
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

First, NHTSA argues that the functional equivalence doctrine does not apply to allow NHTSA not to perform an EIS under EPCA and EISA. But NHTSA's analysis in this respect is conclusory and fails to adequately respond to the Alliance's analysis supplied to the agency in its June 2, 2008 comments.

Second, even if the functional equivalence doctrine does not apply, NHTSA has not taken due account of the en banc petition it filed, with the permission of the Solicitor General, in the Ninth Circuit in *Center for Biological Diversity v. NHTSA*, No. 06-71891 (and consolidated cases). Should NHTSA vindicate the position it has taken in that en banc petition, then the agency could viably choose not to perform an EIS on remand. Yet, NHTSA is currently proposing to perform an EIS. NHTSA should not take this position before the pending en banc petition is resolved. Instead, NHTSA should at least decide in the alternative that performing an EA and issuing a finding of no significant impact ("FONSI") would be sufficient NEPA compliance to support the NPRM here.

Third, NHTSA should consider the Ninth Circuit's recent en banc decision in *Lands Council, Inc. v. McNair*, --- F.3d ---, 2008 WL 264001 (9th Cir. July 2, 2008). In that case, the Ninth Circuit overturned several aspects of its aggressive approach to the NEPA statute, bringing its jurisprudence more in line with of that of other circuits.

Comment Number: TRANS-01-3
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

In its comments, the Alliance noted that NHTSA already considers environmental impact and energy conservation when it sets CAFE standards. Therefore, CAFE rulemaking is the functional equivalent of performing an EIS. Under the functional equivalence doctrine, an agency need not prepare an EIS if it has already undertaken the functional equivalent of an EIS as part of its rulemaking process. However, in its draft EIS for the CAFE rulemaking, NHTSA takes the position that it cannot rely on the functional equivalence doctrine. In our view there is a solid argument for the functional equivalence doctrine here, and NHTSA should reconsider its position on this issue. At a minimum, NHTSA should assert the functional equivalence doctrine as an alternative basis that supports its final course of action.

Response

NHTSA has carefully studied the functional equivalence doctrine, the associated case law, and the Alliance of Automobile Manufacturers' (AAM's) arguments that NHTSA should assert the doctrine's applicability under EPCA. NHTSA declines to adopt the AAM's suggestion. NHTSA believes that its response to the AAM's scoping comment on the issue adequately explains the agency's rationale for this conclusion. See DEIS pp. 1-16 and 1-17.

After receiving the AAM's DEIS comments on this same subject, we again reviewed established case law applying the functional equivalence doctrine, including cases cited by AAM. NHTSA reasserts the conclusions reached in the DEIS. Our review of the cases indicates that the functional equivalence doctrine is not a "broad exemption from NEPA for all environmental agencies or even for all environmentally protective regulatory actions of such agencies." See Environmental Defense Fund v. EPA, 489 F.2d 1247, 1257 (D.C. Cir. 1973). Rather, the doctrine is a "narrow exemption from the literal requirements for those actions which are undertaken pursuant to sufficient safeguards so that the purpose and policies behind NEPA will necessarily be fulfilled." Id. This narrowly drawn exemption has been applied outside of EPA actions on environmental statutes in very few circumstances. These rare cases involved situations "where an agency is engaged primarily in an examination of environmental questions, where the substantive and procedural standards ensure full and adequate consideration of environmental issues." See Cellular Phone Taskforce v. Federal Communications Comm'n, 205 F.3d 82, 94 (D.C. Cir. 2000) (quoting Environmental Defense Fund, 489 F.2d at 1257). NHTSA does not believe that its actions in this rulemaking under EPCA are analogous.

The AAM urged NHTSA to compare the procedures mandated in statutory contexts where the courts have found the functional equivalence doctrine to apply with the statutory procedures created in EPCA and EISA. Nothing in EPCA or EISA explicitly directs NHTSA to consider environmental impacts of the CAFE standards, except what can be read into the statutory factor concerning the need of the United States to conserve energy, one of four factors to be considered in setting the standards. When courts apply the functional equivalence doctrine to excuse agencies from NEPA procedures, they first determine that the agency is in some other way explicitly required to analyze the environmental impacts of the proposed action so that the purposes and goals of NEPA are served, a circumstance that is not present here.

10.1.6 Transboundary Effects

Comments

Comment Number: 0574-12
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

In the DEIS, NHTSA disagrees with the Alliance's reading of NHTSA's pronouncement that "the appropriate value to be placed on changes [in] climate damages caused by carbon emissions should be ones that reflect the change in damages to the United States alone." (73 Fed. Reg. at 24,414) For NEPA purposes, NHTSA insists that "[p]otential environmental impacts are global in this instance and the analysis must look beyond the borders of the United States. . . . NHTSA has an obligation under NEPA to 'recognize the worldwide and long-range character of environmental problems.'" DEIS at 1-11 (quoting 42 U.S.C. § 4332(F)).

However, Section 4332(F), like much in the NEPA statute, is precatory. It does not create an obligation that attaches to the EIS requirement in Section 4332(C), which is judicially enforceable. Moreover, NHTSA selectively quotes Section 4332(f). In its entirety, Section 4332(F) reads as follows:

> The Congress authorizes and directs that, to the fullest extent possible: (1) the policies, regulations and public laws of the United States shall be interpreted and administered in accordance with the policies set forth in this chapter and (2) all agencies of the Federal Government shall . . . .
>
> > (F) recognize the worldwide and long-range character of environmental problems and, where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment . . . .
> > 42 U.S.C. § 4332(F).

To simply read this provision is to see why it cannot be read to be judicially enforceable, and to our knowledge has not been read by any court to be directly enforceable. Courts cannot police whether agencies have sufficiently "recognize[d] the worldwide and long-range character of environmental problems." Similarly, courts lack the power to decide whether agencies have lent enough support to programs maximizing international cooperation and protecting the world environment. Compare *Norton v. Southern Utah Wilderness Alliance*, 542 U.S. 55, 66-67 (2004) (unanimous) (to be enforceable, statutory mandates must be "discrete," and on that basis refusing to enforce an overly broad "non-impairment mandate" for wilderness study areas in a statute because "[i]f courts were empowered to enter general orders compelling compliance with broad statutory mandates, they would necessarily be empowered, as well, to determine whether compliance was achieved — which would mean that it would ultimately become the task of the supervising court, rather than the agency, to work out compliance with the broad statutory mandate, injecting the judge into day-to-day agency management.").

Finally, the proviso limiting Section 4332(F) to situations not inconsistent with the foreign policy of the United States is very significant. The United States in the past has argued in numerous different forums that the extraterritorial application of NEPA would interfere with the President's foreign policy prerogatives. "It has been the long-standing position of the Justice Department that NEPA was not intended nor can it be invoked to interfere with the President's authority as Commander-in-Chief, or with his exclusive responsibility for the conduct of foreign affairs, regardless of whether the government action in question affects the United States environment, the global commons, or the environment of foreign nations, because these responsibilities are confided to the President by the Constitution." Letter from Bruce C. Navarro, Deputy Assistant Attorney General, Department of Justice, to Minority Leader Robert Dole, 3 (Oct. 9, 1990), *quoted in* Joan M. Bondareff, *The Congress Acts to Protect Antarctica,* 1 Terr. Sea J. 223 n.64 (1991).

To support its contrary conclusion that NEPA can and does have extraterritorial application, NHTSA also cites a 1997 guidance document issued by the Council on Environmental Quality ("CEQ"). See id. at 1-11 n.29 (referencing CEQ, *Council on Environmental Quality Guidance on NEPA Analyses for Transboundary Impacts* (July 1, 1997), at 3, available at http://ceq.hss.doe.gov/nepa/regs/transguide.html. The Mexican Trucks decision by the Supreme Court recognizes that CEQ regulations are entitled to deference, see *Public Citizen*, 541 U.S. at 770, but a guidance document of this nature is void because it represents a clear shift in policy that occurred in 1997 without compliance with the Administrative Procedure Act's requirement to subject any substantive change in agency policy to notice-and-comment review by the public. See, e.g., *CropLife Am. v. EPA,* 329 F.3d 876 (D.C. Cir. 2003); *General Elec. Co. v. EPA*, 290 F.3d 377 (D.C. Cir. 2002); *Barrick Goldstrike Mines, Inc. v. Browner*, 215 F.3d 45 (D.C. Cir. 2000); *Appalachian Power Co. v. EPA*, 208 F.3d 1015 (D.C. Cir. 2000). Hence, NHTSA cannot rely on this lone guidance document. It has no legal effect.

Moreover, the guidance document reflects a divergence from Justice Department-approved interpretations of NEPA both prior to 1997 and after 1997. The Navarro letter to Senator Dole referred to above accurately summarizes policy predating the 1997 CEQ guidance document. And the current Administration had repeatedly made clear its position that NEPA is not sufficiently unambiguous to overcome the presumption against extraterritoriality, which remains vital. See *Microsoft v. AT&T Corp*., 127 S. Ct.1746, 1758 (2007). (*Microsoft v. AT&T* also notes that the canon of presuming against extraterritoriality is entirely consistent with a presumption that "'legislators take account of the legitimate sovereign interests of other nations when they write American laws.'" *Microsoft*, 127 S. Ct. at 1758 (quoting *F. Hoffmann-La Roche Ltd. v. Empagran S. A.*, 542 U.S. 155, 164 (2004)). This helps to explain why Section 4332(F) of NEPA, with its emphasis on agencies giving some consideration to the world environment is fully consistent with concluding that the NEPA statute's enforceable duties nonetheless apply only to require the consideration of domestic effects.) To name just two examples, the Bush Administration took that position in *NRDC v. Department of the Navy*, No. CV-01-07781 CAS(RSZ)(C.D. Cal.) and *Manitoba v. Norton*, No. 02-cv-02057 (RMC) (D.D.C.). NHTSA nowhere even acknowledges these briefs, which represent the true position of the United States spanning across multiple agencies. See 28 U.S.C. § 516 (Attorney General represents the United States and agencies thereof in litigation). These positions therefore clearly trump the unlawfully issued and procedurally defective CEQ guidance document. At the very least, NHTSA must consider the positions taken in these briefs and others similar cases (by, *inter alia*, consulting with the Department of Justice) before deciding that NEPA applies extraterritorially in a final EIS or other final document issued for purposes of complying with the NEPA statute.

Comment Number: 0574-7
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

NHTSA concludes that NEPA requires it to analyze transboundary effects associated with the NPRM's proposed CAFE standards — especially climate-change effects outside the United States. This runs contrary to longstanding litigation positions approved by the Department of Justice. NHTSA does not even attempt to grapple with those prior positions in the DEIS. Since NHTSA's analysis concludes that the worldwide effects of higher CAFE standards would be very small, then they logically would be reduced even further once those effects are scaled back to effects within the United States alone. The

Alliance has also submitted a study by National Environmental Research Associates ("NERA") bearing on this issue. That study attempts to calculate the magnitude of properly limiting an analysis of the social costs of carbon emissions to impacts within the United States alone. The analysis in that study, if adopted by NHTSA, would buttress the conclusion that the CAFE rulemaking here can be supported by an EA/FONSI in preference to an EIS. Instead, the DEIS makes no mention of this analysis.

Comment Number: TRANS-01-4
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

The draft EIS appears to be setting a significant precedent regarding analysis of the trans-boundary effects.

On page 1-11 of the draft EIS NHTSA argues it should analyze trans-boundary effects of the CAFE standards quoting a 1997 CEQ guidance document stating that agencies must analyze such effects underneath them. The statement seems directly at odds with judicial precedent and agency precedent, and we would like for NHTSA to reconsider this.

Response

The AAM misunderstands NHTSA's analysis in the DEIS. According to the AAM, NHTSA has concluded that "NEPA requires it to analyze transboundary effects associated with the NPRM's proposed CAFE standards – especially climate-change effects outside the United States." In fact, the DEIS and this FEIS consider environmental impacts relevant to the United States that stem from emissions generated in the United States that subsequently would affect both the U.S. and the global environment. As explained in the DEIS, an appropriate discussion of global climate change does not make sense if it is limited to analysis of emissions within the United States, because this environmental problem is inherently global in nature. Climate science focuses on the effects of carbon emissions in the global atmosphere because the atmospheric concentration of greenhouse gases is essentially uniform across the globe. That is, carbon emissions from one nation disperse into the global atmosphere and have impacts in other nations, and conversely, benefits from emissions reductions in one nation are felt in all nations for the same reason. Nevertheless, NHTSA considers the AAM's comment as a suggestion to focus its environmental impacts analysis within the United States. NHTSA agrees that this type of national rulemaking warrants specific discussion of regional U.S. impacts and how global climate change specifically impacts the United States. NHTSA devoted substantial parts of the DEIS and this FEIS to such a discussion.[1]

[1] *See DEIS Sections 3.2, 4.2 (Energy); 3.3, 4.3 (Air Quality); 3.4.2.2.1 (United States Climate Change Effects); 3.5.4 (Safety and Other Human Health Impacts); 3.5.5 (Hazardous Materials and Regulated Wastes); 3.5.7 (Historic and Cultural Resources); 3.5.8 (Noise); 3.5.9 (Environmental Justice); 4.5.3.3.2 (Observed and Projected Impacts of Climate Change on Freshwater Resources in the United States – Freshwater Resources); 4.5.3.3.3 (Precipitation); 4.5.3.3.4 (Surface Water); 4.5.3.3.6 (Water Quality); 4.5.3.3.7 (Extreme Events – Floods and Drought); 4.5.4.1.2 (Terrestrial Ecosystems in the United States); 4.5.4.2.2 (Projected Impacts of Climate Change in the United States – Terrestrial Ecosystems); 4.5.5.2.1 (Projected Impacts of Climate Change for the United States – Coastal Systems and Low-lying Areas); 4.5.6.2.1 (Projected Impacts of Climate Change for the United States – Food, Fiber, and Forest Products); 4.5.7.2.1 (Projected Impacts of Climate Change for the United States – Industries, Settlements, and Society); 4.5.8.3 (Projected Health Impacts of Climate Change on the United States); 4.6.2.2 (Effects of Climate Change in the United States – Environmental Justice). See FEIS Sections 3.2, 4.2 (Energy); 3.3, 4.3 (Air Quality); 3.4.2.2.1 (United States Climate Change Effects); 3.5.4 (Safety and Other Human Health Impacts); 3.5.5 (Hazardous Materials and Regulated Wastes); 3.5.7 (Historic and Cultural Resources); 3.5.8 (Noise); 3.5.9 (Environmental Justice); 4.5.3.3.2 (Observed and Projected Impacts of Climate Change on Freshwater Resources in the United States – Freshwater Resources); 4.5.3.3.3 (Precipitation); 4.5.3.3.4 (Surface Water); 4.5.3.3.6 (Water*

NHTSA does not presume to invoke NEPA in such a way as to interfere with the President's exclusive responsibility for the conduct of foreign affairs. As explained above, the inherently global nature of climate change makes a global-level discussion necessary. Transportation-sector carbon emissions in the United States contribute to global climate change, which in turn affects various resources and regions within the United States. This relationship of U.S. emissions to a global environmental phenomenon and the associated impacts that affect the quality of the human environment in the United States warrant discussion in this FEIS.

The AAM asserts that NHTSA's analysis of the global effects of CO_2 *emissions is unlawful because 42 U.S.C. § 4332(F) is not an enforceable statutory mandate, and the CEQ guidance document NHTSA cited in the DEIS was improperly promulgated. NHTSA expresses no opinion as to the enforceability of 42 U.S.C. § 4332(F), but disagrees with the AAM's dismissal of these sources as expressing the purpose and intent of NEPA. The AAM overlooks the more important point that NEPA commands an agency to analyze reasonably foreseeable impacts on the human environment. Such an analysis necessarily includes potential impacts related to global climate change.*[2] *To conduct a proper analysis of the impacts on the United States, it is necessary to look at global temperature, precipitation, and sea-level change because current climate models are not sensitive enough to enable NHTSA to model unique temperature, precipitation, and sea-level changes for the United States or for particular regions within the United States.*

Quality); 4.5.3.3.7 (Extreme Events – Floods and Drought); 4.5.4.1.2 (Terrestrial Ecosystems in the United States); 4.5.4.2.2 (Projected Impacts of Climate Change in the United States – Terrestrial Ecosystems); 4.5.5.2.1 (Projected Impacts of Climate Change for the United States – Coastal Systems and Low-lying Areas); 4.5.6.2.1 (Projected Impacts of Climate Change for the United States – Food, Fiber, and Forest Products); 4.5.7.2.1 (Projected Impacts of Climate Change for the United States – Industries, Settlements, and Society); 4.5.8.3 (Projected Health Impacts of Climate Change on the United States); 4.6.1.2 (Effects of Climate Change in the United States – Environmental Justice).

[2] *The Federal Government (U.S. Climate Change Science Program) has recognized that global climate change is having and will have substantial effects on the United States. See generally http://www.climatescience.gov/Library/default.htm (last visited September 4, 2008).*

10.2 PROPOSED ACTION AND ALTERNATIVES

10.2.1 General Context Comments

Comments

Comment Number: 0557-16
Organization: The Natural Resources Defense Council
Commenter: Luke Tonachel, Brian Siu

The NHTSA CAFE DEIS should distinguish how more aggressive alternatives to the proposed standard put the U.S. on a more certain path for solving global warming.

Comment Number: 0598-7
Organization: Sierra Club
Commenter: Caroline Keicher

Fuel economy is only one policy in the tool bag – one which can be effectively utilized to decrease the 20% of U.S. CO_2 emissions that spew from our cars and light trucks. If we are to achieve the goal of the averting dangerous global warming – which requires an 80% reduction in CO_2 below 2000 levels – then we need to assess the CAFE options in this context. In other words, NHTSA should evaluate which of the "right" scenarios will best help the U.S. reduce its emissions to the levels required to avoid dangerous climate change, not whether any of the scenarios will make a difference if we've already gone too far. We must also take measures now to reduce the rate at which emissions are growing. In this context, faster fuel economy increases will result in faster turnover of the fleet, help drive new fuel saving technologies into vehicles, and put the U.S. on the right path to reducing global warming emissions.

Comment Number: 0550-3
Organization: Individual
Commenter: Sarah Larsen

I feel the most disappointing thing about the Draft Environmental Impact Statement is that it fails to analyze the benefits of greenhouse gas emission reductions in the proper context. When NHTSA tries to determine the difference in global ocean temperature rise in the year 2100 resulting from a 31.6 mpg standard vs. a 35 mpg standard, statistically, there is none; however, this does not mean that raising fuel economy standards faster will not have a significant impact in our struggle to reduce global warming pollution.

Comment Number: 0550-7
Organization: Individual
Commenter: Sarah Larsen

In the United States, emissions from the transportation sector account for roughly 20% of our country's greenhouse gas pollution; therefore, any projected decreases in greenhouse gas emissions arising from increased fuel economy standards can never be greater than 20%. For that reason, reductions should be considered as a proportion of the 20% – not as a proportion of the entire planet's combined carbon emissions.

Comment Number: 0554-7
Organization: Individual
Commenter: James Adcock

"Divide and Conquer" NHTSA's analysis of GHG emission from cars and trucks which only looks at U.S. cars and trucks, only looks at the regulatory delta of those cars and trucks, and only looks at the U.S. part of the SCC [social cost of carbon] value of those cars and trucks is a case of "Divide and Conquer" where each regulatory agency of the government claims its actions are small enough to be considered "negligible" in the global context, whereas the reality is that GHG pollution from cars and trucks worldwide represents a large fraction of the entire GHG problem. On the contrary, NHTSA should be considering vehicle GHG emissions as being part of an overall scheme necessary to reduce total GHG emissions in the U.S. and around the world. For example, if GHG is reduced by 10% by NHTSA's regulations, consider if this was part of scheme to reduce total GHG emissions by 10% in the U.S., and around the world.

Comment Number: 0557-2
Organization: The Natural Resources Defense Council
Commenter: Luke Tonachel, Brian Siu

The inability to differentiate the impacts among alternatives is the result of NHTSA's failure to consider light-duty fuel economy increases in the context of other measures designed to reduce global warming pollution. Fuel economy standards must be evaluated in the context of a comprehensive package of emission reduction measures needed to meet GHG emission reduction targets necessary to solve global warming. To draw an analogy, when a state must clean up its air to meet national ambient air quality standards, a State Implementation Plan, or SIP, must be submitted to EPA describing how pollution reductions will be achieved from a package of regulations on vehicles, fuels and consumer products. To solve global warming, GHG emission reductions are needed beyond the transportation from other energy-intensive sectors of the economy including power generation, industrial, commercial and residential sectors. When considered alongside measures in other sectors, it is clear that fuel economy standards play a critical, substantial role in avoiding dangerous climate change and more stringent standards are critical for achieving the necessary global warming pollution reductions in the transportation sector.

The weak passenger vehicle standard proposed by NHTSA for MY 2011-MY2015 does not ensure that vehicle fuel economy levels will be on a continuous, smooth trajectory to meet the longer term fuel economy necessary to achieve 2050 GHG emission reduction targets. This introduces serious risk because the necessary trajectory gets steeper and steeper the longer we wait.

Reducing global warming pollution 80 percent by mid-century will require the United States to substantially transform its energy economy. NRDC examined multiple strategies to reduce global warming pollution on both the demand (energy consuming) side and the supply (energy producing) side of the equation and pinpointed six major groups of energy sector opportunities that will put America on the path to significantly reducing the pace and magnitude of global warming. [Footnote: These measures achieve three-quarters of the reductions needed by 2050. The remainder would come from non-CO_2 gases, forestry measures, and innovations to address thousands of smaller sources.] In this context, fuel economy standards are a very significant strategy for reducing U.S. emissions. As shown in Figure 1 [See original comment document for Figure 1], when combined with smart growth measures, improved vehicle efficiency can contribute 13% of total reductions needed. [See original comment document for Figure 1.]

In terms of the transportation sector alone, fuel economy improvements comprise an even larger share of the GHG reductions. NRDC estimates that improved efficiency can contribute nearly 60 percent of the cumulative GHG reductions needed from the passenger vehicle sector. As shown in Figure 2, achieving 80% reductions from current emissions in the light-duty vehicle fleet requires a combination of improved fuel economy, smart growth, increased transit investments and a transition to low carbon alternative fuels such as electricity and biofuels. [See original comment document for Figure 2.] Without significant and early GHG reductions from greater vehicle efficiency, achieving the 80 percent reduction target becomes extremely challenging, if not impossible.

Comment Number: 0559-5
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

The DEIS disregards these factors and NHTSA concludes that the standards will have a negligible impact on climate change. Quoting from the DEIS:

"…because EISA requires average fuel economy of the passenger car and light truck fleet to reach a combined 35 mpg by 2020, the MY 2016-2020 CAFE standards are a reasonably foreseeable future action. Accordingly, the cumulative impacts analysis assumes the minimum MY 2016-2020 CAFE standards necessary to get to 35 mpg by 2020…Overall, the emission reductions for the MY 2011-2015 CAFE alternatives have a small impact on climate change. The emission reductions and resulting climate impacts for the MY 2011-2020 standards are larger, though they are still relatively small in absolute terms."

NHTSA's approach with the DEIS is unfortunately consistent with EPA's discredited argument in *Massachusetts v. EPA* 127 S. Ct. 1438 (2007) as to why that federal agency should not regulate GHGs emissions from new motor vehicles. EPA's rationale was that such regulations would have an insignificant effect on mitigating climate change. The Supreme Court rejected EPA's argument, pointing out that, "Agencies, like legislatures, do not generally resolve massive problems in one fell regulatory swoop. ('[A] reform may take one step at a time, addressing itself to the phase of the problem which seems most acute to the legislative mind' [internal citation omitted].)… And reducing domestic automobile emissions is hardly a tentative step… [T]he United States transportation sector emits an enormous quantity of carbon dioxide into the atmosphere."

Comment Number: 0564-7
Organization: Consumer Federation of America
Commenter: Mark Cooper

Because improvements in fuel economy alone do not solve the climate change problem, they are shown to have zero effect on the damage that global warming will do. Yet, every reasonable analysis of the big picture and the global impacts of greenhouse gas emissions recognizes that reductions of emissions in the transportation sector must play a large role in the overall solution to the problem. [Footnote: See original comment document.]

- Indeed, because of the nature of the sector, it is vital to get the maximum possible contribution to reductions from this sector to achieve a solution.
- Because no individual policy can solve the problem, this approach will reject every policy measure individually, even though taken together they can actually solve the problem.

Unfortunately, in NHTSA's approach, the whole is not even equal to the sum of its parts. NHTSA's approach embodies a myopic bias against action. NHTSA should start from an estimate of what the value of a solution to the national energy problem would be worth, and then give increases in fuel economy credit for their role in that solution.

Comment Number: 0572-24
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The NHTSA has failed to present, as it must, information and analysis in a way that provides meaningful insight into the relevant environmental problems and available solutions. The information in the DEIS on climate impacts is presented in a misleading manner and without appropriate context. Under NEPA an EIS must be written in "plain language" so that decisionmakers and the public can readily understand it. 40 CFR § 1502.8. The ultimate purpose of an EIS is to inform decisions. To do so, the information must not only be comprehensible to non-experts, but also present the context for the information in a manner that elucidates and explains the importance of each aspect of the decision.

The DEIS fails in this regard because it presents the information on the impacts of climate change in a way that minimizes the apparent potential for substantial harm. Even more problematic is the minimization of the apparent influence of each alternative on climate change. Throughout the DEIS the impact of each alternative as well as the difference between alternatives is presented as insignificant and meaningless. Although the DEIS mentions many of the potential consequences of increased atmospheric CO_2, the data is presented in a disjointed manner and qualified as "uncertain." Yet it has been decades since there has been any real scientific uncertainty regarding whether climate change is occurring as a result of increasing concentrations of anthropogenic (Oreskes 2004).

The reality is that, as discussed in previous sections, there is a substantial risk of climate disaster if U.S. greenhouse gas emissions continue unchecked. This collision course towards climate disaster can be avoided through efforts to reduce quickly reduce emissions. The transportation sector is one of the largest sources of emissions, and therefore also an essential part of the solution. Stringent CAFE standards can be part of one of the most significant components of a national greenhouse gas emissions reduction program. This substantial opportunity, however, is never explained to the reader, but rather, the reader is left with the impression that NHTSA's actions will make very little difference one way or another. This is profoundly misleading and violates NEPA's disclosure requirements.

Comment Number: 0572-4
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

An agency must regulate even if the result of the regulation will be only an "incremental" step towards solving the climate crisis. The Supreme Court noted that "[a]gencies, like legislatures, do not generally resolve massive problems in one fell regulatory swoop... [t]hey instead whittle away at them over time." *Mass. v. EPA* at 1457. Nonetheless, the court notes that [j]udged by any standard, U.S. motor-vehicle emissions make a meaningful contribution to greenhouse gas concentrations and hence, according to petitioners, to global warming. (*Mass. v. EPA* at 1457-58.)

Comment Number: 0572-41
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Global warming is the quintessential cumulative impact – the environmental problem caused by all contributing sources of greenhouse gas emissions together is far greater than that caused by any individual source. The purpose of the cumulative impacts section is to discuss the impact of the

NHTSA's rulemaking on the problem overall when considered along with other actions. The NHTSA must place its action in the proper context in order to provide the reader with meaningful information about the impact of its action. For example, the DEIS should answer the question, "to what degree does the NHTSA rulemaking contribute to or hinder the achievement of the greenhouse gas emissions reductions necessary to avoid catastrophic climate change?" The DEIS fails utterly to do so.

The DEIS considered only a single factor in the cumulative impacts section beyond the rulemaking itself – the impact of fuel economy standards for model years 2016-2020. As discussed above, the impact of future fuel economy standards should have been incorporated into the analysis of direct and indirect impacts, as the level chosen by the NHTSA for one year will impact the level achievable in future years. Regardless, however, limiting the cumulative impacts analysis to only considering fuel economy standards for model years 2016-2020 is clearly inadequate on its face to comply with NEPA's requirements.

The DEIS must include a reasonable analysis of the combined impact of the NHTSA's rulemaking on U.S. transportation sector emissions overall, and U.S. emissions overall. For example, is the impact of the current rulemaking sufficient to ensure that the necessary emissions reductions from the U.S. transportation sector overall will be achievable? If the transportation sector does not achieve its "fair share" of necessary emissions reductions, after all, those reductions will have to come from a different sector. While the NHTSA will likely argue that it is difficult to conduct a cumulative impacts analysis for a problem such as greenhouse gas emissions, it is eminently feasible to do so. While the NHTSA has some discretion in choosing the precise methodology of such an analysis, the agency was clearly not free to omit any such analysis altogether.

Comment Number: 0572-65
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Figure 1-1 on page 24358 of the NPRM is titled "CO_2 tailpipe emissions avoided due to increases in fuel economy 1975-2005." This graphical presentation of estimated reductions from hypothetical emissions levels seriously misrepresents the situation. Global climate change is a result of increasing atmospheric concentrations of greenhouse gases, and greenhouse gas emissions from automobiles has significantly increased over the past thirty years. It would be much more instructive to the public and to NHTSA to consider both annual and cumulative CO_2 tailpipe emissions over that same period of time.

Comment Number: 0575-27
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

If we are the avoid the worst impact of climate change, our nation and the world must adopt a target that will keep global temperature from rising more than 2 ^{o}C above pre-industrial levels. That means stabilizing the concentrations of global warming pollutants in our atmosphere at no more than 450 parts per million carbon dioxide equivalent. Analysis by UCS [Union of Concerned Scientists] shows that one part of achieving this goal means the United States must cut global warming pollution by at least 80% compared to emission levels in 2000. [Footnote: http://www.ucsusa.org/assets/documents/ global_warming/emissions-target-report.pdf.] In addition, UCS analysis indicates that in order to effectively achieve such a long-term goal, U.S. global warming pollution must be cut by more than 20% below 2000 levels by 2020, and at least 50% below by 2030. The need for comprehensive climate policy, both in the near and long term is not properly addressed in the draft EIS, nor is the cost of inaction.

Comment Number: 0575-28
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

Major concern with the draft EIS: The analysis done by NHTSA only presents the reductions in the context of their direct impact relative to all man-made global emissions rather than just the emissions from the sector policy targets. Just because higher U.S. fuel economy standards alone won't solve global warming does not discount the fact that they are a vital, necessary part of the solution. By stating them in terms of the percent reduction from covered vehicles (approximately 30 percent) rather than in percent of worldwide reductions (0.8-1.1 percent reduction according to the DEIS) the value of fuel economy in reducing global warming pollution would be clearer, and less misleading to the public. NHTSA's approach in the EIS is like arguing that we shouldn't worry about smoking in 16 year olds because they only represent a small portion of all smokers. This argument could be applied to any sector of the economy to argue for inaction. Instead we must begin to reduce global warming pollution from every sector as soon as possible.

Comment Number: 0576-6
Organization: Public Citizen
Commenter: Joan Claybrook

For this draft EIS to be useful as a decision-making tool, it must compare the impacts of various alternatives in the proper context. Light duty vehicles built for sale in the United States are part of the whole set of greenhouse gas-emitting sources, regulation of which, as NHTSA has stated, cannot alone stop global warming from happening. [Footnote: See original comment document.] However, the agency has not established a meaningful context, instead choosing to extrapolate the benefits of each alternative over the entire globe 90 years into the future. NHTSA must discuss the benefit of any action in terms of its impact on climate change and it must be placed into a context that includes other strategies to reduce greenhouse gas emissions. This perspective allows for decisionmakers and the public to judge whether the agency's proposed action results in emissions reductions that are consistent with the contribution to emissions from light duty transportation in light of the technological feasibility of making those emissions reductions.

The draft EIS states that none of the proposed alternatives actually result in absolute reductions in greenhouse gas emissions, but instead result in a reduced rate of greenhouse gas emissions from light duty passenger vehicles. [Footnote: See original comment document.] NHTSA must therefore consider fuel economy standards as part of a comprehensive strategy to reduce greenhouse gas emissions from light duty transportation that may include policies that are not within its jurisdiction. NEPA requires "considerations of both context and intensity. . . . [Context] means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action. For instance, in the case of a site-specific action, significance would usually depend upon the effects in the locale rather than in the world as a whole. Both short- and long- term effects are relevant. (40 CFR 1508.27) In this case, significance requires that NHTSA consider impacts in the context of multiple strategies for reducing greenhouse gas emissions from light duty transportation as part of a comprehensive strategy to achieve atmospheric concentrations of greenhouse gases that will prevent the most harmful effects of global warming.

For the context to be meaningful, NHTSA needs to establish a target for greenhouse gas reductions. It can then show how the various proposed alternatives fit into the reductions that are necessary from the U.S. light duty transportation sector to meet that target. Public Citizen supports reduction of atmospheric concentrations of CO_2 to 350 parts per million (ppm) to prevent the most catastrophic effects of climate change. [Footnote: See original comment document.] The policy debate surrounding global warming has considered other targets for atmospheric concentrations, such as 450 ppm or 550 ppm. Public Citizen does not seek to resolve the question of a target for atmospheric concentrations of greenhouse gases at this time, nor does it expect that NHTSA resolve this question in the draft EIS. However, NHTSA must present the regulatory alternatives for fuel economy standards required under EISA such a way as to present a clear choice to decisionmakers and the public. The agency must therefore select a target or range of atmospheric concentrations of greenhouse gases to provide a framework within which it can discuss the relative benefit of different regulatory options.

Comment Number: 0585-7
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary Of The Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

Further, in its cumulative impacts analysis, NHTSA takes into account only the impact of its own rulemaking and ignores actions that can be anticipated in the transportation sector overall, and in other energy sectors in the United States and globally. See, e.g., WCI Statement of Regional Goal; Overview of RGGI CO_2 Budget Trading Program, supra. The DEIS then compares the limited changes in the CAFE sector with worldwide emissions to determine the effect of these changes on CO_2 concentrations and temperature. See, e.g., DEIS at 4-24, 4-31. The analysis demonstrates, not surprisingly, that the change in CO_2 concentrations and temperature caused solely by the CAFE rules will be relatively modest, ranging from 3.5 to 4.9 parts per million (“ppm”) CO_2 concentration, and 0.012 to 0.018 degrees Celsius temperature. Table 4.4-3 at DEIS 4-31.

This comparison is invalid because it considers only the very limited change from the CAFE rules, while ignoring the cumulative impact of all other reasonably anticipated actions that will reduce GHG emissions both in the United States and globally. A proper cumulative impacts analysis requires the agency to consider reasonably anticipated actions by other agencies along with the impact of the CAFE rules, to determine the impact on GHG emissions and global warming.

We recognize that a cumulative impacts analysis is complex in the context of climate change because the problem is global and is being addressed at many levels worldwide. While it is difficult to determine the expected emissions reductions on a global scale, this uncertainty should not result in NHTSA understating the significance of its role in helping to resolve the climate problem. NHTSA thus must make an effort to determine whether better decision-making on its part, and a more stringent CAFE standard, will help to put this country on a path to climate stabilization, even if the Agency, standing alone, cannot resolve the problem.

Comment Number: 0596-5
Organization: Environmental Defense Fund
Commenter: Martha Roberts

We strongly recommend that NHTSA revise this EIS and incorporate a wedge- type analysis of the cumulative emissions resulting from the proposed CAFE alternatives. The EPA transportation sector analysis can serve as a reference, although we find their stabilization target of 560 ppm CO_2 not sufficient to avoid the 2.6 °C increase in global temperature, IPCC’s best current estimate of the threshold that avoids serious climate change effects. We believe the EIS must adopt the 440 ppm CO_2 atmospheric stabilization target identified by the IPCC unless the agency can point to other analyses of equal or greater credibility that justify the use of a higher CO_2 target to reach the same temperature goal.

As a demonstration, we have followed the framework of the EPA's wedge analysis and utilized the predicted future GHG emissions provided in the EIS. We demonstrate in a simplistic manner the contributions of the various CAFE alternatives to a U.S transportation sector target of flattening emissions at 2006 levels. Under the "no action" alternative, cumulative GHG emissions beyond the 2006 baseline total 28,000 MMT [million metric tons] CO_2e [CO_2 equivalent] by the year 2050. The "optimized" alternative results in 21,000 MMT CO_2e and the "technology exhaustion" option releases 18,000 MMT CO_2e. These two options contribute 1.6 wedges ("optimized") and 2 wedges ("technology exhaustion") of 5,000 MMT CO_2e towards flatlining transportation GHG emissions at 2006 levels (figure 2). We note that the EPA's analysis finds 2.4 to 3.0 wedges result from technology exhaustion, while NHTSA claims that this leads to only 2 wedges. We urge NHTSA to account for this difference in their revised EIS, with special attention given to assumptions regarding hybrid vehicle technology.

Increasing fuel efficiency on its own cannot mitigate U.S. transportation-related GHG emissions to an extent that avoids dangerous climate change. However, the transportation sector can stabilize its GHG emissions with a package of approaches. Rapidly increasing fuel efficiency is a key component to reducing cumulative GHG emissions over the next decades, as the EPA recognizes that "[n]ear-term vehicle technologies can have as much of an impact in terms of GHG reductions as future, longer-term technologies." [Footnote: See original comment document.]

Comment Number: 0598-10
Organization: Sierra Club
Commenter: Caroline Keicher

NHTSA should consider the Supreme Court decision in *Massachusetts v. EPA* and that the Court stated, on pages 2 1-23 concerning vehicle emissions, that "reducing domestic automobile emissions is hardly a tentative step." The Court also noted that cars and trucks account "for more than 6% of worldwide carbon dioxide emissions. To put this in perspective: Considering just emissions from the transportation sector, which represent less than one-third of this country's total carbon dioxide emissions, the United States would still rank as the third-largest emitter of carbon dioxide in the world, outpaced only by the European Union and China. Judged by any standard, U.S. motor-vehicle emissions make a meaningful contribution to greenhouse gas concentrations and hence, according to petitioners, to global warming."

This DEIS turns these words on their head – diminishing the differences between the options (which are too low to begin with) and failing to meaningfully express the role fuel economy can have on U.S. emissions. In addition, by allowing that Massachusetts had legal standing in the findings of *Mass. v. EPA*, the Court also recognized the importance of the remedy – that even a small step provides relief from global warming. We would agree that increasing fuel economy, while an important part of this remedy, cannot be the only solution.

Comment Number: 0598-6
Organization: Sierra Club
Commenter: Caroline Keicher

We also have serious concerns that the DEIS fails to meet its primary function to "inform the public that [the agency] has indeed considered environmental concerns in its decision-making process." In this case the agency does not give a fair or reasonable evaluation of the environmental impacts of the proposed standards nor does NHTSA provide a context that reasonably informs the public.

The DEIS takes the real differences between the flawed options considered and runs them so far out – to 2100 – that they cannot meaningfully be differentiated or evaluated. Faster fuel economy increases will help the U.S. cut the 20% of CO_2 emissions that come from vehicles. The difference between 35 in 2015 and 35 in 2020 is real and significant. It creates room for reaching 42 mpg in 2020 – and increases beyond (surpassing 50 mpg by 2030). It would also mean saving an additional 880,000 barrels of oil per day in 2020 and further reductions in emissions.

It is worth noting that the DEIS reveals that this one policy is significant enough that it could affect the climate in 2100 assuming no other action is taken. The problem with NHTSA's analysis is that if we hit 700 plus ppm referenced in the DEIS, then we have not acted to prevent dangerous climate change as provided in Article 2 of Framework Convention on Climate Change.

There is no requirement that NHTSA run its analysis though 2100. NHTSA notes that the VOLPE model estimates emission reductions through 2060. The agency provides that "as a simplifying assumption, annual emissions reductions from 2061-2100 were held constant." NHTSA should assess how the correct scenarios will impact emissions from cars and light trucks in a time frame that is meaningful to the public, within the context of science, and not "simplify" its "assumptions."

Comment Number: 0598-8
Organization: Sierra Club
Commenter: Caroline Keicher

The DEIS fails to analyze the benefits of greenhouse gas emission reductions from various fuel economy standards in the proper context. Not surprisingly, when NHTSA tries to determine the global warming impacts in 2100 resulting from a 31.6 mpg in 2015 standard vs. a 35 mpg in 2015 standard, statistically, the difference is very little. But this does not mean that raising fuel economy standards faster will not have a significant impact in our struggle to reduce global warming pollution.

In order to prevent the worst effects of climate change, the U.S. must decrease its carbon emissions by around 80% by 2050 – with meaningful short-term and interim targets. In order to be on-target for reductions such as these, by 2020 the U.S. needs to reduce its carbon emissions back to at least 1990 levels. The Environmental Protection Agency's (EPA) Greenhouse Gas (GHG) emission inventory reports that 1990 levels were 6,147 Million Metric Tons of CO_2 ($MMTCO_2e$). If our emissions continue to grow, along a "business as usual" trajectory, EPA estimates that by 2020, carbon emissions will have grown to 8,264 $MMTCO_2e$. Therefore, in order to return to 1990 emission levels by 2020, we must cut (=8,264-6,147) 2,116 $MMTCO_2e$ worth of greenhouse gas pollution from various sources by 2020, or equivalent to a 25% decrease in emissions.

Now, considering that the transportation sector is responsible for nearly a third of all GHG emissions in the U.S., with cars and light trucks accounting for 20%, it would make sense that we must proportionally reduce emissions from cars and light trucks to help meet this overall 2,116 $MMTCO_2e$ reduction. Since 20% of emissions come from cars and light trucks, 20% of the 2,116 $MMTCO_2e$ target reduction, or 423 $MMTCO_2e$, should come from cars and light trucks.

Comment Number: TRANS-05-5
Organization: Consumer Federation of America
Commenter: Mark Cooper

The analysis of environmental impact suffers from the same affliction, because improvements in fuel economy alone do not solve the climate change problem. They are shown to have zero effect on the damage that global warming will do. Yet every reasonable analysis of the big picture and the global impact of greenhouse gas emissions recognize that the reduction of emissions in the transportation sector must play a large role in the overall solution. Indeed, because of the nature of the sector, it is vital to get the maximum contribution from transportation sources. NHTSA's approach embodies a myopic bias against action. Because no individual policy can solve the problem, this approach will reject every policy measure individually, even though taken together they can actually do the job. In NHTSA‘s view the whole is not even equal to the sum of the parts.

Comment Number: TRANS-06-8
Organization: Public Citizen
Commenter: Lena Pons

Considering that this is a new type of environmental impact statement, because it considers global impacts, it's very important that the agency put the impacts in a proper context. The agency has not put the environmental impacts into a proper context, considering the issues of global warming. Regardless of the target, NHTSA needs to provide some means of comparing the various alternatives. The way the draft environmental impact statement is currently contextualized, NHTSA states that fuel economy standards alone cannot stop global warming. But the issue is not whether fuel economy standards alone can stop global warming. The issue is to evaluate various environmental impacts of the various regulatory alternatives.

Comment Number: TRANS-07-3
Organization: Individual
Commenter: Eliza Berry

The draft environmental impact statement does not use the appropriate scale with which to measure the benefits of an increase in fuel economy standards. This scale has only allowed NHTSA to prove that a 3.4 mile per gallon increase in vehicle efficiency in the U.S. is not going to be the one thing to save the entire planet from global warming. I don‘t think that very many people would be surprised by this conclusion.

By measuring the importance of a shift in fuel economy standards like this, NHTSA has fundamentally missed something. Few people would claim that there is one silver bullet to solving global warming. Rather, we need to do everything in our power to cut greenhouse gas emissions in all sectors, the transportation sector included.

Together these seemingly small changes will make a major difference. And if the U.S. leads the way in cutting emissions, other countries will follow, thus making an even greater difference on a global scale.

I would like to ask NHTSA to acknowledge the power of collective action and take responsibility for greenhouse gas emissions from the transportation sector. As I have explained, the intergovernmental panel on climate change has emphasized the importance of requiring that greenhouse gas emissions reach their peak in no more than 10 years.

Comment Number: TRANS-08-13
Organization: Sierra Club
Commenter: Ann Mesnikoff

In this case the agency does not give a fair or reasonable evaluation of the environmental impacts of the proposed standards, nor does NHTSA provide a context that reasonably informs the public.

The draft environmental impact statement takes the real differences between the options considered and runs them out so far to 2100 that they cannot meaningfully be differentiated or evaluated. Faster fuel economy increases will help the U.S. cut the 20 percent of CO_2 emissions that come from vehicles.

The difference between 35 in 2015 and 35 in 2020 is real. It is worth noting that the draft environmental impact statement reveals that this one policy could affect climate in 2100. The problem with NHTSA‘s analysis is that if we hit 700 parts per million plus, referenced in the DEIS, we have not averted dangerous climate change.

There is no requirement that NHTSA run its analysis through 2100. NHTSA notes that its Volpe model estimates emissions reductions through 2060. The agency provides, as a simplifying assumption, annual emission reductions from 2061 to 2100 were held constant. NHTSA should assess how the correct scenarios will impact emissions from cars and trucks in a time frame that is meaningful to the public, and within the context of science, not simplifying assumptions.

Fuel economy is only one policy in the tool bag. It will diminish the 20 percent of CO_2 that comes from cars and trucks, but we must achieve and 80 percent reduction below 2000 levels by 2050 if we are to avert dangerous climate change.

Comment Number: TRANS-09-4
Organization: Individual
Commenter: Doug Molof

NHTSA‘s draft EIS fails to analyze, also, the benefits of greenhouse gas emissions reductions through various fuel economy standards in the proper context. Not surprisingly, when NHTSA tries to determine the difference in global ocean temperature rise in 2100, resulting from a 31.6 mile per gallon standard in 2015, versus a 35 mile per gallon standard in 2015, statistically there is no difference.

But emissions from the transportation sector in the United States account for roughly 20 percent of our country‘s greenhouse gas pollution. And as any projection, decreases in greenhouse gas emissions arising from increased fuel economy standards can never be greater than this. These reductions should be considered as a proportion of the 20 percent, not as a proportion of the entire planet‘s combined carbon admissions.

This can simply overwhelm any measurable progress. Success and progress should be measured by how close these fuel economy improvements get us to reducing the transportation sector‘s carbon emissions by 80 percent in 2050. To do otherwise fails to realistically evaluate vehicle emission reductions as a key part of the overarching strategy to curb global climate change.

Comment Number: TRANS-13-3
Organization: Individual
Commenter: Joseph Frewer

As you‘ve heard multiple times, the scientific conclusion is that to mitigate the worst effects we really need to cut our carbon pollution by 80 percent by 2050.

And many of us are agreed that the best way to do this is by utilizing every tool we can. We‘ve got to look at every aspect of our economy, not only the transportation sector, which is addressed here, but many other parts, industrial – I don‘t need to go into them.

But this 20 percent is part of a bigger picture, and we must take that into account when looking at a global solution. Just because it‘s 20 percent doesn’t mean that it’s any less important and that it can be ignored, just because when you look at in the context of 100 percent global emissions picture, it doesn’t seem that important as it is.

NHTSA's draft environmental impact statement fails to analyze the benefits and reduction for fuel economy standards in the proper context because it is going by the bare minimum. As we have said, I'll try not to go into the same statistics that we've heard, but 31.6 miles per gallon, the bare minimum, just won't cut it. There are already cars being released that promise to offer more than 31.6 miles per gallon of gasoline.

Comment Number: TRANS-19-1
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

The fuel economy standards are being measured for their global impact, even though they only affect a portion of all manmade sources of global warming pollution.

Comment Number: TRANS-19-3
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

Analysis by UCS [Union of Concerned Scientists] shows that one part of achieving that goal means the United States must cut its global warming pollution at least 80 percent compared to emissions levels in 2000. In addition, our analysis indicates that in order to effectively achieve such a long term goal, we have to start now. We have to reduce our pollution 20 percent below 2000 levels by 2020 and at least 50 percent below by 2030. The need for these long term targets and immediate action is not effectively covered in the EIS, and the cost of inaction of the size of this challenge also should be better reflected.

Comment Number: TRANS-19-4
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

Unfortunately, the analysis done by NHTSA only presents the reductions from the fuel economy rule in the context of their direct impact relative to all manmade global emissions, rather than just the emissions from our cars and trucks. Because higher fuel economy standards alone won't solve global warming does not discount the fact that they are a vital, necessary part of the solution. By stating them in terms of their percent reduction from the sector, approximately 30 percent, rather than a percent of world reductions which is .8 to 1.1 percent, according to the draft EIS, the value of the fuel economy in reducing global warming pollution and helping us meet those near term targets will be clear and less misleading to the public.

Comment Number: TRANS-20-2
Organization: Sierra Club
Commenter: Caroline Keicher

In the short term this is going to mean that we need to reduce our emissions between 25 and 40 percent by 2020, so a much sooner time line. This is a much bigger number, and this is what's most relevant with these new CAFE increases.

If we're going to evaluate how an increase in corporate average fuel economy affects global warming, this is the target that we should be focused on, not some obscure number in 2100.

Comment Number: TRANS-20-5
Organization: Sierra Club
Commenter: Caroline Keicher

The scientists made it clear that to avoid the worst effects of global climate change, we must achieve 80 percent reduction in our emissions by 2050. This gives us approximately 40 years to get our act together, and we have no time to lose.

Unfortunately, there is no single thing that we can do, or single sector in our economy that we can cut to get us all the way there. We must instead start making manageable emission reductions from each single carbon emitting sector of our economy. And when considering the benefits of doing so, we must consider each reduction as part of the larger long term goal, both for the United States and globally. Each reduction that we fail to make in one area will have to come from somewhere else.

The most disappointing thing for me about NHTSA's draft environmental impact statement is that it fails to analyze the benefits of greenhouse gas emission reductions from various fuel economy standards in the proper context. Not surprisingly, when NHTSA tries to determine the global warming impacts resulting in 2100 from various standards, 31.6 miles per gallon in 2015 versus 35 miles per gallon, there isn't statistically much of a difference.

And this isn't surprising. It also doesn't mean that raising fuel economy standards faster will not have a significant impact in our struggle to reduce global warming pollution.

Emissions from the transportation sector in the United States account for roughly one-third of our greenhouse gas emissions, with cars and light trucks coming in at about 20 percent. That's a fairly large chunk of our contribution to this global problem.

So what is the proper context? How do we consider these various CAFE increases? Globally the science has called for long term reductions of emissions of about 50 percent for the entire world by 2050. Here in the U.S. as an industrialized nation that accounts for nearly a fourth of world carbon dioxide emissions, this translates for us into about 85, 80 to 95 percent needed reductions below 2000 levels by 2050.

Comment Number: TRANS-21-1
Organization: Individual
Commenter: Christina Marie Yagjian

NHTSA's draft environmental impact statement fails to analyze the benefits of greenhouse gas emissions, emission reductions from fuel economy standards in the proper context. As I mentioned, we know that emissions from the transportation sector account for roughly 20 percent of the country's global warming pollution.

The EIS projected decreases in emissions rising from increased fuel economy standards are analyzed as a proportion of combined global carbon emissions. This figure is more clearly evaluated when presented as a proportion of the current 20 percent of domestic emissions.

Comment Number: TRANS-21-4
Organization: Individual
Commenter: Christina Marie Yagjian

The science has made it clear that to avoid the worst effects of global warming, we must achieve 80 percent reductions in global warming emissions by 2050. As cars and light trucks account for 20 percent of the country's global warming emissions, the single biggest step that we can take in this country to reduce global warming emissions, save consumers money at the gas pump, and reduce America's dependence on foreign oil is to make our cars and light trucks go further on a gallon of gas.

Comment Number: TRANS-24-7
Organization: Individual
Commenter: Heather Moyer

Although there is no silver bullet to get us to an 80 percent reduction in carbon emissions by 2050, the single biggest step we can take in this country to reduce our global warming emissions, save consumers money at the pump, and reduce our dependence on foreign oil, is to make our cars and trucks go farther on a gallon of gasoline.

Comment Number: TRANS-27-2
Organization: Individual
Commenter: Sarah Karlin

The science has made it clear that in order to avoid the worst effects of global warming, we must achieve an 80 percent reduction in greenhouse gases by 2050. At first glance, this may seem like a daunting task, but if we start now, and if like the Little Engine That Could, we believe we can, the U.S. can achieve the necessary emission cuts to prevent the most tragic impacts of climate change.

Yet NHTSA's draft environmental impact statement fails to analyze the benefits of greenhouse gas emission reductions from various fuel economy standards in the proper context.

Not surprisingly, when NHTSA tried to determine the difference in global ocean temperature rise in 2100, resulting from a 31.6 miles per gallon in 2015 standards, versus a 35 mile per gallon in 2015 standards, statistically there is none.

But this does not mean that raising fuel economy standards faster will not have a significant impact in our struggle to reduce global warming pollution. Emissions from the transportation sector in the United States account for roughly 20 percent of our country's greenhouse gas pollution, and as any projected decreases in greenhouse gas emission arising from increased fuel economy standards can never be greater than this, those reductions should be considered as a proportion of the 20 percent, not as a proportion of the entire planet's combined carbon emission. The latter simply overwhelms any measurable progress.

Adequate fuel economy standards can help the U.S. make a significant dent in our overall carbon emissions by 2050. Sure, other measures will need to be taken to meet the 80 percent reduction by 2050. But the transportation sector must play its part.

Comment Number: TRANS-32-4
Organization: Environmental Defense Fund
Commenter: James Keck

By presenting only the isolated impact of this one set of U.S. regulations upon the entirety of global climate change, and then asserting that health and other impacts are too uncertain to distinguish among the range of alternatives, NHTSA is certainly closing its eyes to the context of this regulation as well as the full set of cumulative impacts relevant to this EIS.

The EIS draws heavily upon the most recent IPCC report in describing the causes of climate change and its impacts on the environment and human welfare. However, the EIS ignores the IPCC's description of targets for avoiding the most drastic of these impacts. For example, the IPCC states that avoiding a temperature increase of more than 2.6 degrees centigrade from pre-industrial times reduces the risk of key environmental and health vulnerabilities, and to do this greenhouse gas emissions must peak within 10 years, and atmospheric carbon dioxide levels stabilize at less than 440 parts per million.

The absence of this critical context within the EIS leaves the public and policy makers unclear whether the preferred CAFE alternative will support a cumulative strategy to avoid the most serious climate change impacts. Although the IPCC report provides a clear context and benchmark by which NHTSA can assess the alternatives, the EIS has failed to do so.

Comment Number: TRANS-35-4
Organization: Individual
Commenter: Alina Fortson

In order to address climate change, scientists are stressing the importance of achieving an 80 percent reduction in greenhouse gas emissions by the year 2050. This means making small reductions in all of our emission areas, including transportation.

The United States transportation sector amounts to approximately 20 percent of our total greenhouse gas emissions. Therefore, measuring our progress requires considering reductions as a portion of that 20 percent, not as part of the global emissions. In this light, every small improvement does make a difference.

Comment Number: TRANS-36-1
Organization: Individual
Commenter: Matt Kirby

So now the science says we need 80 percent reductions by 2050, as several people have said. And one of the most significant being the cars and light trucks, the 20 percent, the 20 percent of emissions in this country, which emits 25 percent of global emissions. 20 percent of 25 global emissions. That’s the power you have. And that’s what you can change and significantly alter the course of global warming.

As far as the environmental impact statement goes, we know we need to look at this proportionally to our domestic emissions, to our 20 percent of our domestic emissions, and not as part of the global outreach to get a better idea of how to evaluate it.

Also, NHTSA has picked 2100 as a time line for measuring success, which seems a little ridiculous, considering we have until 2050 to avert catastrophic climate change. So I would urge you to actually set a much closer goal, 2020-25 when you actually are going to begin measuring the success.

Comment Number: TRANS-37-4
Organization: Individual
Commenter: Jaafar Rizvi

While the DEIS report shows very detailed calculations and extensive research, the claims of NHTSA just don’t coincide with the claims of other incredibly credible scientific institutions. Like so many people have said, there’s a call for 80 percent reductions by 2050, and this report doesn’t seem to acknowledge that.

And that’s fine, of course, but since, you know, research was done, but there’s no description of where the divergence is coming from.

Comment Number: TRANS-41-3
Organization: Individual
Commenter: Catherine Easton

Global warming is happening right now, and reducing greenhouse gas emissions by 80 percent by 2050 will save us from the worst effects of global warming. But unfortunately, as I think we've all noticed, 80 percent is a lot and increasing CAFE standards will not achieve this.

In fact, no individual sector could reach such a dramatic decrease. And this is why we must strive for smaller achievable decreases in all sectors. These small decreases combined could make a substantial difference.

Comment Number: TRANS-44-1
Organization: Individual
Commenter: Emily Spear

Increasing fuel economy standards would be one step in curbing global warming. Scientific reports have concluded that in order to avoid catastrophic effects of global warming, we must reduce our greenhouse gas emissions by 80 percent by 2050, 2050.

This issue is staring us in the face, but I believe that NHTSA can do its part by requiring vehicles to be more fuel efficient. We know that carbon emissions from transportation mechanisms are great at 20 percent, which contribute directly to global warming. However, it concerns me when NHTSA's draft environmental impact statement analyzed the resulting benefits of greenhouse gas emissions from higher fuel economy standards in an improper context, which makes the greenhouse savings appear insignificant, though increasing fuel economy standards to 35 miles per gallon by 2015 would save 280 million metric tons of carbon dioxide.

Response

The comments above share the themes that the DEIS diminished the effect of the CAFE standards by evaluating them in a global context (thus, their effect on climate conditions would be small, and their contribution to total emissions reductions required to meet any of several long-term stabilization goals would be small); that a timeline stretching to 2100 is too long; and that the environmental impacts can only be characterized adequately if this rulemaking is considered in light of all other possible actions to mitigate climate change.

NEPA requires NHTSA to analyze the reasonably foreseeable environmental impacts of a range of alternatives in setting new CAFE standards for MY 2011-2015. According to NEPA, the alternatives are the "heart of the environmental impact statement." 40 CFR § 1502.14. Under EPCA, as amended by EISA, NHTSA is required to set standards at the "maximum feasible" level, considering technological feasibility, economic practicability, the effect of other government motor vehicle standards on fuel economy, and the need of the United States to conserve energy." 49 U.S.C. § 32902(f). NHTSA has a long-standing practice of analyzing regulatory options based on the best available information regarding: (1) the future vehicle market, (2) the technologies expected to be available during the relevant model years, and (3) the key economic factors, such as future fuel prices, and other statutory factors. The Volpe model is a tool NHTSA uses to help balance these factors. NHTSA has rigorously explored and objectively evaluated the range of possible alternatives, including reasonable alternatives not within the agency's jurisdiction, to provide decisionmakers and the public with information on a broad range of *impacts. NHTSA took the requisite "hard look" at environmental impacts, quantified to the degree possible, from these alternatives.*

Climate change is a global phenomenon. GHGs persist in the atmosphere, and the effects of a given level of emissions in one location occur no matter the location of the emissions. Thus, the appropriate scale is to evaluate the effects of this rulemaking in relation to global emissions and global climate conditions. This is the standard approach for climate modeling. While Sections 3.4 and 4.4 of this FEIS show that the differences in climate effects (CO_2 concentration, temperature, sea–level rise, precipitation) might seem small when expressed in terms of climate endpoints, NHTSA agrees with commenters that this is likely to be true for any given GHG mitigation strategy when taken alone. NHTSA's hard look at the rule's effect on global climate conditions is not intended to diminish the effectiveness or importance of the regulatory options in reducing CO_2 emissions and global warming impacts, but to quantify these potential reductions using the best available science.

Several commenters stated that NHTSA is claiming a reduction in emissions even though total vehicle emissions are rising over time. Specifically, CBD stated that Figure 1-1 on page 24358 of the NPRM titled "CO_2 tailpipe emissions avoided due to increases in fuel economy 1975-2005" was misleading because total vehicle emissions increase over time. NHTSA does not have the authority to control factors that affect total vehicle emissions, such as the number of vehicle miles traveled. NHTSA's CAFE standards set minimum requirements for the fuel efficiency of the vehicles used in travel. In the absence of these minimum requirements, the actual emissions release (if all other factors stayed the same) would be higher. Consequently, NHTSA states that the CAFE rulemaking results in reduced emissions levels compared to not having implemented the regulations. To help the reader understand that the rulemaking reduces the rate of increase of emissions, NHTSA has included a new analysis and a diagram in Section 3.4.4.1 of this FEIS showing the reduction in emissions rates.

To complement the analysis of climate effects, Section 3.4.4.1 of this FEIS includes a section on emissions reductions, putting them in context by comparing them to other large-scale regional programs in the United States. This indicates that the emissions reductions (in relation to Alternative 1, the No Action Alternative) are indeed quite large compared to the other programs. Even though the initiatives might vary in their approach, goals, and reduction comparisons, this discussion places the contribution of this rulemaking in the context of current CO_2 reduction plans.

A theory on climate change mitigation promulgated by Pacala and Socolow (2004), called the Wedge Theory, shows that by taking numerous actions that reduce CO_2 from various sectors, overall there can be CO_2 reductions great enough to reduce further global warming. As several commenters point out, the alternatives identified in this FEIS serve as another contribution to reduce CO_2 emissions that requires a global effort to be successful. NHTSA has expanded the discussion on this issue. <u>See</u> FEIS Section 3.4.4.1.

On the point that environmental impacts can only be characterized adequately if this rulemaking is considered in light of all other possible mitigation actions, IPCC notes that the momentum in the climate system is enormous, and that it would take large-scale action across many sectors and nations to deflect the current course of climate change. These large-scale actions remain to be determined (specific courses of action are not reasonably foreseeable) and they are outside NHTSA's regulatory purview. As discussed in detail in Section 4.4.4.1, U.S. cars and light trucks account for 19.2 percent of CO_2 emissions in the U.S. and about 2.5 percent of global CO_2 emissions. NHTSA's influence from this rulemaking can only affect this set of emissions, and only a portion of that, because NHTSA does not directly control VMT. Establishing national policy or GHG targets (such as an 80 percent reduction by 2050) exceeds NHTSA's authority. Addressing climate change in a meaningful way would likely require new Congressional legislation in conjunction with that from other nations.

Nevertheless, NHTSA fully appreciates the fact that, despite the complex global nature of the problem, NHTSA still has an obligation to take the requisite "hard look" regarding, the effects of this rulemaking on global warming within the context of other actions that affect global warming. Thus, NHTSA believes that the range of alternatives considered in the DEIS and this FEIS will fully inform the decisionmaker and the public about the environmental impacts, including climate change issues, of any CAFE standard that is reasonable to promulgate.

Contrary to several comments, the emissions analysis provides important information concerning the differences between the alternatives. Table 3.4-2, in particular, provides the emissions impact of each alternative for each decade through 2060.

Many comments appear to draw the conclusion that NHTSA does not think the CO_2 reductions from the rulemaking are important and that NHTSA does not show differences between the alternatives. NHTSA recognizes that merely because the reductions are small in a global context does not mean they are unimportant. In addition, NHTSA's analysis shows clear emissions reductions between the alternatives, even if not every climate effect shows measurable differences. NHTSA's environmental analysis differentiates the various alternatives presented in the DEIS and this FEIS.

On the issue of the timeline used in this analysis, the DEIS and this FEIS present climate effects not only for 2100 (a benchmark commonly used in climate change analysis), but also for 2050 and 2075. See DEIS Section 3.3.2.1.2; FEIS Section 3.3.2.2. Thus, the results at earlier points in time are also available to support decisionmaking. At least one commenter suggested that analysis to the year 2100 is not meaningful. Analysis to the year 2100 is necessary to consider NHTSA's action in light of the IPCC's projections and to the extent possible, to identify climate effects. Recognizing the difficulty of forecasting so far into the future, NHTSA tries to limit the number of moving variables to demonstrate the reduction in impacts associated with the various alternatives, while using IPCC emissions projections.

The effects of CO_2 emissions have been modeled and observed but are still difficult to accurately predict. The likely range of the climate sensitivity, which represents the increase in global warming due to increases in CO_2 emissions, ranges from 2.5 to 4.5 ºC. In this FEIS, NHTSA performs an analysis of variations under climate sensitivities of 2.5 and 4.5 ºC. See Section 4.4.4.2.1. The rate and ultimate levels of sea-level rise due to increases in CO_2 concentrations are also uncertain and estimated within very large ranges in the IPCC's Fourth Assessment Report. Recent literature suggests that the IPCC Fourth Assessment Report might have been low in its estimates of sea-level rise resulting from GHG concentration levels from the Special Report on Emission Scenarios (SRES) scenarios.[3] The different SRES scenarios illustrate the uncertainty in future emissions of greenhouse gases, which affect the impact of the CAFE standard alternatives on global mean surface temperature, sea-level rise, and CO_2 concentrations.

Several of the comments involved the issue of sudden and abrupt climate changes (or tipping points). In Section 3.4.3.2.4 of this FEIS, NHTSA has expanded its consideration of the issue of tipping points to include new research, as suggested by commenters, and has expanded the discussion from the IPCC and CCSP literature. NHTSA also includes paleoclimatic research, as suggested by commenters, which supports the theory that abrupt and severe climate change has occurred in the past, and that these changes could occur in multiple climate systems or other climate-related systems on the planet that affect global climate patterns. Readers are encouraged to review FEIS Section 3.4.3.2.4 and NHTSA's detailed response on the issue of tipping points. See Section 10.3.3.

[3] *The SRES scenarios are long-term emissions scenarios representing different assumptions about key drivers of GHG emissions. They are described in more detail in Section 3.4 of this FEIS.*

Finally, several commenters asked NHTSA to state the projected emissions reductions in terms of the overall U.S. transportation emissions sector. NHTSA has expanded the discussion of emissions in FEIS Section 3.4.4.1 to show the emissions reductions in the context of total emissions from cars and light trucks in the United States and to provide a more detailed description by sector.

10.2.1.1 Clarifying Comparative Reduction Plans

Comments

Comment Number: 0585-3
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary Of The Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

The DEIS must clarify that GHG emissions from passenger cars and light trucks will continue to increase from past levels.

One of the most significant pieces of information that must be clarified in the DEIS is that, under the new CAFE rule, GHG emissions from passenger cars and light trucks will continue to rise over past levels, because the increase in miles per gallon ("mpg") mandated by the rule will not completely offset the increase in vehicle miles traveled ("VMT").

Rather than making this increase clear, the DEIS buries the information in the text of the document (*e.g.*, DEIS at 3-57) and repeatedly refers to the *reductions* in emissions, CO_2 concentration, and temperature. [Footnote: See original comment document.] In fact, the only reduction is in the amount of growth in each of these measures over what would otherwise occur without the new rule. The absolute levels are rising and will continue to rise. This distinction must be made clear both in the labeling of the graphs and figures, and in the text of the DEIS.

Response

NHTSA acknowledges that the absolute level of GHG emissions will continue to rise over current levels. This was expressed throughout the DEIS and remains in this FEIS, explicitly in Figure 3.4-4 and Table 3.4-1. The increase in emissions from factors such as an increase in vehicle miles traveled (VMT) is beyond NHTSA's jurisdiction to control. As explained in the NPRM and the DEIS, EPCA (as amended by EISA) requires NHTSA to set average fuel economy standards at least 18 months before the start of each model year and to set them at "the maximum feasible average fuel economy level that [NHTSA] decides the manufacturers can achieve in that model year." 49 U.S.C. §32902(a). In view of this statutory directive, it is not reasonable for NHTSA to explore strategies related to the quantity of vehicle miles traveled by the public. However, NHTSA notes that VMT is related to fuel economy in that higher stringency standards will generally increase VMT (because the per-mile cost of fuel decreases). This is known as the "rebound effect," and is considered by the Volpe model. Similarly, increasing fuel prices will generally decrease VMT. Thus, although CAFE standards indirectly affect VMT, the agency is not authorized to control the growth of VMT.

NHTSA has framed its analysis in terms of reductions because the levels of fuel savings and emissions are projected to be below what they would be without the new CAFE standards, i.e., compared to the emissions reductions that would occur if CAFE levels remained at their MY 2010 levels (the higher of a manufacturer's plans and the manufacturer's required level of average fuel economy for MY 2010).

CEQ's NEPA implementing regulations require that the alternatives be compared against a "no action" alternative – an alternative that projects what emissions levels would be if the proposed action was not implemented. NHTSA's No Action Alternative assumes that the agency would not issue a rule regarding CAFE standards. The MY 2010 fuel economy level (27.5 mpg for passenger cars and 23.5 mpg for light trucks) represents the standard NHTSA believes manufacturers would continue to achieve, assuming that the agency did not issue a rule.

Comparison to a "no action" alternative is done to draw a clearer, more refined distinction in the analysis of the standards and alternatives. NHTSA has endeavored to address this comment from the Attorneys General through additional discussion in Section 2.3.1 of this FEIS. In addition, NHTSA has performed additional analysis to calculate emissions reductions based on different IPCC emissions scenarios, including more aggressive emissions increase scenarios. See Section 4.4.3.5.

10.2.1.2 Effects on Other Countries' Standards

Comment

Comment Number: 0554-8
Organization: Individual
Commenter: James Adcock

NHTSA's analysis of GHG emissions assumes implicitly these regulatory changes only affect the behavior of vehicles in the United States. However most manufacturers are world-wide and can be expected to apply developed technology world-wide. Further, if the U.S. reduces GHG emissions from vehicles that should be expected to engender at least some amount of goodwill "diplomatic synergy" with other nations, particularly with Europe. If the U.S. reduces vehicle GHG Europe can also be expected to reduce vehicle GHG. If a 10% reduction in U.S. vehicle GHG resulted in a 10% reduction in European vehicle GHG one would have 100% diplomatic synergy between the regions. NHTSA is currently assuming implicitly 0% diplomatic synergy, *i.e.*, "Cowboy Diplomacy" where the U.S. acts alone without any other nation following suit. Since both major candidates for the presidency during the years of these regulations have pledged better cooperation with other nations NHTSA should be assuming something more than 0% diplomatic synergy. Further, U.S. GHG reductions from vehicles can be a starting point for cooperation in reducing GHG in other areas, increasing even more the "diplomatic synergy." NHTSA implicitly is assuming a value of 0% for all these synergies when NHTSA rationally should be expecting a higher value.

Response

One commenter suggested that there is a certain level of "diplomatic synergy" that would occur from NHTSA's rulemaking. The commenter states that NHTSA errs by not including the benefits that would occur if other countries increase their fuel economy because of this rulemaking. The international impacts of this rulemaking remain difficult to assess and are not quantifiable, and the commenter did not suggest how the agency could reasonably do so. NHTSA cannot accurately predict the actions of other countries and would point out that fuel economy standards differ from country to country.

10.2.2 VOLPE MODEL

Comments

Comment Number: 0576-27
Organization: Public Citizen
Commenter: Joan Claybrook

In the fuel economy standards for 1981-1984, set in 1977, NHTSA said "[a] cost benefit analysis would be useful in considering [economic practicability] but sole reliance on such an analysis would be contrary to the mandate of th[e Energy Policy and Conservation] Act." (42 *FR* 33537). But such reliance is precisely what the agency has done — it uses a cost benefit analysis to set the standards based on economic practicability as its first criterion.

NHTSA justifies this approach by citing *Public Citizen v. NHTSA* in its 2005 NPRM on light truck fuel economy standards ". . .in determining the maximum feasible level of CAFE, the agency assesses what is technologically feasible for manufacturers to achieve without leading to adverse economic consequences, such as a significant loss of jobs or the unreasonable elimination of consumer choice." [Footnote: See original comment document.] Public Citizen acknowledges that Congress in EPCA named economic practicability as one of the four factors, and that the court in *Public Citizen v. NHTSA* said that consumer choice was part of economic practicability; however, in *Center for Biological Diversity v. NHTSA*, the court states:

> Whatever method it uses, NHTSA cannot set fuel economy standards that are contrary to Congress's purpose in enacting the EPCA—energy conservation. We must still review whether NHTSA' s balancing of the statutory factors is arbitrary and capricious. . . .The need of the nation to conserve energy is even more pressing today than it was at the time of EPCA's enactment. . . . What was a reasonable balancing of competing statutory priorities twenty years ago may not be a reasonable balancing of those priorities today. (*Center for Biological Diversity v. NHTSA*, 508 F. 3d 508 at 14869-71.)

This shift of priorities is exactly relevant to the current situation. Fuel economy has become a significant public concern as gas prices have risen sharply. [Footnote: See original comment document.] Only NHTSA hasn't appropriately responded to these trends, and the Volpe Model, with its now outdated economic assumptions, would set fuel economy standards at a level that is less than consumers need based on a balancing of the statutory factors that does not reflect the current priorities.

Comment Number: 0576-37
Organization: Public Citizen
Commenter: Joan Claybrook

Public Citizen opposes the use of marginal cost-benefit analysis in estimating the maximum feasible level of fuel economy, as this type of economic analysis structurally fails to set the maximum feasible level.

Comment Number: 0572-37
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Furthermore, the DEIS fails to consider the economic costs of the collapse of the ocean food web. This cost must be included in any cost-benefit assessment conducted by NHTSA to accurately reflect the proper balance between the costs and benefits of reducing CO_2 emissions.

Comment Number: 0572-40
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The cost-benefit analysis is incomplete because it does not include a monetization of the impacts of black carbon.

Response

Regarding the potential costs associated with ocean acidification and black carbon expressed by the Center for Biological Diversity (CBD), NHTSA considers the societal costs of carbon dioxide emissions by including a monetary value for the "social cost of carbon emissions" in the Volpe model. That value per ton of carbon is the agency's effort to account for the economic value of reductions in CO_2 *emissions. Toward this end, NHTSA took a hard look at numerous published estimates of the social cost of carbon emissions, which assess and monetize future economic damages from climate change. The agency believes that the values in these peer-reviewed studies include damage to the ocean due to carbon emissions, and thus, NHTSA does not explicitly consider ocean acidification's impact on the food web in the Volpe model. However, due to the agency's analysis of peer-reviewed published estimates of social cost of carbon, NHTSA is confident that the social cost of carbon used in the Volpe model addresses CBD's concern.*

NHTSA explained in the DEIS that ocean acidification due to increases in CO_2 *emissions, the cause suggested by CBD for the collapse of the ocean food web, is difficult to assess quantitatively because the interactions are so complex and difficult to project. See DEIS Section 4.7. Where information presented in the EIA analysis was incomplete or unavailable, NHTSA relied on CEQ regulations regarding incomplete or unavailable information. See 40 CFR § 1502.22(b). The DEIS and this FEIS acknowledge that information on ocean acidification is incomplete, and that the state of the science does not allow for a characterization of how the alternatives considered influence these risks, other than to say that the greater the emissions reductions, the lower the risk of ocean acidification.*

Comments

Comment Number: 0572-54
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The CAFE Compliance and Effects Model, generally referred to as the Volpe model, is designed and used primarily to determine the economic costs and benefits to consumers and automakers with regard to application of technologies. Although an estimate of the social cost of global climate change (estimated by NHTSA at $7 per ton of CO_2) was entered as an input, the Volpe model focuses on the marginal costs and benefits provided to consumers and automakers by each potential technology, under the assumptions of costs and efficiency gains as purported by the automakers. It is much less adept at evaluating costs and benefits to society as a whole.

Comment Number: 0572-58
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The conclusions of the cost-benefit analyses are highly dependent on the values input into the model, and are particularly sensitive to the estimate of the economic cost of climate change and the projected price of gasoline. NHTSA has consistently chosen unreasonable input values to minimize the fuel economy level that emerges from the "black box" of the Volpe model. The absurdly low gas prices chosen by NHTSA are perhaps the best example. Increasing the gas price by $0.88 in 2016 leads to a nearly 7 mpg increase in the "socially optimal" fuel economy level. 73 FR 24476. Yet nowhere does NHTSA disclose the model results from simply entering today's average gas price of $4.09 per gallon [Footnote: See original comment document.] or the environmental impacts of running the model with "reality-based" inputs. NHTSA has a legal obligation to do so.

NHTSA, on page 24414 of the NPRM, states that, "[for] most of the analysis it performed to develop this proposal, NHTSA required a single estimate for the value of reducing CO_2 emissions." While it may be true that the Volpe model and the calculations used for the cost-benefit analysis required a single estimate—rather than a range of potential values—for each value for any single calculation, such methodological limitations do not restrict NHTSA from running successive calculations with a range of discrete values. This method should be applied to both the Volpe model and the cost-benefit analyses. In general, the projections for the price of gasoline must, at the very least, incorporate the current price of gasoline, and a range of possible scenarios for future prices. The economic cost of climate change must include the range of values reported in Stern (2007). We note that analysis of a range of values is legally required by the National Environmental Policy Act, which requires the analysis of a reasonable range of alternatives to the proposed action. NHTSA's sensitivity analysis is particularly indefensible as the agency has used $14 per metric ton as an upper bound of economic cost of carbon dioxide. The selection of such a low number as the upper bound is utterly unsupportable. Similarly, NHTSA has failed to analyze a gas price that even approaches today's prices, even in the sensitivity analysis. Today's gas price must form the starting point for the analysis, and calculations must be performed that consider the overwhelmingly likely scenario that gas prices will be significantly higher than the projections used in the NPRM.

Comment Number: 0574-13
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

On May 18, 2008, the Alliance sent a letter to NHTSA posing a series of questions about the Volpe model that Sierra Research had formulated because Sierra found it necessary "to resolve [those questions] in order to be able to understand and fully unpack the technical analysis behind NHTSA's notice of proposed rulemaking, as published at 73 *Fed. Reg.* 24,352 (May 2, 2008), and the accompanying preliminary regulatory impact analysis." Appendix B at 1. NHTSA has still not responded to the questions posed.

As NHTSA knows, courts have interpreted the Administrative Procedures Act and other, analogous sources of law to require agencies to provide opportunities not just to comment, but to comment meaningfully upon the agency's analysis. See, e.g., *Honeywell Int'l, Inc. v. EPA*, 372 F.3d 441, 449 (D.C. Cir. 2004). Moreover, an agency cannot rely on data or analysis known only to itself. See *National Classification Committee v. United States*, 779 F.2d 687, 695 (D.C. Cir. 1985). In addition, agency reliance on its experience cannot overcome evidence that shows a particular methodology to be flawed. See *American Pub. Gas. Ass'n v. FERC*, 567 F.2d 1016, 1043 (D.C. Cir. 1977), *cert. denied*, 435 U.S. 907(1978). Finally, in exploring the validity of the various assumptions that NHTSA made, Sierra needs to be able to test NHTSA's conclusions and its reliance on matters requiring judgment. Therefore, under OMB's [Office of Management and Budget's] aegis, NHTSA has been obligated to ensure that its scientific and technical conclusions are "substantially reproducible." (Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies, 67 *Fed. Reg.* 8,452 (Feb. 22, 2002). Sierra Research was not able to replicate NHTSA's analysis in some significant ways because the questions it posed were not answered.

Numerous environmental organizations commented at the August 4 public hearing that the Volpe model was central to NHTSA's NEPA analysis. Hence, for NHTSA's protection both against potential legal challenges by those groups and to provide a rational response to the questions raised by the Alliance, NHTSA must provide answers to the issues posed in the May 18 Alliance letter. NHTSA's use of confidential product plans by manufacturers cannot form the answer to the concerns posed in that letter. See *Riverkeeper*, *Inc. v. EPA*, 475 F.3d83, 112 (2d Cir. 2007) (approving agency use of confidential information only so long as it did not prevent the public "from commenting on the methodology and general cost data underlying EPA's approach").

Comment Number: 0574-8
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

As several environmental groups and individual commenters noted at the August 4, 2008 public meeting, NHTSA's NEPA analysis relies heavily on its Volpe model analysis. This makes it critical that the public be able to understand how the Volpe model functions. The letter the Alliance sent to NHTSA on May 18, 2008 presenting questions posed by Sierra Research, Inc. concerning the Volpe model has still not been answered. See Appendix B. This violates basic principles of administrative law. As a general matter, NHTSA's use of confidential product plan information also cannot be used to obscure the functioning of the Volpe model.

Response

The AAM referred to a letter it sent NHTSA in which Sierra Research, Inc. raised very specific issues concerning the application of fuel economy-improving technologies in the Volpe model. After receiving that letter, NHTSA contacted the AAM and informed it that if it believed that the agency did not use correct numbers or make the correct assumptions or calculations, AAM should make what it believed were the necessary corrections for the purposes of its analysis of the agency proposal and submit the results to NHTSA as part of its comments, including an explanation of what errors it believed the agency had made and why the AAM's values and approaches were better than the agency's. Further, in developing the FEIS, NHTSA has taken all of AAM's questions in its letter and suggestions in its comments to the docket regarding technology costs and standards analysis into consideration while revising and updating the technology inputs to the Volpe model. NHTSA does not believe that the agency's handling of the AAM's original letter in the amendments to the technology assumptions in the final rule restricted the ability of the AAM to comment meaningfully on the alternatives presented in the DEIS and their environmental impacts. Indeed, the AAM submitted extensive, detailed comments to the dockets for the NPRM and DEIS.

Moreover, CEQ regulations state that the purpose of an EIS is to "provide full and fair discussion of significant environmental impacts and … inform decision makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment." 40 CFR § 1502.1. The agency purposefully analyzed a range of alternatives that would capture a full spectrum of potential impacts from vehicles continuing to maintain their MY 2010 fuel economy to standards based on the maximum technology expected to be available over the period. The various alternatives analyzed create mpg standards that essentially represent several points on a continuum of alternatives. NHTSA has further refined the fuel saving technology cost and benefit assumptions that go into the Volpe model based on numerous comments received on the NPRM and DEIS.

Comments

Comment Number: 0575-26
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

The following examples illustrate the lack of transparency in NHTSA' s work:

Example A. NHTSA's sensitivity analysis shows that the use of higher externality values (gasoline price, CO_2 valuation, etc.) has a much more significant impact on passenger car fuel economy than it does on light truck fuel economy. NHTSA hypothesizes on some possible reasons for this, but provides no evidence for their hypothesis. If NHTSA cannot explain why this happens, their work appears flawed as it is not even transparent to them. Alternatively, if they can explain, they must provide the data and evidence. NHTSA's current approach is not sufficient for providing the public the ability to fully understand the mechanisms behind NHTSA's methodology.

Example B. One of NHTSA's frequent arguments is that their model is based on specific manufacturer product plans, and that because of this, NHTSA can employ the most realistic scenarios of product availably in their modeling efforts. However, certain assumptions NHTSA makes about product plan availability stand in stark contrast to public statements made by manufacturers. For example, despite the fact that General Motors has repeatedly touted the 2010 target release of its Chevy Volt plug-in hybrid (and a target volume in the tens of thousands) [Footnote: See original comment document.], NHTSA has opted to not include this technology in its model.

It appears that either (a) NHTSA is receiving incomplete or, worse, intentionally distorted product plans—thereby leading the agency to erroneous conclusions about technology availability and applicability, or that (b) NHTSA is disregarding manufacturer claims and selectively applying product plan information. Neither option is acceptable.

Example C. NHTSA appears to restrict final mpg levels using an opaque economic practicability assessment. A 5-year "consumer valuation" criterion is employed that appears to restrict deployment of technology that takes more than five years to recoup, and to value only the first five years of fuel savings. However, how or why this criterion was used in NHTSA's model is far from clear. It should be here noted that use of consumer valuation as a way to restrict application of fuel saving technologies, if indeed that is what is occurring, is incorrect and inappropriate.

Example D. NHTSA's sensitivity analysis includes evaluation at low and high fuel prices. While some of the results seem logical (i.e. an increase in fuel economy with the use of higher gasoline prices) others are completely counterintuitive. For example, the passenger car sensitivity analysis indicates that, relative to proposed fuel economy levels, an *increase* of 0.2 mpg can be achieved in 2015 by employing a *lower fuel price*. This type of information contradicts even the most fundamental logic of the Volpe model, and undermines the value of NHTSA's work.

Inconsistent Data

In reviewing the NPRM and PRIA, issues of inconsistent data came up. UCS understands that typos and errors will occur in volumes of its size, but these errors could also contribute to a perception of a hastily-performed analysis.

Example A. NHTSA claims to apply weight reduction technology to light trucks over 5,000 lbs. curb weight only. However, multiple tables in both the NPRM and PRIA, a 6,000 lb. curb weight threshold is also identified.

Example B. Pages 14 and 15 of the NPRM specify proposed passenger car and light truck standards, along with interim year fleet average estimates. Similarly, this information is shown in Table lb and Appendix Table A-l of the PRIA. Oddly, however, some of this information is inconsistent. While passenger car and light truck standards are consistent with the standards proposed in the NPRM, the PRIA indicates a 0.1 mpg higher fleet average fuel economy for both model years 2012 and 2013, as shown in Table 3. [See original comment document for Table 3 and footnotes.]

We assume this was merely a computational oversight; however we do wish to have NHTSA double-check this information to ensure that fleet average requirements are properly set.

Comment Number: 0576-24
Organization: Public Citizen
Commenter: Joan Claybrook

The model used to set fuel economy standards is heavily influenced by the economic assumptions. NHTSA's failure to make the correct assumptions about potential benefits will put downward pressure on the level and rate of the standards, which robs consumers of considerable value from increased standards, through fuel savings, reduced greenhouse gas emissions, and improved energy security and independence.

Comment Number: 0576-25
Organization: Public Citizen
Commenter: Joan Claybrook

The logic behind the restructured CAFE standards is to add the minimum amount of fuel saving technology to bring a manufacturer into compliance with the standard for a given year, with significant latitude given to individual manufacturers for compliance based on the specific fleet mix of a given manufacturer. This approach necessarily undercuts the maximum feasible level of fuel economy. In its November 2007 decision in *Center for Biological Diversity v. NHTSA* the Court of Appeals for the Ninth Circuit said: "the agency's cost-benefit analysis does not set the CAFE standard at the 'maximum feasible' level and fails to give due consideration to the need of the nation to conserve energy." (*Center for Biological Diversity et al., v. NHTSA.* 508 F. 3d 508. (November 15, 2007)).

NHTSA states in this notice on fuel economy standards: "In striking [a] balance [between costs and benefits], the agency was mindful of the growing need of the nation to conserve energy for reasons that include increasing energy independence and security and protecting the environment." (73 *FR* 24457] However, analysis of the Volpe Model suggests that the assumptions NHTSA uses to set the standards are not sufficiently mindful of the need to conserve energy or environmental protection.

Public Citizen recognizes that since the Ninth Circuit decision there have been changes to the Volpe Model since the 2006 light truck rule: "the set of technologies represented was updated, the logical sequence for progressing through these technologies was changed, methods to account for 'synergies' (*i.e.*, interactions) between technologies and technology cost reductions associated with a manufacturer's 'learning' were added, the effective cost calculation used in the technology application algorithm was modified, and the procedure for calibrating a reformed standard was changed, as was the procedure for estimating the optimal stringency of a reformed standard." (73 *FR* 24396] But these changes have not corrected the problems with the model that prevent it from setting standards at the maximum feasible level. Although Congress authorized NHTSA to restructure the CAFE scheme for passenger cars, but it did not mandate the NHTSA use Volpe Model. There are other ways the agency could model fuel economy that would set targets at the maximum feasible level and would improve public participation in the process.

Comment Number: 0576-26
Organization: Public Citizen
Commenter: Joan Claybrook

Public Citizen raises the following concerns about the Volpe Model:

- fails to correct the light truck loophole, which is the failure to have one continuous standard for passenger cars and light trucks, and ignores the impact of crossover vehicles
- the claim that the Volpe Model protects safety is based on a misapprehension of the relationship between fuel economy and safety
- potentially erodes the fuel savings when the price of oil drops lower than expected
- allows manufacturers to effectively set their own standards by manipulating product plans
- bases fuel economy increases on industry-biased cost assumptions and underestimates of benefits

Response

EPCA, as amended by EISA requires NHTSA to set separate standards for passenger cars and light trucks. Therefore, the option of "one continuous standard for passenger cars and light trucks" is not available. Before EISA, NHTSA had the discretion to prescribe separate standards for different classes of automobiles between 6,000 and 10,000 pounds, which is how the term "light truck" evolved. Under EISA's new definitions, all vehicles under10,000 pounds are classified as passenger automobiles, non-passenger automobiles, or work trucks, and all are subject to a CAFE standard (including crossover vehicles).[4]

Regarding the rest of this comment, see the general response at the end of Section 10.2.2.

Comments

Comment Number: 0576-28
Organization: Public Citizen
Commenter: Joan Claybrook

Another serious problem with the Volpe Model is that it is not transparent, which significantly undermines the ability of public commenters to provide an opinion as to whether NHTSA has set standards at the maximum feasible level that maximizes public good. Automakers provide the inputs for the Volpe Model through product plans, which are closed from public view as confidential business

[4] *A work truck is a vehicle between 8,500 and 10,000 pounds gross vehicle weight and is not a medium duty passenger vehicle as defined in 40 CFR § 86.1803-01. See 49 U.S.C. § 32901(a)(19). EISA requires NHTSA to set CAFE standards for work trucks after a NAS study on the fuel economy of this class of vehicles. See 49 U.S.C. §§ 32902(b)(1), 32902(k).*

information. This significantly biases the standards in favor of industry by shutting the public out of the process. NHTSA does not establish what is technological feasible and economically practicable based on an independent assessment of the current vehicle fleet and the available technology to improve the fleet, but rather accepts industry inputs, which are run through the black box of the Volpe Model, and a variety of "optimization" factors, which are tied to maximizing industry-wide benefits. (73 *FR* 24416). In the past, rulemaking NHTSA has done its own research and evaluation of these factors which was more transparent.

Thus, the public is foreclosed from real participation in this system. There is intense public interest in new fuel economy standards. These upgrades are the first for passenger cars in over twenty years, and they will dictate the level of fuel economy new vehicles will get until 2015, which affects the new car market and will skew purchase decisions. High gas prices and concern about global warming contribute to increased consumer interest in fuel economy; however, the agency's scheme for setting fuel economy standards leaves them largely in the dark. Consumers must essentially trust that NHTSA has set standards in their interest using information provided by industry.

Comment Number: 0576-29
Organization: Public Citizen
Commenter: Joan Claybrook

The Volpe Model uses incremental cost and incremental benefit estimates to determine the increase in fuel economy model-by-model. However, incremental costs are difficult to estimate accurately; many companies are unable even to produce a complete list of regulations that apply to them. [Footnote: See original comment document.] The GAO concluded that industry often overestimates costs or provided cost estimates that were not incremental. [Footnote: See original comment document.] Inaccurate estimates also plague the benefits side. As described above, many of the economic assumptions NHTSA made in estimating benefits were too low and too conservative. Since the Volpe Model only adds technology until marginal cost balances marginal benefit, the standards will not be set at the maximum feasible level, and consumers will not get the best available technology. (73 *FR* 24416)

Comment Number: 0576-31
Organization: Public Citizen
Commenter: Joan Claybrook

The Volpe Model estimates are also skewed by out-of-date and incomplete product plans. If NHTSA is to rely on product plans as their primary source of information for setting fuel economy standards, then those plans should be as up-to-date and complete as possible. However, not all manufacturers provided NHTSA with complete product plans, and in light of recent shifts in the auto industry in response to high gas prices and consumer demand shifts, the product plans that NHTSA used to run the model for this proposal are now out-of-date. [Footnote: See original comment document.] These insufficiencies in the information stream potentially undercut the potential for NHTSA to set technology-forcing standards which appropriately serve the need of the U.S. to conserve energy.

Comment Number: 0576-13
Organization: Public Citizen
Commenter: Joan Claybrook

The Volpe model also uses incomplete and inaccurate inputs from the auto industry to make projections about the future fleet mix and market preference. NHTSA solicited the automakers to provide product plans with which it could complete the modeling to set the fuel economy standards. However, many of the automakers solicited provided incomplete data, or no data at all. In these cases, NHTSA assumed that automakers would make no change from model year to model year, which skews the model to prefer no change in vehicle characteristics or fleet mix. In recent months, several major automakers have announced plans to substantially change their product plans. [Footnote: See original comment document.]

Comment Number: 0576-38
Organization: Public Citizen
Commenter: Joan Claybrook

The structure of the Volpe model is such that the standards it prescribes are heavily influenced by the economic assumptions and product plans provided by the auto industry.

Comment Number: 0576-39
Organization: Public Citizen
Commenter: Joan Claybrook

The minimizing effect of the economic assumptions used Volpe model serves to obscure the relative benefits of its proposed alternatives.

Comment Number: 0576-40
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA has a responsibility to respond to these problems in the most expedient possible manner. The agency estimates that if fuel economy standards are set at the level where total costs balance total benefits (the truly "maximum feasible" level) then passenger cars should reach an average of 43.3 mpg and light trucks should reach an average of 33.1 mpg by model year 2015. [Footnote: See original comment document.] This gets us to a fleetwide average of 37.3 in model year 2015, assuming NHTSA's assumptions that the fleet mix between passenger cars and light trucks stays around 50 percent — a dubious assumption given the flight from these vehicles in the face of high gas prices. This exceeds the goal set by EISA in level and speed; however, Congress mandated a *minimum* level of fuel economy. Gas prices have been rising steadily since 2004. However, the price increases in the last six to 12 months have been especially dramatic, rising by over a third in the past six months, and by nearly 170 percent in five years.

The agency appears to have considered 35 mpg by 2020 to be a ceiling, and has not attempted to strive for the maximum feasible level of fuel economy. "While the agency carefully considered alternative stringencies . . . it tentatively concludes that in stopping at the point that maximizes net benefits, it has achieved the best balancing of all of the statutory requirements, including the 35 mpg requirement." (73 *FR* 24457) NHTSA's conservative estimates for future fuel costs, undervaluation of carbon dioxide, zero valuation of military and strategic costs of oil, and high discount rate all push the outcome of the Volpe Model towards inaction.

If NHTSA increased fuel economy by 4.5 percent per year through the entire period over which standards are set, then the fleetwide fuel economy would reach 33.1 mpg by 2015. In addition, NHTSA's total cost balances total benefit scenario would increase fuel economy by nearly 10 percent per year to reach a fleetwide average above 37 mpg by 2015. This suggests that the technologically feasible pace of increasing fuel economy is much higher than what NHTSA is requiring in this proposal. The agency has given the industry considerable lead time to adjust for higher standards in the later years, yet inexplicably requires a slower pace of increases for these years.

Response

NHTSA recognizes that EISA identifies 35 mpg as a floor and not a ceiling for the combined fleet average statutory fuel economy required by 2020. Accordingly, NHTSA has considered and evaluated the environmental impacts of CAFE standards that reach to at least this level in 2015, such as the Total Costs Equal Total Benefits Alternative and the Technology Exhaustion Alternative. NHTSA also notes that EISA requires the agency to set fuel economy standards "based on 1 or more vehicle attributes related to fuel economy and express each standard in the form of a mathematical function." 49 U.S.C. § 32902(b)(3)(A).

Several reviewers expressed concern – and some have evidenced confusion – regarding NHTSA's approach to establishing the stringency of CAFE standards, the "Volpe model." Some commenters claimed that the Volpe model, by generating standards at levels that maximize net benefits to society, does not comport with EPCA's requirements. The Center for Biological Diversity (CBD) and Public Citizen referred to the Volpe model and its inputs as a "black box." NHTSA does not agree with this characterization.

As required by EPCA, NHTSA sets standards at the maximum feasible level, considering technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, the need of the nation to conserve energy, as well as other relevant considerations such as safety.

NHTSA has a long-standing practice of analyzing regulatory options based on the best available information regarding (1) the future vehicle market, (2) the technologies expected to be available during the relevant model years, and (3) the key economic factors, such as future fuel prices and the other statutory factors.

Among these categories, all information except NHTSA's forecast of the future vehicle market is made available to the public. The forecast of the future vehicle market is based significantly on confidential product planning information manufacturers submit to the agency. Individual manufacturers are better able than any other entity to anticipate what mix of products they are likely to sell in the future. The submitted product plans contain confidential business information, which the agency is prohibited by federal law from disclosing; making this information publicly available would cause competitive harm to manufacturers. <u>See</u> 5 U.S.C. § 552(b)(4); 18 U.S.C. § 1905; 49 U.S.C. § 30167(a); 49 CFR Part 512; <u>Critical Mass Energy Project v. Nuclear Regulatory Comm'n</u>, 975 F.2d 871 (D.C. Cir. 1992). Notwithstanding this restriction, in its publicly available rulemaking documents, the agency provides aggregated information (compiled from individual manufacturer submissions) regarding its forecasts of the future vehicle market.

All of the other information NHTSA uses to conduct its analysis – such as estimates of economic factors and estimates of the availability, cost, and effectiveness of fuel-saving technologies – is presented in the agency's rulemaking documents and is available to the public. <u>See</u> NPRM, 73 <u>FR</u> 24352, 24391 (May 2, 2008); CAFE Compliance and Effects Modeling System Documentation, Docket No. NHTSA-2008-0089-0047; How to Obtain Volpe Model Installation Files, Docket No. <u>NHTSA-2008-0089-0048</u>; PRIA, Docket No. NHTSA-2008-0089-0003.1, pp. V1-V141. The agency requested and received comment on all of these inputs to its analysis and has addressed these comments in analyses conducted in this FEIS and will do so in the final rule.

Until 2002, when NHTSA began work on CAFE standards for light trucks sold during model years 2005-2007, the agency used tools such as spreadsheets to analyze regulatory options. For that rulemaking and ensuing rulemakings, the agency has supplemented such tools with a modeling system *developed specifically to assist NHTSA with applying technologies to thousands of vehicles and developing estimates of the costs and benefits of potential CAFE standards. The CAFE Compliance and Effects Modeling System, developed by DOT's Volpe National Transportation Systems Center and commonly referred to as "the Volpe model," enables the agency to efficiently, systematically, and reproducibly evaluate many more regulatory options, including attribute-based CAFE standards required by EISA, than was previously possible, and to do so much more quickly.*

The Volpe model needs the following types of information as input: (1) a forecast of the future vehicle market, (2) estimates of the availability, applicability, and incremental effectiveness and cost of fuel-saving technologies, (3) estimates of vehicle survival and mileage accumulation patterns, the rebound effect, future fuel prices, the social cost of carbon, and many other economic factors, (4) fuel characteristics and vehicular emissions rates, and (5) coefficients defining the shape and level of CAFE curves to be examined. The model makes no a priori assumptions regarding inputs such as fuel prices and available technology, and does not dictate the form or stringency of the CAFE standards to be examined. The agency makes those selections and, in the case of technology assumptions, has determined that confidential product plans are a vital source of information.

Using the inputs selected by the agency based on best available information and data, NHTSA projects a set of technologies each manufacturer could apply in attempting to comply with the various levels of potential CAFE standards to be examined. The model then estimates the costs associated with this additional technology utilization, as well as accompanying changes in travel demand, fuel consumption, fuel outlays, emissions, and economic externalities related to petroleum consumption and other factors.

NHTSA specifically sought comment on the estimates, which it had developed jointly with EPA, of the availability, applicability, cost, and effectiveness of fuel-saving technologies, and the order in which the technologies were applied. See 73 FR 24352, 24367. While NHTSA asked manufacturers to submit such information in the request for product plans, the agency also conducted its own independent analysis of the all the comments and data—including comments and information from entities outside the automobile manufacturing community—received through the rulemaking process. This involved hiring an international engineering consulting firm that specializes in automotive engineering, and that was used by the EPA in developing its recent Advance Notice of Proposed Rulemaking to regulate greenhouse gas emissions under the Clean Air Act.[5]

NHTSA and its consultants undertook a thorough review of the NPRM technology assumptions and all comments received on those assumptions, based on both old and new public and confidential manufacturer information. NHTSA and its consultants reviewed and compared comments on the availability and applicability of technologies, and the logical progression between them. NHTSA also reviewed and compared the methodologies used for determining the costs and effectiveness of the technologies as well as the specific estimates provided. Relying on the expertise of its consultants and taking into consideration all the information available, NHTSA revised its estimates of the availability and applicability of many technologies, and revised its estimate of the order in which the technologies were applied. In addition, the agency and its consultants generally agreed with commenters who said that in several cases, the technology related costs used in the NPRM and DEIS were underestimated and benefits were overestimated. The agency also agreed with commenters that both sets of estimates were not well differentiated by vehicle class and that the technology decision trees needed to be expanded and refined. Relying on the expertise of its consultants and taking into consideration all the information available, NHTSA revised its technology and effectiveness estimates and used them in analyzing all of the alternatives and scenarios presented in this FEIS. The agency believes that the representation of

[5] *73 FR 44354 (July 30, 2008).*

technologies—that is, estimates of the availability, applicability, cost, and effectiveness of fuel-saving technologies, and the order in which the technologies were applied—used in this action is the best available.

Recognizing the uncertainty inherent in many of the underlying estimates in the model, NHTSA has used the Volpe model to conduct both sensitivity analyses, by changing one factor at a time, and a probabilistic uncertainty analysis (a Monte Carlo analysis that allows simultaneous variation in these factors) to examine how key measures (e.g., mpg levels of the standard, total costs, and total benefits) vary in response to change in these factors. This type of analysis is used to estimate the uncertainty of the costs and benefits of a given set of CAFE standards.

Finally, the model can be used to fit coefficients defining an attribute-based standard, and to estimate the stringency that either (a) maximizes net benefits to society, (b) achieves a specified stringency at which total costs equal total benefits, (c) imposes a specified average required CAFE level, or (d) results in a specified total incremental cost. The agency uses this information from the Volpe model as a tool to assist in setting standards, consistent with the requirements of EPCA.

Model documentation, publicly available in the rulemaking docket, explains how the model is installed, how the model inputs and outputs are structured, and how the model is used. The model can be used on any Windows-based personal computer with Microsoft Office 2003 and the Microsoft .NET framework (the latter available without charge from Microsoft) installed. The executable version of the model, with all of its codes and accompanying demonstration files, is available upon request, and has been provided to manufacturers, consulting firms, academic institutions, nongovernmental organizations, research institutes, foreign government officials, and other organizations. The current version of the model was developed using Microsoft Development Environment 2003, and every line of computer code (primarily in C#.NET) has been made available to individuals who have requested the code. Many of these individuals have run the model using market forecast data that they estimated on their own.[6]

Given the comprehensive disclosure of information about the Volpe model and the fact that many entities and individuals have made use of it, the characterization of the Volpe model as a "black box" is not accurate.

Although NHTSA uses the Volpe model as a tool to inform its consideration of potential CAFE standards, the Volpe model does not determine the CAFE standards NHTSA will propose or promulgate as final regulations. The results it produces are completely dependent on inputs selected by NHTSA, based on best available information and data available at the time standards are set. In addition to identifying the input assumptions underlying its decisions, NHTSA provides the rationale and justification for selecting those inputs. NHTSA also determines whether to use the model to estimate at what stringency net benefits are maximized, or to estimate other stringency levels, such as the point where total costs equal total benefits. NHTSA also determines whether to use the model to evaluate the costs and effects of stringencies that fall outside of the scope of maximum feasible. For example, the standards for the "Technology Exhaustion" Alternative examined by NHTSA were estimated outside the model, which was subsequently used to estimate corresponding costs and effects.[7] *Finally, NHTSTA is guided by the statutory requirements of EPCA in ultimate selection of a CAFE standard.*

NHTSA does not agree with Public Citizen that the agency "does not establish what is technologically feasible and economically practicable based on an independent assessment of the current

[6] *Resources for the Future (RFF) has run the model and is working under contract with EPA to expand its capability.*
[7] *By definition, the "maximum technology" scenario far exceeds the maximum feasible CAFE standard.*

vehicle fleet and the available technology to improve the fleet, but rather accepts industry inputs, which are run through the black box of the Volpe model and a variety of 'optimization' factors, which are tied to maximizing industry-wide benefits." The manufacturers' plans are only the starting point for the agency's determination of how much technology can and should be required consistent with the statutory factors. NHTSA considers the results of analyses conducted by the Volpe model and analyses conducted outside of the Volpe model, including analysis of the impacts of carbon dioxide and criteria pollutant emissions, analysis of technologies that may be available in the long term and whether NHTSA could expedite their entry into the market through these standards, and analysis of the extent to which changes in vehicle prices and fuel economy might affect vehicle production and sales. Using all of this information—not solely that from the Volpe model—the agency considers the governing statutory factors, along with environmental issues and other relevant societal issues such as safety, and promulgates the maximum feasible standards based on its best judgment on how to balance these factors.

This is why the agency considered seven alternatives, only one of which maximizes net benefits. The others assess alternative standards that in many cases exceed the point at which marginal costs equal marginal benefits. These comprehensive NEPA analyses are intended to inform and contribute to the agency's consideration of the "need of the United States to conserve energy," as well as the other statutory factors. 49 U.S.C. § 32902(f). Additionally, within the model the agency considers the need of the nation to conserve energy by monetizing the economic costs of incremental CO_2 *emissions in the social cost of carbon.*

CEQ regulations state that the purpose of the EIS is to "provide full and fair discussion of significant environmental impacts and … inform decisionmakers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment." 40 CFR § 1502.1. Accordingly, the agency analyzed alternatives that capture a full spectrum of potential impacts, ranging from vehicles continuing to maintain MY 2010 fuel economy levels to standards based on the maximum technology expected to be available over the period. The technology assumptions used in the NPRM produced CAFE standards that went beyond EISA's statutory goal (at least 35 mpg by 2020) in 2015. As a further refinement, NHTSA has updated the fuel-saving technology cost and benefit assumptions that go into the Volpe model based on comments to the NPRM and DEIS and on updated manufacturer product plans. NHTSA acknowledges that these changes affect the CAFE standards.

<u>Volpe Model Input Estimates</u>

Several commenters asserted that NHTSA used inaccurate input variables in the Volpe model, resulting in an underestimation of the projected CAFE standards. Commenters questioned NHTSA's choice of fuel price, social cost of carbon, discount rate, and military costs. The agency recognizes that many of these variables are subject to change based on differing economic circumstances that may or may not exist during the period the CAFE standards are intended to cover, making the estimation process a difficult one. Taking this into account, the agency has expanded its evaluation of the alternatives to account for different valuations of these variables and made this information available in this FEIS. In Section 2.5, Section 3.4.4, and Section 4.4.4, the agency presents the standards and accompanying environmental impacts that occur when the Volpe model is run with varying economic input values.

10.2.2.1 Fuel Price Assumptions

Comments

Comment Number: 0595-1
Organization: Environmental Protection Agency
Commenter: Susan Bromm

The DEIS uses official 2008 AEO [Annual Energy Outlook] Early Release fuel price projections of $2.04- $3.37 per gallon in the relevant timeframe. EPA's work with the Volpe Model, as well as the High Fuel Price sensitivity analyses presented in Section IX of the Preliminary Regulatory Impact Analysis (PRIA) associated with the CAFE Notice of Proposed Rulemaking (NPRM), indicates that the Volpe model is very sensitive to fuel price projections. Using projections at the high end of the AEO range would change the base case (as the market reacts to higher fuel prices) and the projected net benefits, and it would likely increase the level of the "optimized" fuel economy standard. EPA urges NHTSA to carefully consider projections for fuel prices and notes the important nexus between this estimate and future projections for the Final EIS.

Comment Number: 0551-1
Organization: Individual
Commenter: Jim Derzon

I think it is unlikely that gas will be below $3.00 per gallon again in my lifetime, so get busy and strengthen fuel economy standards. Current standards are criminal.

Comment Number: 0535-1
Organization: Individual
Commenter: James Farrelly

As of today the average price per gallon of gas is 4.07 – not 2.25 or 2.60 a gallon. That was what maybe 2006? So auto manufacturers don't feel the need to change fuel efficiency standards when these sorts of numbers are given.

Comment Number: 0549-1
Organization: Individual
Commenter: Nancy Miller

I am writing to protest the ridiculous assertion that we will be paying between $2.25 to $2.60 per gallon for gas through 2020. DOT [Department of Transportation] is calling for fuel economy improvements only if they pay for themselves through fuel savings—the money saved from the gas the cars wouldn't use. This gas price fantasy allows automakers to shave three to four miles per gallon off of the historic new fuel economy requirements that became law in 2007. If accurate gas prices are used, the new requirements would further reduce global warming pollution equivalent to taking about 10 million cars off the road.

Comment Number: 0554-1
Organization: Individual
Commenter: James Adcock

EIA estimates of future gas prices are not rational estimates given the recent run-up in gas prices. The EIA estimates can be compared to the estimate of future gas prices implied in the short-term and long-term NYMEX [New York Mercantile Exchange] oil and gas futures. If the EIA estimates were correct estimates, and the NYMEX futures greatly differ (which they do) then that difference represents an arbitrage opportunity that traders can exploit, which in turn would drive NYMEX prices back to EIA Estimates. (Modem Arbitrage Theory) This hasn't happened. The conclusion is that EIA estimates cannot be current rational estimates. See attached graph. [See original comment document for graph.] Based on NYMEX future estimates of gas prices during the regulatory time frame I suggest that NHTSA adopt its "HOP - High Oil Price" scenario rather than its current "MOP - Moderate Oil Price" scenario. Or use NYMEX futures values directly rather than outdated EIA estimates.

Comment Number: 0557-7
Organization: The Natural Resources Defense Council
Commenter: Luke Tonachel, Brian Siu

NHTSA relies on the Energy Information Administration's Reference Case forecast for fuel prices. However, both the Reference and High Case forecasts have consistently underestimated fuel prices and NHTSA fails to use a reasonable forecast consistent with likely price trajectories.

Comment Number: 0559-8
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

NHTSA acknowledges that the price of gasoline has the greatest impact on the cost analysis for the standards. Yet, NHTSA assumes fuel prices ranging from $2.26 per gallon in 2016 to $2.51 per gallon in 2030. These numbers are unrealistically low. Currently, the average price of a gallon of gasoline exceeds $4.00 and the principal reason given is high global demand in a supply constricted market. There is little expectation that the gap between supply and demand will be narrowed in the foreseeable future. Therefore, assuming this reasoning is correct, the price of gasoline should remain high; certainly well above the mid-$2.00 range. We urge NHTSA to reevaluate the effect of a wider range of gasoline prices to the $4.00 per gallon level and above. We would expect the results to show that there are more fuel savings technologies capable of cost-effectively achieving greater overall average fuel economy, even according to NHTSA's conservative "net societal benefit" cost-analysis approach.

Comment Number: 0564-9
Organization: Consumer Federation of America
Commenter: Mark Cooper

[NHTSA] used gasoline prices that are far too low — a price of only $2.45 per gallon for 2015 (in 2008 dollars);

Comment Number: 0572-14
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Another major determinant of the output from the Volpe model is the cost of fuel. DEIS at 2-2. The NHTSA used the EIA's Annual Energy Outlook Early Release Forecast to select fuel prices, and assumes future fuel prices ranging from $2.26 per gallon in 2016 to $2.51 per gallon in 2030.Considering that national average gasoline prices are currently $3.81 per gallon [Footnote: See original comment document.] and over a dollar higher than one year ago, there is every indication that the price of oil will continue to increase over the short term, and there is every indication that the price of oil will continue to remain in the short term higher than projected by the administration, this estimate is impossible to justify. It is important to note that these price projections are based in 2006 dollars, and include Federal, State, and local taxes. However, the estimated 2008 fuel price of $2.69 per gallon of gasoline in 2006 dollars, adjusted by a 3% estimated annual inflation rate, is approximately $2.85 per gallon of gasoline, far below the current prices and projections. The use of an inappropriate gasoline price projection greatly skews the results, since the savings in fuel expenditures are by far the largest components of the cost-benefit analysis, accounting for $2.27 of the $2.51 in net benefits from each gallon of gasoline reduced, overwhelmingly drives the conclusions of the cost-benefit analysis as constructed by NHTSA.

Comment Number: 0572-57
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

For the purposes of cost-benefit analysis, on page 24449 of the NPRM, NHTSA assumes future fuel prices "ranging from $2.26 per gallon in 2016 to $2.51 per gallon in 2030." Considering that national average gasoline prices are currently over $4.00 per gallon, there is every indication that the price of oil will continue to increase over the short term, and there is no indication that oil prices will subside in the long term, this estimate is impossible to justify. It is important to note that these price projections are based in 2006 dollars, and include Federal, State, and local taxes. [Footnote: See original comment document.] However, the estimated 2008 fuel price of $2.69 per gallon of gasoline in 2006 dollars, adjusted by a 3% estimated annual inflation rate, is approximately $2.85 per gallon of gasoline, far below the current prices and projections. The use of an inappropriate gasoline price projection greatly skews the results, since the savings in fuel expenditures are by far the largest components of the cost-benefit analysis, accounting for $2.27 of the $2.51 in net benefits from each gallon of gasoline reduced, overwhelmingly drives the conclusions of the cost-benefit analysis as constructed by NHTSA in the NPRM.

Comment Number: 0575-2
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

While gasoline prices soared above $3 per gallon this winter and have hovered around $4 per gallon this summer, NHTSA relied on projections of $2.25-$2.50 per gallon.

Comment Number: 0575-29
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

At around $2.50 or lower, the gasoline price projection used by NHTSA dramatically undervalues the savings associated with improved fuel economy. According to NHTSA's own analysis, the use of an undervalued gasoline projection, rather than the Energy Information Administration's High Oil Price projection (which itself falls below today's pump prices), robs the nation of an additional 3-4 mpg. At a minimum, NHTSA should use EIA's High Price projection.

Comment Number: 0575-9
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

Between 2001 and 2008, inflation-adjusted gasoline pump prices nearly doubled [Footnote: See original comment document.], leaving consumers burdened with drastically increased vehicle operating costs. The auto industry, stagnant with a fleet average fuel economy comparable to that of the mid 1980s [Footnote: See original comment document.], offered consumers few fuel-efficient options, and even fewer options from the domestic automakers. Today, gasoline prices continue to break record levels; in late June, gasoline surpassed a national average of $4 per gallon, with the potential of $5 per gallon fuel in the near future. [Footnote: See original comment document.]

The above facts underscore the importance of properly assessing future fuel prices when setting smart energy policy. Indeed, as noted in the agency's NPRM, "projected future fuel prices are a critical input" (NPRM, p. 186) into the economic analysis used to assess economically practicable CAFE levels. The agency proposes using Annual Energy Outlook (AEO) Reference Case forecasts by the Energy Information Administration (EIA), because they "represent the EIA's most up-to-date estimate of the most likely course of future prices for petroleum products." (NPRM, p. 186) This appears to be a flawed assumption. Nowhere in the Annual Energy Outlook (2007 or 2008 edition) is the Reference Case projection referred to as a "most likely course." In fact, according to EIA, the reference case merely "assumes that current policies affecting the energy sector remain unchanged throughout the projection period." (EIA, 2008. AE02008 Overview, p. 2.)

NHTSA's decision to regard Reference Case gasoline price projections—which have substantially under-predicted the price of gasoline in recent years—as the most likely course of future prices is fundamentally flawed and undervalues the benefits of fuel saving technology in the determination of maximum feasible fuel economy standards. According to NHTSA's own sensitivity analysis, employing a High Price Case would enable application of additional fuel saving technologies on vehicles, increasing passenger car fuel economy between 6.1 – 6.7 mpg over the proposed standards, and increasing light truck fuel economy between 0.1 – 0.8 mpg over the proposed standards. (PRIA, Tables IX-5a and IX-5b) The use of EIA's High Price Case projections would be far more realistic assumption to employ (though, since 2003, even the High Price Case projections have dramatically underestimated the real price of gasoline). [Footnote: See original comment document.]

UCS does not stand alone in this opinion. Even Guy Caruso, Administrator of the EIA—the agency that authors and publishes the AEO—has publicly recommended that NHTSA use the High Price Case in setting fuel economy standards. At a hearing by the House Select Committee on Energy Independence and Global Warming, Mr. Caruso stated, in direct reference to NHTSA's rulemaking process, "We're on the higher price path right now. If you were to ask me today what I would use, I would use the higher price." [Footnote: See original comment document.]

As shown in Figure 1, EIA's Reference Case projections have substantially under-predicted the price of gasoline, falling short of the actual price by as much as 80 cents per gallon. Even near-term Reference Case assessments, such as the 2009 projection, fall well short of today's gasoline price. Moreover, as shown in Figure 2, EIA has consistently predicted a decline in gasoline prices when, in fact, gasoline has faced a precipitous price escalation. [See original comment document for figures and footnote.]

NHTSA points to recent increased fuel prices in AEO 2008 to justify use of AEO Reference Case data. Yet, as shown in Figure 2, even with the upward revision, EIA's 2008 Reference Case projection still falls well below current gasoline prices

NHTSA also points to a comparative assessment of fuel price projections, identifying EIA's Reference Case forecast as providing the highest publicly available estimates: "Comparing different forecasts of world oil prices also shows that EIA's Reference Case forecast reported in Annual Energy Outlook 2007 (AEO 2007) was actually the highest of all six publicly-available forecasts of world oil prices over the 2010-30 time horizon." (NPRM, p. 190)

However, this statement ignores the fact that the same EIA table referenced by NHTSA specifies the High Price Case forecast with oil prices 20 percent higher than the Reference Case in 2010, 60 percent higher than the Reference Case in 2015, and 71 percent higher than the Reference Case in 2020. (Only 5-year increments are shown.)

Given current gasoline market conditions, gasoline market trends, and the historical inaccuracy of EIA's Reference Case for much of this decade, UCS recommends that NHTSA employ the High Price Case forecast in its cost-benefit assessment. As shown in Figure 2, the High Price Case forecast remedies the predicted decline in gasoline prices. Yet even this projection still falls far below current gasoline prices which reside over $4 per gallon. Without question, the High Price Case is not a prediction of extreme, never-before-seen fuel costs, but rather a modestly more representative projection of the energy-dependent environment that we now live. UCS strongly suggests that NHTSA employ, at a minimum, EIA's High Price Case projection in its analysis.

Comment Number: 0576-18
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA has assumed retail gas prices of $2.31 per gallon for model year 2015, with a high estimate of $3.19. For 2030, the forecast price is $2.51 per gallon, and the high price is $3.76. (PRIA, X-5) Guy Caruso, administrator of the Energy Information Administration (EIA), recommended in a hearing of the House Select Committee on Energy Independence and Global Warming in June 2008 that NHTSA should use the high price estimate when setting fuel economy standards. [Footnote: See original comment document.] Public Citizen strongly urges NHTSA to base its final rulemaking on a more realistic estimate of future fuel price based on the high estimate and an at-the-pump price that pushes the standard in the direction of real-world gas prices.

Comment Number: 0576-9
Organization: Public Citizen
Commenter: Joan Claybrook

The future fuel price assumptions are unjustifiably low, assuming a 2030 price of gasoline at $2.51. The administrator of the Energy Information Administration has publicly stated that NHTSA should use the high-end estimate in setting fuel economy standards. [Footnote: See original comment document.]

Comment Number: 0588-4
Organization: New York State Department of Transportation
Commenter: Stanley Gee

NHTSA uses unrealistically low predictions of motor fuel prices, thereby underestimating economic benefits, and overestimates the rebound effect, which underestimates fuel savings and underestimates vehicle-related criteria and toxic pollutant emissions.

Comment Number: 0588-7
Organization: New York State Department of Transportation
Commenter: Stanley Gee

The DEIS (page 3-59) states that the Preliminary Regulatory Impact Analysis (PRIA) uses the Energy Information Administration reference price estimate for gasoline in the *AEO 2008 Early Release Forecast*, Please note that the EIA International Energy Outlook Highlights, June 2008 states, "Given current market conditions, it appears that world oil prices are on a path that more closely resembles the projection in the high price case than in the reference case." Therefore, NYSDOT [New York State Department of Transportation] believes that the analysis of alternatives analysis should use EIA's "high price case" scenarios. In addition, the Final Environmental Impact Statement should specifically explain why *current* market prices are excluded from the factoring process for economic practicability.

Comment Number: 0598-2
Organization: Sierra Club
Commenter: Caroline Keicher

NHTSA' s own analysis shows that between 2011 and 2015, significantly higher standards are technologically feasible and economically practicable when higher gas prices are used ($3.14 per gallon in 2016). NHTSA's final rule should be, at a minimum, consistent with the analysis provided in the PRIA. NHTSA's use of below-cost energy estimates is arbitrary and capricious and violates the agency's statutory charter to impose mandatory maximum feasible fuel economy standards based upon a review of economic and technological feasibility.

Comment Number: TRANS-02-2
Organization: Lee Auto Malls
Commenter: Adam Lee

NHTSA plays a real role in determining what our fuel economy will be. You analyze the impact of CAFE on Detroit. And I think that your assumptions are based on incorrect data. Gas costs $4 a gallon, not $2.

Comment Number: TRANS-08-14
Organization: Sierra Club
Commenter: Ann Mesnikoff

The proposed rule and the PRIA both show that the gas prices are major forces in setting fuel economy. NHTSA short changes America by using gas price assumptions that are far too low, a price for carbon that is randomly selected, and artificially constraining technologies.

Comment Number: TRANS-09-5
Organization: Individual
Commenter: Doug Molof

The agency's proposal assumes future gasoline prices to be only $2.25 per gallon in 2016, when American future gas prices – when American consumers are already paying prices nearly twice as much today. In fact, since NHTSA first released its draft CAFE rulemaking, the price of gasoline has jumped by over a dollar.

NHTSA's own analysis shows that between 2011 and 2015 significantly higher standards are technologically feasible and economically practical when higher gas prices are used. NHTSA's final rule should be, at a minimum, consistent with the analysis provided in the preliminary impact analysis that accompanied the notice of proposed rulemaking.

NHTSA's use of the low cost energy estimates is arbitrary and violates the agency's statutory charter to impose mandatory maximum feasible fuel economy standards based upon a review of economic and technological feasibility.

The high gas price scenario yields cost effective and technologically feasible standards that will help meet the nation's need to conserve energy, and will help lower gas prices for the average American consumer. NHTSA should ensure that final standards are set using this value at a minimum.

Comment Number: TRANS-10-4
Organization: Individual
Commenter: Matt Dernoga

I am baffled that our new CAFE standards are based on the presumption that the cost of a gallon of gas will be only $2.25 by 2016.

Comment Number: TRANS-12-2
Organization: Individual
Commenter: Sam Blodgett

Economists agree $2, even $3 gas price days are over. Your environmental impact statement must reflect this new reality. In your draft EIS you analyze two price projections for the cost of gasoline; one that predicts $2.25 gas prices by 2015, and another that predicts $3.14 gas prices by 2015.

In your EIS you chose to use the lower price estimation. Given current gas prices, this was an obvious misstep. It is only prudent to use the higher cost estimation. Even it undervalues gas by almost a dollar.

According to your analysis, if gasoline is $3.14 by 2015 then higher fuel economy standards are both technologically feasible and economically practicable. If true, then it is nonsensical to continue as planned.

Comment Number: TRANS-13-2
Organization: Individual
Commenter: Joseph Frewer

the current estimation of the price of a gallon of gas, which is, I think $2.25, not counting inflation in 2016, is unrealistic. I mean, we all prices right now, while they've been fluctuating, they're not going to drop back down to what they used to be. They are definitely staying above $3, and I think that's what most economists are saying. So we need to at least take this into account when coming up with what our standards need to be.

Comment Number: TRANS-14-6
Organization: U.S. Public Interest Research Group
Commenter: Annie Chau

NHTSA unrealistically predicts gasoline prices to be only $2.25 per gallon in 2016. But Americans are already paying nearly twice as much today. U.S. PIRG [Public Interest Research Group] research from squandering to stimulus shows that in the last five months American families have spent the entirety of their stimulus checks filling their tanks, while the cost of gasoline skyrocketed more than 40 percent.

Comment Number: TRANS-18-2
Organization: Individual
Commenter: Pamela Woodward

You need to use realistic gas prices, prices that are, that equal the current average, which is much higher than the $2 plus range. It's in the $4 plus range.

Comment Number: TRANS-22-3
Organization: Individual
Commenter: Julie Locascio

Nonetheless, many consumers will look first to the impact on their own finances in assessing the value of increased CAFE standards. A higher priced vehicle will be worth the extra cost to the consumer, if the consumer gets higher fuel efficiency. But if NHTSA is saying that such a consumer will only save about $2.50 for every gallon of gas longer needed, well into the next two decades, this analysis is completely distorted.

As everyone knows the price of gasoline at the pump is current hovering around $4 a gallon, and one would be hard pressed to find a cross-section of economists who would predict that the price of gasoline is going to drop back down below $3 a gallon in the two decades to come.

Indeed, even Guy Caruso, EIA administrator has testified that the CAFE cost benefit analysis should be using an oil price between $2.96 and $3.63 per gallon. I don't see how NHTSA can ignore the expert recommendation of the man responsible for ensuring that the statutory and regulatory requirements for legally performing the environmental impact assessment are fulfilled.

Comment Number: TRANS-23-4
Organization: Greater Washington Interfaith Power and Light
Commenter: Tara Morrow

Another matter for closer examination in the DEIS is the estimate of the price of gasoline used to determine what is cost effective. Many here have already referred to this, but I, too, was quite shocked to see an assumption of only in the $2 range for 2016, that's in terms of 2006 dollars, and it does seem quite unrealistic given current realities.

Comment Number: TRANS-24-2
Organization: Individual
Commenter: Heather Moyer

As others have said, I also was surprised and shocked to see the proposal assuming that future gas prices would be only $2.25 in 2016 using 2006 dollars. I found that shocking and saddening, and also laughable. And I urge you to use realistic gas prices.

Comment Number: TRANS-25-1
Organization: Individual
Commenter: Emanuel Figueroa

It doesn't make sense when we assume that the price of gasoline is $2 or $3, when we go outside and see the first, any gas station, doesn't matter if it's an Exxon, Mobile, Shell, any. You can choose your brand. You can choose the one that you like for your car, but it's way over $4 right now.

Comment Number: TRANS-28-2
Organization: Individual
Commenter: Jim Pierobon

So I urge you, just to quickly conclude here, to use more realistic assumptions about how high future gasoline prices could go. And looking back on how high they've been this year.

Comment Number: TRANS-29-1
Organization: Individual
Commenter: Allison Forbes

The figure you're considering right now for cost of gas is offensive to consumers. And I'm sure you know that, but we definitely need to be considering the higher cost of gas in our analysis. I paid $4.15 a gallon over the weekend driving around, and it's not easy. So please consider that in your rulemaking.

Comment Number: TRANS-30-1
Organization: Jewish Community Relations Council of Greater Washington
Commenter: Debbie Linick (for Ron Halber)

We must regulate fuel economy based on realistic assumptions about the likely future cost of fuel, and with an eye toward encouraging cleaner vehicles, and the pursuit of renewable and alternate sources of energy.

Comment Number: TRANS-33-2
Organization: Individual
Commenter: Fred Dobb

I'm no statistician, but as a citizen and clergy person it seems that whatever method yielded $2.25 or even $2.60 as an estimate for a decade out is an outlier at best, and a statistic beyond [expletive deleted] lies at worse.

Comment Number: TRANS-33-4
Organization: Individual
Commenter: Fred Dobb

I'm particularly concerned about calculations for the likely cost of gas in the future.

Comment Number: TRANS-34-3
Organization: Individual
Commenter: Fred Teal, Jr.

In summary, I wish to say that I disagree strongly with the arbitrarily low future gasoline prices contained in NHTSA's calculations. It's just incredible that you would use mileage figures for gas costs per gallon for gasoline that would be that low. It's just so impractical, considering our current situation.

Comment Number: TRANS-35-3
Organization: Individual
Commenter: Alina Fortson

Your analysis uses assumptions for future gas prices that are simply unrealistic. Today, Americans are paying nearly $4 per gallon and there's currently no reason to expect prices to drop as low as $2.25.

Comment Number: TRANS-36-3
Organization: Individual
Commenter: Matt Kirby

The unrealistic gas price of $2.25 assumption which is, frankly, an insult to my parents and an insult to the students who can't afford to eat.

Your own analysis shows that between 2011 and 2015 significantly higher standards can be achieved if you only up the presumed gas price at $3.14. So the use of these below cost energy estimates, it violates your own charter to impose mandatory maximum feasible fuel economy standards on a review of economic and technological feasibility.

Comment Number: TRANS-38-2
Organization: Environment America
Commenter: Ben Schreiber

You know, we're using a price of gasoline of $2.30 to justify doing the bare minimum on fuel economy standards, and yet at the same time the price of $4 is being justified to open up our very last protected wild spaces to more and more oil and gas exploration. And it's unacceptable.

Comment Number: TRANS-39-3
Organization: American Jewish Committee
Commenter: Ami Greener

Further, the current proposal relies on fanciful gas price assumptions, which result in insufficient fuel economy levels. The proposal assumes future gasoline prices of $2.25 per gallon, when American consumers are already paying prices nearly double that today.

Comment Number: 0599-2
Organization: Center for Biological Diversity
Commenter: Multiple Signatories

Your assumption that gas will cost $2.36 per gallon in 2020 is completely unsupportable and contributed to the ridiculously low proposed standards.

Response

As explained in Section 10.2.2 above, in response to all the comments NHTSA received pertaining to the fuel price forecast used in the Volpe model, this FEIS examines how the alternatives are affected by variations in the economic assumptions input into the Volpe model. Specifically, the agency calculated and analyzed mpg standards and environmental impacts associated with each alternative under both the "Reference Case" for key model inputs, which uses the U.S. Energy Information Administration's (EIA's) Reference Case fuel price forecast, a domestic social cost of carbon, and a 7-percent discount rate; and under a "High Scenario" set of input assumptions, which uses the EIA "High Case" for fuel price forecast, a global social cost of carbon, and a 3-percent discount rate. This FEIS also analyzes the impacts of various other combinations of economic assumptions inputs.

In the DEIS, NHTSA relied on the EIA's Annual Energy Outlook (AEO) forecasts for the estimate of fuel price during the period covered by the agency's action (EIA 2008a). Federal government agencies generally use EIA's projections in their assessment of energy-related policies. In the DEIS and NPRM, the agency selected the EIA's Reference Case fuel price forecast in performing the analysis. The EIA also includes a "High Price Case" and "Low Price Case" in AEO analyses that reflect uncertainties regarding future levels of oil production. Several commenters suggested that the agency apply the AEO "High Price Case" forecast to the Volpe model. In response to these comments, NHTSA has analyzed scenarios using the "High Price Case" and the "Reference Case." The agency declines to apply the current cost of gasoline to the Volpe model, as some commenters have suggested. Applying current fuel prices would be speculative. Indeed, at the time the DEIS was published, market prices for fuel were *generally rising. However, since that time commodity prices for light sweet crude oil have been declining. The current volatility in fuel prices gives NHTSA greater confidence in relying on EIA forecasts, rather than current prices in the marketplace.*

NHTSA's modeling incorporates the annual plans of the car manufacturers in the United States. Given the volatility and rapid movement of the market and the resulting decline in demand for large SUVs and pick-up trucks, the car manufacturers have moved quickly to adjust production of vehicles. EIA incorporates these and other economic trends in its AEO 2008 Forecast. In particular, AEO 2008 Forecast includes the impact of the Energy Independence and Security Act of 2007 (EISA 2007) that was enacted in December 2007, reflecting updates to the renewable fuel standard and the influences of higher CAFE standards for new light-duty vehicles. It also includes additional revisions that reflect historical data issued after the early release version of the AEO 2008 was completed, the EIA Short-Term Energy Outlook released in January 2008, a more current economic outlook, and updates to correct modeling problems in the early release version (EIA 2008d).

10.2.2.2 Rebound Effect

Comments

Comment Number: 0564-11
Organization: Consumer Federation of America
Commenter: Mark Cooper

Assumed that consumers irrationally burn up their fuel savings on increased driving, rather than using it to buy other goods and services, and applied this excessive "rebound" effect to analyses where it should not play a role.

Comment Number: 0575-11
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

NHTSA assumes a rebound effect of 15 percent. Yet recent research from Small and Van Dender, [Footnote: See original comment document.] which NHTSA "attaches greater significance" (NPRM, p. 201], notes that the rebound effect in the U.S. is small and has been getting smaller.

"*...the rebound effect declined substantially over time*—which we confirmed by estimating the equation (without the three interaction terms) separately for time periods 1966-1989 and 1990-2004... the short-run rebound fell from 4.8% to 2.9%, while the long run rebound fell from 21.1% to 7.7%" (emphasis added)

Given the Small and Van Dender conclusions, there is no justification for NHTSA's 15 percent rebound effect, especially given the low gas prices used by the agency. [Footnote: See original comment document.] A rebound of up to 10 percent may be reasonable if NHTSA employs the high price gasoline projection (or today's fuel prices). UCS suggests that, in accordance with use of the High Price Case gasoline projection, NHTSA employ a rebound effect no higher than 10 percent.

Comment Number: 0575-31
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

NHTSA assumes a rebound effect of 15 percent. This value is too high, based upon recent research which NHTSA "attaches greater significance to." Along with use of the High Price Case gasoline projection, NHTSA should employ a rebound effect no higher than 10 percent.

Comment Number: 0576-11
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA has assumed a very high rebound effect, which also influences its assumptions both in the appropriate level of standards and the potential environmental benefits of each of the range of alternatives.

Comment Number: 0576-23
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA has assumed a very high rebound effect – 15 percent – for this proposal. The rebound effect assumes that the amount of driving will increase as a result of decreased fuel consumption, which reduces the per mile cost of driving. (PRIA VIII-8) NHTSA looks at 29 estimates and attempts to reflect the current conditions; however according to the Small and Van Dender study, "most empirical measurements of the rebound effect rely heavily on variations in the fuel price," which raises again the question of whether NHTSA's assumptions about the rebound effect are colored by the estimates of future fuel price. [Footnote: See original comment document.]

Comment Number: 0588-10
Organization: New York State Department of Transportation
Commenter: Stanley Gee

The rebound effect is defined as an increase in Vehicle Miles Traveled (VMT) in response to decreased operating costs. Such an effect may occur as a result of higher fuel economy. Additional driving uses more fuel; thus, the rebound effect reduces the net fuel savings that accrue to vehicle owners, for a given increase in fuel economy. In chapter VIII of the PRIA, NHTSA summarizes the results of studies done on the rebound effect across the country, and chooses the study performed in 2005 by Dr. Kenneth Small at the University of California, Irvine. That study concluded that California would experience a dynamic rebound effect of 3 percent. NHTSA claims that updating this study for the country as a whole and for the period covered by this rulemaking would yield a rebound effect of at least 15 percent. It seems counterintuitive that the nation as a whole would see a rebound effect that is five times that of California, particularly in the face of significantly higher fuel costs. In a 2003 report, the Congressional Budget Office notes that the U.S. is a "mature market" and that as such, the rebound effect is small. The report also points out that even though the real cost of fuel per kilometer decreased in the U.S. by about 65 percent between 1982 and 1995, that decrease was not accompanied by a strong rebound in VMT. NHTSA's 15 percent downward adjustment to the economic benefits resulting from this fuel economy rulemaking is not warranted by economic research literature, or actual consumer behavior.

Comment Number: 0600-3
Organization: Centers for Disease Control and Prevention
Commenter: Sarah Heaton, Andrew Dannenberg

In Chapter 3, Affected Environment and Consequences, the assumption is stated that, "the tightened CAFE standards would create an incentive to drive more because they would decrease the vehicle's fuel cost per mile. The total amount of passenger car and light truck VMT would increase slightly due to this 'rebound effect'." There is substantial uncertainty in this argument and an insufficient analysis in the DEIS of variables affecting VMT projections, such as current and projected fuel costs. A sensitivity analysis is warranted to examine the implications of higher or lower assumptions about rebound effects.

Comment Number: TRANS-04-4
Organization: National Automobile Dealers Association
Commenter: David Westcott

Similarly, to the extent vehicles regulated by the CAFE proposal are used by NHTSA predicts after introduction into the fleet, the proposal will necessarily fail to achieve its expected level of environmental benefit. Due to the rebound effect, vehicles with lower operating costs predictably will be used more than the vehicles they replace. Environmental impacts that correlate with miles driven, traveled, such as those associated with greenhouse gases will be impacted to the degree of any such rebound effect, reducing any delay or forecast in environmental performance benefits.

Response

To derive an estimate of the rebound effect for use in assessing the fuel savings and other impacts of more stringent CAFE standards, NHTSA reviewed many studies (PRIA pp. VIII-6 and VIII-7). NHTSA then performed a detailed analysis of 66 estimates of the long-run rebound effect reported in these studies. The 66 estimates range from as low as 7 percent to as high as 75 percent, with a mean value of 23 percent. Approximately two-thirds of all 66 estimates reviewed range from 10 to 30 percent, as do two-thirds of all published estimates, and two-thirds of authors' preferred estimates.

In selecting a single value for the rebound effect to use in analyzing the fuel savings and other impacts of stricter CAFE standards for future model years, NHTSA attaches greater significance to studies that allow the rebound effect to vary in response to changes in the various factors that have been found to affect its magnitude. The agency also updated authors' originally reported estimates of variable rebound effects to reflect current conditions. Commenters referred to studies by Small and Van Dender, and NHTSA notes that it considered two papers by Small and Van Dender (2005a & b); however, NHTSA informs its decision with many studies rather than relying on a select few.

Considering the empirical evidence on the rebound effect as a whole, while according greater importance to the updated estimates from studies allowing the rebound effect to vary, NHTSA uses a rebound effect of 15 percent (with a range of uncertainty extending from 10 percent to at least 20 percent) to evaluate the fuel savings and other effects resulting from stricter fuel economy standards for future model year vehicles.

10.2.2.3 Social Cost of Carbon

Comments

Comment Number: 0557-8
Organization: The Natural Resources Defense Council
Commenter: Luke Tonachel, Brian Siu

The social cost of carbon used by NHTSA is based on an arbitrary range of values and incorrectly relies on a central estimate of $7 per metric ton of CO_2. Unmitigated, costs of dangerous climate change are very likely much higher than estimates in standard literature, and NHTSA must use a reasonable risk premium in its calculations.

Comment Number: 0572-15
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The NHTSA's methodology for the selection of an estimate of the value of reducing greenhouse gas emissions is arbitrary and designed to minimize the estimate. The Volpe model assumes that the value of CO_2 reductions is the midpoint between a so-called "high" of $14/ton CO_2 and a "low" of $0/ton CO_2. DEIS Appx. C at VIII-30. This valuation is flawed because: (1) it is based on an out-dated and otherwise flawed analysis; (2) the use of a $0 low value is unjustified; and (3) simply splitting the difference between two values does not take into account the distribution of economic projections for the cost of carbon.

The NHTSA relies entirely on the 2005 *Energy Policy* article, Tol (2005), as the source for the estimate of $14 per ton of CO_2, but fails to address the much higher estimates also reported by Tol. Tol (2005) states that "The marginal damages caused by a metric ton of carbon dioxide emissions in the near future were estimated in the [IPCC] Second Assessment Report at US$5-125 per tC." In addition, the NHTSA overlooks the fact that the studies cited in the Tol (2005) survey dated back as much as 18years, to 1991, and 25 of the 28 studies cited were published more than five years ago. Considering that the understanding of climate change has expanded dramatically in the past five years, and that impacts of climate change are progressing much more rapidly than were previously projected, this represents a fatal flaw in the analysis. Of the 28 papers cited by Tol (2005), only three were published since 2003, only one of which was peer reviewed. That paper estimated the social cost of carbon as high as $14 per ton of CO_2. (Pearce 2003).

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change also refers to the Tol (2005) survey, but is careful to point out, on page 813 of Yohe (2007), that "[it] is likely that the globally-aggregated figures from integrated assessment models underestimate climate costs because they do not include significant impacts that have not yet been monetized…," and, on page 17 of Adger (2007), that "taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time." The NHTSA concedes this point: "[taken] as a whole, recent estimates of the SCC may underestimate the true damage costs of carbon emissions because they often exclude damages caused by extreme weather events or climate response scenarios with low probabilities but potentially extreme impacts, and may underestimate the climate impacts and damages that could result from multiple stresses on the global climatic system." DEIS Appx. C at VIII-28.

In fact, the IPCC, on page 813 of Yohe (2007), estimates the cost of carbon as high as $350 per ton of carbon ($97.67/ton CO_2), and states that "It is virtually certain that the real social cost of carbon and other greenhouse gases will increase over time; it is very likely that the rate of increase will be 2% to 4% per year."

The DEIS places great weight on the fact that the IPCC Fourth Assessment report cites to Tol (2005). Yet, the DEIS does not acknowledge the many other studies that the IPCC refers to. For example, the IPCC contrasted the Tol estimate of carbon costs with that of Downing (2005), which indicated that the lower benchmark of $50/tC ($13.95/t CO_2) was reasonable. Most importantly, the IPCC gives great weight to the estimates in the Stern Review 2007. As the most recent and most comprehensive analysis of the costs of climate change, the Stern Review is the best available information. As the IPCC notes, the Stern Review 2007 estimates the cost of carbon at $85/t CO_2. The NHTSA must re-calibrate the Volpe model results to reflect the actual range of values in the current literature.

The NHTSA also uses an impermissible value for the lower bound on the cost of carbon dioxide reductions. The DEIS acknowledges that the IPCC indicates that the costs of global climate change will be non-zero. DEIS Appx. C at VIII-30. But then it jumps to the amazing and illogical conclusion that "it does not necessarily rule out low or zero values for the benefit to the U.S. itself from reducing emissions." DEIS Appx. C at VIII-30. This statement is completely erroneous. The evidence is clear that the U.S. will be severely adversely affected by climate change. Just a few examples: some of the most expensive real estate and most densely populated regions are along our expansive coastlines; the desert Southwest is gripped by drought and projected to continue to be; much of our fresh water is supplied by annual snowpack, which is already declining; forest fires are raging through most of the forested regions of the country; and human health, especially in the Southwest where there are large retired populations, will be affected by extreme heat events and in many other ways. Furthermore, our economy depends heavily on imports and exports from other countries. If the rest of the world is economically harmed by climate change, the U.S. will undoubtedly pay. There is no doubt that the U.S. will suffer severe impacts along with the rest of the world: the cost of carbon is most certainly non-zero.

Finally, the DEIS uses an impermissible method for reducing the range of potential carbon costs to a single value. The DEIS takes the midpoint between its chosen "upper" and "lower" bound. But as emphasized by the IPCC there are numerous estimates of carbon cost. This constellation of carbon costs will have some distribution. It is very likely that the estimated values do not fall along a normal "bell" curve. Consequently, taking the midpoint between the extreme values does not reflect the true "consensus" value for the cost of carbon.

The NHTSA must first re-analyze the available and current estimates of the cost of carbon, with particular attention to the leading analyses in the Stern Review 2007. Next, the NHTSA must ascertain a proper non-zero lower bound for its estimates. Finally, the distribution of estimated values should be taken into account when a single value is selected for use in the Volpe model.

Comment Number: 0572-22
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Furthermore, the NHTSA makes the mistake of elevating the decisional process over the substantive character of the alternatives. As the court in *California v. Block* noted with regard to an EIS prepared under NEPA, "[a]lthough it is worthwhile to consider a broad range of variables in constructing policy alternatives, the procedure becomes meaningless if the variables are assigned numerical values such that only a limited range of outcomes result." 690 F.2d 753, 769 (9th Cir. 1982) Here, NHTSA has limited its consideration, and range of alternatives, to the results of the model, yet those results are meaningless for a number of reasons, including the fact that the input values were simply incorrect. Thus, the range of values used as inputs to the Volpe model has unreasonably constrained the universe of alternatives under NEPA.

Moreover, as discussed above, the Volpe model arbitrarily constrains the universe of NEPA alternatives. The purpose of NEPA is to inform decision-making, but application of a specialized tool designed for cost-benefit analysis indicates that a decision has already been made by the agency. If the cost-benefit analysis is applied to select alternatives, there is no potential for considering alternatives that may carry less environmental impact. Yet, the Volpe cost-benefit analysis was employed to define all alternatives, including the maximal technology alternative. This alternative was based on what the NHTSA "considered to be available" and based on market penetration rates defined in the Volpe model DEIS at 2-10.

Comment Number: 0572-55
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Like the Volpe model, this analysis uses an estimate of the economic costs of global climate change, set in the proposed rule at $7 per ton of CO_2. However, this cost-benefit analysis fails to incorporate the full economic costs of global climate change, values that are difficult to monetize, and costs to the world outside the boundaries of the United States. In general, the estimate of the social costs of climate change fails to incorporate the loss of biodiversity, complex and large-scale ecosystem services, and the disproportionate impacts of global climate change on the developing world.

Comment Number: 0572-56
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

NHTSA's methodology for the selection of an estimate of the value of reducing greenhouse gas emissions is arbitrary and designed to minimize the estimate. The proposed rule, on page 24414, explains that NHTSA "elected to use the midpoint of the range from $0 to $14 (or $7.00) per metric ton of CO_2 as the initial value for the year 2011..." However, the range of estimates extends much higher than $14; there is no justification for a value of $0; and simply splitting the difference between two points is not a defensible methodology, particularly when the low point of the range is not part of a valid range but simply an arbitrary selection of zero as an endpoint.

NHTSA relies entirely on the 2005 *Energy Policy* article, Tol (2005), as the source for the estimate of $14 per ton of CO_2, but fails to address the much higher estimates of $95 per ton of CO_2 reported in Tol (2005). Tol (2005) states that "The marginal damages caused by a metric ton of carbon dioxide emissions in the near future were estimated in the [IPCC] Second Assessment Report at US$5-125 per tC." In addition, NHTSA overlooks the fact that the studies cited in the Tol (2005) survey dated back as much as 18 years, to 1991, and 25 of the 28 studies cited were published more than five years ago. Considering that the understanding of climate change has expanded dramatically in the past five years, and that impacts of climate change are progressing much more rapidly than were previously projected, this is a serious limitation. Of the 28 papers cited by Tol (2005), only three were published since 2003, and only one, Pearce (2003), was peer reviewed, and that paper estimated the social cost of carbon as high as $14 per ton of CO_2.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change also refers to the Tol (2005) survey, but is careful to point out, on page 813 of Yohe (2007), that "[it] is likely that the globally-aggregated figures from integrated assessment models underestimate climate costs because they do not include significant impacts that have not yet been monetized...," and, on page 17 of Adger (2007), that "taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time." [Footnote: See original comment document.] In fact, the IPCC, on page 813 of Yohe (2007), estimates the cost of carbon as high as $350 per ton of carbon, and states that "It is virtually certain that the real social cost of carbon and other greenhouse gases will increase over time; it is very likely that the rate of increase will be 2% to 4% per year."

The IPCC, on page 821 of Yohe (2007), specifically refers to the findings of Stern (2007) with regard to the economics of climate change. Stating, "[most] recently, Stem (2007) took account of a full range of both impacts and possible outcomes (i.e., it employed the basic economics of risk premiums) to suggest that the economic effects of unmitigated climate change could reduce welfare by an amount equivalent to a persistent average reduction in global per capita consumption of at least 5%. Including direct impacts on the environment and human health (i.e., 'non-market' impacts) increased their estimate of the total (average) cost of climate change to 11 % GDP [gross domestic product]; including evidence which indicates that the climate system may be more responsive to greenhouse gas emissions than previously thought increased their estimates to 14% GDP." Ultimately, Stern (2006) estimates the social cost of climate change at $25 to $30 per ton of CO_2, or much higher. In fact, as Stern points out "If consumption falls along a path, the discount rate can be negative. If inequality rises over time, this would work to reduce the discount rate, for the social welfare functions typically used. If uncertainty rises as outcomes further into the future are contemplated, this would work to reduce the discount rate, with the welfare functions typically used." A negative discount rate would dramatically increase the cost of climate change in the cost-benefit analyses in the proposed rule.

For the lower end of the range of values for reducing global warming, NHTSA proposes an estimate of $0 per ton of CO_2. NHTSA, on page 24414 of the NPRM, states, "Although this finding suggests that the *global* value of economic benefits from reducing carbon dioxide emissions is unlikely to be zero, it does not necessarily rule out low or zero values for the benefit to the U.S. itself from reducing emissions..." Presumably, this is meant to imply that the United States might benefit economically by letting other countries bear the costs of unabated American greenhouse gas emissions. Setting aside the tremendous ethical implications of such a position, NHTSA provides absolutely no evidence to support the claim. Furthermore, only one study surveyed in Tol (2005) included central estimates below $0.00; and that was a non-peer-reviewed article, also authored by Tol.

NHTSA, on page 24413of the NPRM, offers a justification for the low valuation by stating, "many studies fail to consider potentially beneficial impacts of climate change, and do not adequately account for how future development patterns and adaptations could reduce potential impacts from climate change or the economic damages they cause." Although this statement is paraphrased from page 2067 of Tol (2005), it is important to note that this is not cited by Tol (2005) as a finding, and is not reported by Tol as one of the factors contributing to the range of estimates. In fact, the sum of the findings of the IPCC, Tol (2005), and the Stern Review, shows that NHTSA's selection of $14 per ton of CO_2 is unreasonably low and completely unsupported by the literature and by reality. In fact, NHTSA itself concedes this point, on page 24413, with the statement that, "[taken] as a whole, recent estimates of the SCC may underestimate the true damage costs of carbon emissions because they often exclude damages caused by extreme weather events or climate response scenarios with low probabilities but potentially extreme impacts, and may underestimate the climate impacts and damages that could result from multiple stresses on the global climatic system."

Comment Number: 0572-61
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

NHTSA, on page 24414 of the NPRM, states that, "[in] order to be consistent with NHTSA's use of exclusively domestic costs and benefits in prior CAFE rulemakings, the appropriate value to be placed on changes climate damages [sic] caused by carbon emissions should be one that reflects the change in damages to the United States alone. Accordingly, NHTSA notes that the value for the benefits of reducing CO_2 emissions might be restricted to the fraction of those benefits that are likely to be experienced within the United States."

This statement indicates that NHTSA fails to fully understand the tremendous threats and challenges posed by global climate change, and the fundamental challenges global climate change presents in comparison to previous approaches to addressing pollution reductions. Unlike other pollutants, the air basin for greenhouse gases, and CO_2, in particular, is the global atmosphere. The impacts of global warming are local, regional, national, international, and global. The cost-benefit analysis should incorporate the social costs of climate change, and the economic benefits of reducing greenhouse gas emissions, wherever those impacts or benefits are experienced. The alternative, in which only the impacts and costs experienced in United States territory are considered, would lead to a dramatic underestimation of the aggregate costs of climate change. In addition, it would carry the terrible and arrogant implication that the people of the United States believe that people in other countries should bear the environmental and economic burdens caused by American consumer preferences. Nothing in EPCA, NEPA, or other applicable law allows NHTSA to artificially constrain the analysis or under report the costs of global warming in this manner.

Comment Number: 0575-13
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

In its NPRM, NHTSA proposes the use of a 2011 value of carbon between $0 and $14 per metric ton. Even the upper end of this range, selected by NHTSA based on a 2005 Tol study, is an unacceptably low valuation of the pollutant. The European Climate Exchange, which provides a futures market value for global warming pollution in Europe's carbon constrained market, indicates 2011 contracts for carbon dioxide at approximately $45 (U.S.) per metric ton – well above the figure cited by NHTSA. [Footnote: See original comment document.]

Further, NHTSA proposes a 2011 value of carbon at $7 per metric ton CO_2, a computed mean average of the proposed $0 and $14 boundaries. This computation places as much weight on the $0 per metric ton value as it does on the $14 per metric ton value. Valuing carbon at $0 was declared by the ninth circuit court to be arbitrary and capricious – and implies the possibility that climate change won't have any negative consequences. This is unrealistic and stands in stark contrast to recent government study findings on U.S. climate change effects and findings from the International Panel on Climate Change and the Academies of Science for the G8+5. [Footnote: See original comment document.]

NHTSA includes a sensitivity analysis using varied valuation of CO_2 emissions, and concludes that "the results of the sensitivity analyses indicate that the value of CO_2... has almost no impact on the level of the standards." (NPRM, p. 364). NHTSA juxtaposes this seemingly insignificant impact with that of a gasoline price sensitivity analysis, which shows significantly higher sensitivity. It is not surprising that NHTSA came to such conclusions. The dollar per gallon price equivalent of a $0-$14 per metric ton CO_2 range is (assuming full in-use and upstream emissions of 24 lbs. of CO_2/gallon consumed) a mere $0.00-

$0.15 per gallon. A sensitivity analysis examining such a confined range will of course arrive at such an erroneous conclusion.

UCS recommends that NHTSA employ a value of at least $45 per metric ton CO_2, the value currently trading on the European Climate Exchange. This value represents a predicted marginal abatement cost (the cost of avoiding global warming pollution), and is likely a conservative estimate of the benefit of reducing global warming pollution since the cost of avoiding climate change is lower than the cost of fixing the damage after it occurs.

The value recommended by UCS for use in this 2008 rule is generally consistent with other recent allowance price estimates, such as the EPA' s assessment of GHG allowance prices under Lieberman-Warner: $22 – $40 in 2015 and $28 – $5 1 in 2020 (EPA figures are in 2005 dollars per ton of CO_2-equivalent). [Footnote: See original comment document.]

Comment Number: 0575-3
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

While carbon dioxide futures are currently trading at more than $40 per metric ton in Europe, NHTSA used a value of $7 per ton. NHTSA even considered $0 per ton to be in the range of possible values. In the face of numerous economic analyses which indicate that combating global warming will greatly reduce the cost of adapting to climate change, factoring a $0 value into the rule is unacceptable.

Comment Number: 0576-10
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA has set the price of CO_2 arbitrarily and too low. The agency chose a value of $7/ton CO_2 based on a 2005 meta-analysis of estimates of the price per ton of carbon by Richard S. J. Tol, from which NHTSA estimated prices per ton of carbon, and NHTSA converted the range to $0-14 per ton CO_2. In comments to NHTSA's NPRM, Tol commented that NHTSA has improperly indexed the values in the Tol paper, as they were in 1995 dollars instead of 2005 dollars, and also that a 2007 paper he authored found larger estimates than the 2005 paper. [Footnote: See original comment document.]

Comment Number: 0576-21
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA's estimate for the value of CO_2 is arbitrary and too low. The agency's estimate for the price of CO_2 examines a range of values from $0-14 per metric ton CO_2, based on a 2005 meta analysis of CO_2 valuation. Emissions allowances have recently been trading on the European Climate Exchange at around €30 per allowance (one metric ton CO_2 equivalent). [Footnote: See original comment document.] An analysis done by EPA in March 2008 for the Senate Committee on Environment and Public Works for S. 2191, America's Climate Security Act, estimated the value of CO_2 in 2015 between $22 and $40 per metric ton of CO_2, and cited two other analyses with higher estimates of $48 and $50 per metric ton CO_2. [Footnote: See original comment document.] The agency should extend the range of CO_2 prices considered at least as high as EPA's estimates, which are more recent than the Tol estimate cited in NHTSA's notice. All of the estimates EPA cited for its analysis of Lieberman-Warner exceed the $14 ceiling on carbon price.

The agency provides no justification for selecting the midpoint of the range it took from the Tol study. NHTSA should weight the credibility of each estimate. Averaging the results of multiple studies can substantially skew the result, especially if the estimates are not parallel comparisons. Estimating the value of something like CO_2 requires careful selection of factors considered, and requires subjective determination of assumptions. Failure to make "apples to apples" comparisons by looking at studies based on their assumptions can produce a result that does not reflect the actual value.

In discussing monetized value of CO_2, it is also important to take into consideration the costs of inaction on reducing greenhouse gas emissions and the resultant consequences of global warming. In the EPA notice on the California waiver denial, the agency outlines some of these consequences:

> …along with exacerbating ozone impacts and increasing wildfires. . . declining snowpack and early snowmelt and resultant impacts on water storage and release, sea level rise, salt water intrusion, and adverse impacts to agriculture (e.g., declining yields, increased pests, etc.), forests, and wildlife. . . .In addition, some commenters specifically point to a direct threat to public health (e.g., asthma) since increased temperatures due to increased GHG emissions will lead to increased levels of ozone and other pollutants. [73 *FR* 12156, 12169 (March 6, 2008) at 12164.]

A recent report from the University of Maryland found that economic impacts of global warming will be far-reaching, unevenly distributed, and will put a significant strain on public sector budgets. [Footnote: See original comment document.] It is therefore important that when considering any policy relevant to reducing global warming pollution that the costs of inaction be factored into the decision. NHTSA has not made such an estimate in its proposal or the accompanying economic analysis.

Comment Number: 0588-3
Organization: New York State Department of Transportation
Commenter: Stanley Gee

NHTSA also uses an arbitrary low value for the benefits of avoided greenhouse gas emissions, reducing estimated benefits.

Comment Number: 0588-8
Organization: New York State Department of Transportation
Commenter: Stanley Gee

Under NHTSA's cost-benefit based standard setting methodology, the values assigned to benefits are critical. Higher value benefits justify more stringent standards. NHTSA arbitrarily chose $7.00 per metric ton of carbon dioxide avoided as the benefit of reduced fuel consumption, rather than $13.60 per metric ton of carbon dioxide ($50 per metric ton of carbon) recommended by the National Academy of Sciences Committee on which NHTSA says it relies for this analysis.

Comment Number: 0595-22
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Also, the social cost of a non-CO_2 GHG can be quite different from the social cost of carbon dioxide emissions (IPCC WGII, 2007). NHTSA should estimate the global changes in non-CO_2 GHG emissions and apply, or at least acknowledge, non-CO_2 marginal benefits estimates.

Comment Number: 0595-3
Organization: Environmental Protection Agency
Commenter: Susan Bromm

NHTSA selected a single marginal benefits value of \$7.00/tCO_2 to represent the social cost of carbon (SCC) for their main analysis. This value and the \$0-14/tCO_2 range NHTSA considers are characterized as domestic SCC estimates. While OMB [Office of Management and Budget] guidance instructs Agencies to consider benefits that accrue to U.S. residents, it does allow for the additional consideration of global benefits. Given that U.S. emissions have global externalities, NHTSA should analyze global SCC estimates in addition to any domestic estimates to more fully capture all of the externalities. This could be justified from the fact that U.S. citizens may value impacts felt outside our borders. Moreover, to the extent that the United States regards the CAFE standards as a component of its contribution to a global effort to address climate change, a global SCC is needed to accurately characterize that contribution. It is also important that NHTSA recognize that the current monetized estimates of marginal benefits are incomplete and very likely underestimated.

Therefore, EPA recommends that NHTSA do Volpe runs with a range of domestic and global SCC estimates that capture the uncertainty in estimates and the potential risks of significant climate change impacts. The ranges and growth rates should be based in the peer reviewed literature and should cover a substantial range, given the wide uncertainties in estimates of the SCC. For example, see the estimates and discussion in the "Technical Support Document on the Benefits of Regulating GHG Emissions" developed in support of EPA's Advanced Notice of Proposed Rulemaking (found at www.regulations.gov; search on "Technical Support Document – Benefits").

It should also be noted that SCC estimates are only a partial accounting of the social costs of carbon. NHTSA does not currently account for the non-monetized impacts and potential catastrophic risks of climate change in its decision-making approach. The IPCC WGII [Work Group II] (2007) report states that SCC values are "very likely" underestimated, where the report defines "very likely" as a greater than 90% probability. The models used to generate the SCC estimates cited by NHTSA leave out major types of climate change damage that have been identified by the IPCC.

Furthermore, most SCC estimates exclude the value of avoiding or reducing the risk of potential catastrophic effects of climate change, due to scientific and economic uncertainties. It is noteworthy that the risk of such effects is one of the major policy considerations for Congress, the public, and the executive branch in developing a climate change mitigation policy, yet is excluded in most economic analysis. Risk increases with increases in the rate and magnitude of climate change, due to a greater chance to stress systems. NHTSA should clearly note in the DEIS that emissions reductions reduce the probability of higher climate outcomes and therefore reduce the level of associated risk and acknowledge that benefits estimates do not include a risk premium, i.e., the value people have for greater certainty and the reduced risk of more extreme outcomes.

Comment Number: 0598-5
Organization: Sierra Club
Commenter: Caroline Keicher

NHTSA should first use more accurate values for gasoline prices and carbon values and more realistic assumptions about hybrid penetration and an accelerated introduction of PHEVs [plug-in hybrid electric vehicles] and EVs [electric vehicles] – all of which will justify a standard of at least 35 mpg in 2015. NHTSA should then recalibrate its alternative scenarios to reflect these changes.

Comment Number: TRANS-08-14
Organization: Sierra Club
Commenter: Ann Mesnikoff

The proposed rule and the PRIA both show that the gas prices are major forces in setting fuel economy. NHTSA short changes America by using gas price assumptions that are far too low, a price for carbon that is randomly selected, and artificially constraining technologies.

Comment Number: TRANS-19-6
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

The value of carbon dioxide that NHTSA used, they assume $7 per ton. Carbon dioxide is currently trading in the European futures market at $40 per ton.

Comment Number: TRANS-23-3
Organization: Greater Washington Interfaith Power and Light
Commenter: Tara Morrow

While I was glad to see that the DEIS does assign a dollar value greater than zero to CO_2 reductions, I ask you to take another look at the value range and price carbon more accurately given the most recent analysis, as others have referred to here today.

Response

As commenters noted and as shown by a significant body of literature, there is a wide range of values associated with the social cost of carbon (SCC) and extremely wide variations in published estimates for SCC. However, NHTSA has taken a hard look at this issue and the associated literature, and believes its analysis falls within the mainstream views on the issue.

Emissions of CO_2 and other GHGs occur throughout the process of producing and distributing transportation fuels, and from fuel combustion itself. By reducing the volume of fuel consumed by passenger cars and light trucks, higher CAFE standards will reduce emissions generated by fuel use, and throughout the fuel-supply cycle. Quantifying and monetizing the benefits from reducing these emissions first requires an estimate of the resulting effect on the projected pace and extent of future changes in the global climate, and then an estimate of the value of any resulting reduction in future economic damages that changes in the global climate would otherwise have caused.

If projected future changes in the global climate ultimately exceed critical thresholds in the dynamics of global geophysical or biophysical systems, those changes might also lead to large-scale events, such as a sudden large rise in sea levels or irreversible alteration of critical regional ecosystems. By reducing the probability that climate changes with potentially catastrophic economic or environmental impacts will occur, reducing GHG emissions might also confer benefits that extend beyond their resulting reduction in the expected future economic costs caused by more gradual changes in Earth's climatic systems.

The environmental impacts of GHG emissions differ in several important ways from those of conventional air pollutants. Most important, as the IPCC has noted, CO_2 and other GHGs are chemically stable, and therefore remain in the atmosphere for periods of a decade to centuries, or even longer, becoming well-mixed throughout Earth's atmosphere. As a consequence, current emissions of these gases have extremely long-term effects on the global climate, and emissions from the United States *are expected to contribute to changes in the global climate that will affect many other nations. Similarly, emissions occurring in other countries will contribute to changes in Earth's future climate that are expected to affect the well-being of the United States.*

Researchers usually estimate the economic benefits from reducing GHG emissions in several steps; the first is to project future changes in the global climate and the economic damages that are expected to result under a baseline projection of net global GHG emissions. These projections are usually developed using models that relate concentrations of GHGs in Earth's atmosphere to changes in summary measures of the global climate, such as temperature and sea levels, and in turn, estimate the reductions in global economic output that are expected to result from changes in climate. Because the effects of GHG emissions on the global climate occur decades or even centuries later, and there is considerable inertia in Earth's climate systems, changes in the global climate and the resulting economic impacts must be estimated over a comparably long future period.

Next, this same modeling process is used to project future climate changes and resulting economic damages under the assumption that GHG emissions will be reduced by some increment beginning in a stated future year. The reduction in projected global economic damages resulting from the lower future trajectory of GHG emissions, which also occurs over a prolonged period extending into the distant future, represents the estimated economic benefit from the assumed reduction in emissions. Discounted to its equivalent present value and expressed per unit of GHG emissions (usually per ton of carbon emissions, with non-CO_2 *GHGs converted to their equivalents in terms of carbon emissions), the resulting value represents the global economic benefit from reducing GHG emissions by one unit beginning in a stated future year. This value is often referred to in published research and debates over climate policy SCC.*

This process involves multiple sources of uncertainty, including those in scientific knowledge about the effects of varying levels of GHG emissions on the magnitude and timing of changes in the functioning of regional and global climatic and ecological systems. In addition, sunstantial uncertainty surrounds the anticipated extent, geographic distribution, and timing of the resulting impacts on the economies of nations in different regions of the globe. Because the climatic and economic impacts of GHG emissions are projected to occur over the distant future, uncertainty about the correct rate at which to discount these future impacts also substantially affects the estimated economic benefits of reducing GHG emissions.

Finally, researchers have not yet been able to quantify many of the potentially substantial effects of GHG emissions and their continued accumulation in Earth's atmosphere on the global climate. Researchers also have not developed complete models to represent the anticipated impacts of changes in the global climate on economic resources and the productivity with which they are used to generate economic output. As a consequence, the estimates of economic benefits from reducing GHG emissions produced by integrated models of climate and economic activity are likely to exclude some potentially substantial sources of benefits that will result from lower emissions.

Some researchers are concerned that the combination of multiple sources of uncertainty in estimating climate damages and the omission of some potentially substantial economic impacts of climate change limits the usefulness of deterministic estimates of SCC for valuing the economic impacts of GHG emissions and developing policies that are intended to reduce their emissions. They argue that the modeling approach typically used to monetize the impacts of climate change and value reductions in GHG emissions does not appropriately represent or account for risks posed by the possibility of catastrophic changes in climate and the correspondingly large economic damages. This could lead the conventional approach to substantially underestimate the economic benefits resulting from policies that reduce GHG emissions.

While conventional probabilistic uncertainty analysis might be useful in identifying the range of uncertainty surrounding estimates of SCC derived using the typical modeling approach, a risk management approach might be more appropriate in these circumstances. Instead of using estimates of SCC to value reductions in GHG emissions, this approach would specify a maximum acceptable extent of climate change (as measured, for example, by a maximum increase in global mean temperature), and derive from it the maximum permissible level of GHG emissions over the foreseeable future.

Estimates of the costs of achieving the emissions reductions necessary to limit emissions to this maximum level – and thus prevent climate change from proceeding beyond its maximum acceptable extent – would then be developed. The estimated incremental costs for achieving the final emissions reductions necessary to keep emissions below their maximum permissible level would then be used to estimate the value of reducing GHG emissions via policies or regulations.

In developing the fuel economy standards proposed in the NPRM and evaluated in the DEIS, NHTSA used an initial estimate of $7 per metric ton for the value of reducing U.S. CO_2 *emissions from fuel production and use. This figure was intended to represent the amount by which the economic value of damages to the United States from potential climate change effects in the United States was likely to be reduced for each ton of* CO_2 *emissions that would be avoided by producing and consuming less fuel. NHTSA also examined the sensitivity of the optimized CAFE standards and their accompanying environmental impacts to a range of values for reducing* CO_2 *emissions extending from zero to $14 per metric ton of* CO_2*.*

As discussed in detail in the NPRM, these values were based on Tol's (2005) extensive survey of published estimates of the global economic damage likely to be caused by changes in climate resulting from increased carbon emissions, often referred to as the social cost of carbon (SCC)[8] *(Tol 2005). Specifically, NHTSA's estimate of $7 per metric ton for the domestic value of reducing* CO_2 *emissions, which was intended as an estimate of the reduction in climate-related economic damages that occur within the United States as a consequence of lower* CO_2 *emissions, was based on Tol's calculation that the mean value of peer-reviewed estimates of the global SCC included in his survey was $43 per metric ton of carbon. Tol's estimate corresponds to a global value for the economic benefits from reducing* CO_2 *emissions of $14 per metric ton (Tol 2005, Yohe et al. 2007).*[9]

NHTSA's estimate implicitly reflected the assumption that approximately half of the global economic damages resulting from climate change would be borne within the United States, thus resulting in the figure of $7 per metric ton of CO_2 *emissions. The range from zero to $14 per metric ton used in the NPRM sensitivity analysis reflected the additional assumption that the range of uncertainty surrounding the likely economic benefits to the United States from reducing the threat of climate change extended from a low estimate of zero benefits to a high estimate equal to 100 percent of the $14 per metric ton value derived from Tol's analysis.*

NHTSA received numerous comments on the value of reducing CO_2 *emissions it employed to develop the standards proposed in the NPRM and DEIS. This FEIS examines how the alternatives are affected by variations in the economic assumptions input into the Volpe model. Specifically, NHTSA*

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[8] *Richard S. J. Tol, The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties, Energy Policy 33 (2005), 2064-2074.*

[9] *Carbon itself accounts for 12/44, or about 27 percent, of the mass of carbon dioxide (12/44 is the ratio of the molecular weight of carbon to that of carbon dioxide). Thus, each ton of carbon emitted is associated with 44/12, or 3.67, tons of* CO_2 *emissions. Estimates of SCC are typically reported in dollars per ton of carbon, and must be divided by 3.67 to determine their equivalent value per ton of* CO_2 *emissions.*

calculated and analyzed mpg standards and environmental impacts associated with each alternative under both the "Reference Case" for key model inputs, which uses the U.S. Energy Information Administration's (EIA's) Reference Case fuel price forecast, a domestic SCC, and a 7 percent discount rate; and under a "High Scenario" set of input assumptions, which uses the EIA "High Case" for fuel price forecast, a global SCC, and a 3 percent discount rate. This FEIS also analyzes the impacts of various other combinations of economic assumptions to illustrate the variations in environmental impacts and mpg stringency that result from using various combinations of Volpe model inputs. See Sections 3.2.4, 3.3.4, 3.4.5, 4.2.3, 4.3.4, and 4.4.3.

In response to new research on the potential economic costs of climate change that has become available since publication of the recent NPRM, and the many comments NHTSA received, we have evaluated in this FEIS the environmental impacts resulting from standards associated with a substantially higher global estimate of the value of reducing CO_2 emissions. Specifically, this FEIS analyzes environmental impacts under the assumption that the global value of reducing CO_2 emissions is $33 per metric ton, and conducts a sensitivity analysis using a value of $80 per metric ton. This FEIS also presents the environmental impacts resulting from a revised domestic SCC assumption of $2 per metric ton of CO_2 emissions. To develop these new estimates, NHTSA has relied on Tol's (2008)[10] expanded and updated survey of 211 published estimates of SCC, which was published after the completion of the analysis NHTSA performed to develop CAFE standards it proposed in the NPRM.

Tol's 2008 survey encompasses a substantially larger number of estimates for the global value of reducing carbon emissions than its previously published counterpart. Like that author's earlier survey, it represents the only recent, publicly available compendium of peer-reviewed estimates of SCC that has been peer-reviewed and published itself. Thus, NHTSA believes that it is the most reliable source on which to base our own updated estimate of the global value of reducing CO_2 emissions from fuel production and use.

As indicated previously, the long-lived nature of atmospheric GHGs means that emissions of these gases from any location or source can affect the global climate over a prolonged period, and can thus result in economic damage to many nations and over multiple generations. Reducing GHG emissions to an economically efficient level, or one that maximizes the difference between the benefits from limiting the extent of climate change and the costs of achieving the emissions reductions necessary to do so, therefore requires individual nations to limit their own domestic emissions to the point where their domestic costs for further reducing emissions equal the global value of reduced economic damages that result from limiting climate change.

In its Technical Support Document on the Benefits of Regulating GHG Emissions referenced in its comments on the DEIS, EPA argued that if individual nations consider only the domestic benefits they each receive from limiting the pace or extent of climate change, they will each reduce their emissions only to the point where their respective domestic costs for achieving further reductions equal the benefits to their own domestic economies from limiting the impacts of climate change. Because no individual nation is likely to experience a large share of total global damages from climate change, however, none will capture a substantial share of the benefits from limiting it. Thus, the combined global reduction in emissions resulting from individual nations comparing their domestic benefits from limiting climate change to their domestic costs for reducing emissions will likely be inadequate to substantially slow or limit the progress of climate change.

[10] *Richard S.J. Tol (2008), "The Social Cost of Carbon: Trends, Outliers, and Catastrophes," Economics – the Open-Access, Open-Assessment E-Journal, 2 (25), 1-24.*

Tol's updated survey reports that the mean value of the 125 estimates of SCC published in peer-reviewed journals through the year 2007 is $71 per ton of carbon emissions. All of these estimates are intended to represent the global value of reduced economic damage from climate change that would be likely to result from lower carbon emissions. In direct communications with Tol, NHTSA staff confirmed that this value applies to carbon emissions occurring during the mid-1990s, and is expressed in approximately 1995 dollars (Tol 2008, Table 1). The $71 per metric ton estimate of the social cost of increased carbon emissions corresponds to a global value of $19 per metric ton of CO_2 *emissions reduced or avoided, also expressed in 1995 dollars.*

Separately, the IPCC notes that the climate-related economic damage resulting from an additional ton of carbon emissions is likely to grow at a rate of 2.4 percent annually (Yohe et al. 2008). This growth occurs because the increase in the expected pace and degree of climate change – and thus in the resulting economic damage – caused by growth in emissions rises in proportion to the existing concentration of CO_2 *in Earth's atmosphere.*

Several comments on the NPRM asserted that the IPCC intended the 2.4-percent growth rate it reports for SCC to instead read "2-4 percent." NHTSA staff reviewed the underlying references from which this figure was derived, and those sources clearly report the growth rate in the future value of SCC as 2.4 percent, rather than the 2-4 percent asserted in various comments (Hope 2006, Hope and Newberry 2006). Applying the 2.4-percent annual rate of increase to the $19 per ton mean value for mid-1990s CO_2 *emissions, and expressing the result in 2007 dollars, results in a global value of $33 per metric ton of* CO_2 *for emissions occurring during 2007. In this FEIS, NHTSA uses this global value for SCC in the Mid-1 and High Scenario combinations of economic assumptions. See Table 2.3-2 and Appendix B.*

NHTSA uses this figure, which is assumed to continue increasing from its 2007 value at the 2.4-percent annual rate specified by the IPCC, to estimate the global economic benefits from reducing future CO_2 *emissions by establishing higher CAFE standards for MY 2011-2015 cars and light trucks. Continuing growth in the value of reducing* CO_2 *emissions over the expected lifetimes of those vehicles, which extend through approximately 2050, means that the value of eliminating each ton of* CO_2 *emissions by reducing fuel production and use averages approximately twice its $33 value during 2007.*

Like the underlying estimate from which it is derived, the $33 per metric ton of CO_2 *figure represents the estimated world-wide or global economic benefits from reducing U.S.* CO_2 *emissions during 2007. As indicated previously, there are important reasons for individual nations to take these world-wide benefits into account when deciding the extent of reductions in their domestic emissions to seek or require, because reducing their domestic emissions confers substantial benefits on the large number of other nations for which potential economic damages from climate change are also reduced as a result.*

The substantial magnitude of these "external" benefits (EPA estimates that 90 to 95 percent of the total global benefits from reducing U.S. CO_2 *emissions will be experienced by other nations) implies that a globally efficient level of total emissions reduction can only occur if individual nations base their respective decisions about how extensively to reduce their own domestic emissions on a comparison of the global benefits from reducing the threat of climate change to their respective costs for reducing domestic emissions. Basing its decisions about emissions reductions on this comparison is particularly likely to be required for the U.S. to achieve reductions that are efficient from a global perspective, since as much as 90-95% of the total global benefits from reducing U.S. CO2 emissions may be experienced by other nations (EPA 2008i; calculated from Table 1).*

NHTSA notes that there is a risk for nations that unilaterally attempt to reduce emissions by adopting policies, regulations, or taxes to reduce the threat of climate change. The potential risk is that they will economically disadvantage the domestic industries those policies affect. There is also the possibility of unintended consequences. By doing so, they could induce economic activity – particularly production by emissions-intensive industries – to shift to nations that adopt less stringent or no regulations on emissions. This shift could take either the form of industries relocating production capacity to other nations or the loss of market share by domestic industries to overseas producers.

In either case, the result is likely to be reductions in domestic economic output and employment. Thus, nations attempting to reduce emissions to the levels called for by considering the global benefits from doing so could bear substantial costs, without resulting in comparably valuable reductions in the potential economic damages they face from climate change.

In the specific context of this rulemaking, establishing CAFE standards partly on the basis of the global benefits projected to result from lower GHG emissions would likely impose higher costs on automobile manufacturing activity to serve the U.S. vehicle market, regardless of whether that activity occurs within the U.S. or overseas. If vehicle manufacturers located in the U.S. respond by reducing production, the U.S. economy could bear substantial costs, without resulting in a measurable net reduction in global GHG emissions.

Recognizing this prospect, NHTSA has estimated the economic damage from climate change effects that is likely to be borne within the United States, and employed this value to estimate the domestic benefits to the United States from reducing GHG emissions. NHTSA constructed this value using estimates of U.S. domestic and global benefits from reducing greenhouse gas emissions developed by EPA and reported in that agency's Technical Support Document accompanying its Advance Notice of Proposed Rulemaking on motor vehicle CO_2 emissions[11] (EPA 2008i). Specifically, NHTSA applied the ratio of domestic to global values of reducing CO_2 emissions estimated by EPA using its Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) integrated assessment model to the $33 per metric ton estimate of the global value of reducing CO_2 emissions, which was developed as described above.

EPA's central estimates of domestic and global values for reducing GHG emissions from the FUND model using a 3 percent discount rate are $1 and $17 per metric ton (in 2006 dollars) (EPA 2008i; Table 1, p.12). Applying EPA's ratio to NHTSA's $33 per metric ton estimate of the global value of reducing CO_2 emissions, developed as described above, produces an estimate of $2 per metric ton for the domestic benefit from reducing U.S. CO_2 emissions in 2007. NHTSA have employed this estimate as an alternative to the global value of reducing U.S. CO_2 emissions in establishing CAFE standards for MY 2011-2015 and evaluating their economic benefits.

NHTSA has also applied the 2.4 percent rate of growth to calculate the annual increase in its estimate of the domestic benefits from reducing CO_2 emissions. Over the lifetimes of cars and light trucks subject to the CAFE standards for MY 2011-15, the resulting value averages $4 per metric ton of CO_2 emissions avoided by reducing fuel production and consumption.

In its Technical Support Document, EPA argues that the most appropriate estimate of SCC that can be derived from Tol's 2008 survey is the mean value of the estimates from only those studies that

[11] *EPA Technical Support Document on Benefits of Reducing GHG Emissions, June 12, 2008. EPA Docket No. EPA-HQ-OAR-2008-0318* (http://www.regulations.gov/fdmspublic/component/main?main=DocumentDetail&o=0900006480669358).

were published after 1995 and that do not employ so-called equity weighting.[12] *Further, Tol notes that estimates of SCC vary substantially with the rate used to discount increased future economic damages resulting from climate change to the date that the emissions causing that increased damage are assumed to occur.*

EPA also suggests that estimates of benefits from reducing emissions should employ the mean of only those estimates of SCC that are derived using the specific rate that will subsequently be used to discount CO_2 emissions from the date they occur to the present.[13] *Because NHTSA uses a rate of 3 percent to discount future benefits from reducing CO_2 emissions (see Section 10.2.2.8), EPA's Technical Support Document appears to suggest that the most appropriate estimate of SCC from Tol's 2008 survey for use in NHTSA's analysis of benefits from reducing fuel consumption corresponds to a value of $40 (in 2007 dollars) per metric ton of CO_2 emissions occurring today (EPA 2008i; Table 1, p 12).*

However, NHTSA's view is that the mean value of all 125 SCC estimates from peer-reviewed studies reported by Tol provides a more appropriate basis for valuing reductions in CO_2 emissions. This is because NHTSA believes that excluding pre-1995 studies and those that employ equity weighting (which would eliminate 40 of the 125 estimates) could eliminate many studies that produced sound, defensible estimates of SCC, particularly recognizing that those studies have been published in peer-reviewed journals. Including those studies improves the reliability of the resulting average value by reducing the uncertainty surrounding it.

NHTSA also believes that its estimate of the value of reducing CO_2 emissions should not be based solely on estimates developed using a 3-percent discount rate. Instead, NHTSA recognizes that the varying discount rates employed by different researchers are an important source of variation in their resulting estimates of SCC. The discount rate is a parameter about which there is substantial disagreement, analogous to the uncertainty surrounding the many other parameters involved in modeling future climate change and the resulting economic damage.

Thus, NHTSA believes that incorporating estimates of SCC that employ varying discount rates increases the extent to which the resulting average value fairly incorporates the many sources of uncertainty that complicate researchers' attempts to identify the correct value. Another more practical reason for not restricting the sample of estimates to those using a 3-percent discount rate is that this would reduce the number of estimates on whichNHTSAbases the estimate of the value of reducing CO_2 emissions to only 10 of the 125 peer-reviewed estimates included in Tol's recent survey (Tol 2008, Table 1).

The agency also conducted sensitivity analysis using $80 per ton as an estimate of the global value for reducing CO_2 emissions to illustrate the resulting stringencies, fuel savings, and CO2 reductions that result from higher estimates of the global social cost of CO_2 emissions. In his updated survey of SCC estimates, Tol reports that the standard deviation associated with the mean value from 125 peer-reviewed estimates of the global SCC of $71 per ton of carbon emissions is $98 per ton. Like Tol's original $71 estimate, this value applies to mid-1990s emissions of carbon (rather than carbon dioxide), and is expressed in approximately 1995 dollars.

[12] *Equity weighting assigns higher weights per dollar of economic damage from climate change that are expected to be borne by lower-income regions of the globe, in an attempt to make the welfare changes corresponding to those damages more comparable to the damages expected to be sustained by higher-income world regions.*
[13] *Tol notes that estimates of SCC vary substantially with the rate that is used to discount increased future economic damages resulting from climate change to the date that the emissions causing those increased damages are assumed to occur.*

Thus, a range of one standard deviation above and below the $71 mean value extends from minus $27 (i.e., $27 per ton benefit for each ton of carbon emitted) to $169 per ton of carbon. Converting this range to 2007 dollars per ton of CO_2 *and applying the same 2.4-percent annual growth rate to these values produces a range of minus $13 to $80 around the $33 per ton mean estimate of the global benefit from reducing* CO_2 *emissions in 2007.*

While NHTSA uses the $80 per ton benefit of reducing CO_2 *emissions in its sensitivity analysis, the agency has elected not to employ the minus $13 per ton figure, in part because, based on information from the U.S. Climate Change Science Program and the IPCC, it views the implication that there are measurable economic benefits from climate change as implausible. NHTSA believes that the range extending from the $2 per ton estimate of the domestic value of reducing* CO_2 *emissions to the $80 per ton upper estimate of the global value is sufficiently broad to illustrate the sensitivity of fuel savings and resulting environmental impacts to differing SCC values.*

10.2.2.4 Technologies/Vehicle Attributes Considered

Comments

Comment Number: 0550-8
Organization: Individual
Commenter: Sarah Larsen

NHTSA proposes to raise the fuel economy of cars and light trucks to a combined average of 31.6 mpg for Model Year 2015. While this increase is more than half of what is required to meet the mandate of 35 mpg by 2020, I believe NHTSA fails to take full advantage of available fuel saving technologies, and fails to fully and fairly evaluate the benefits of greenhouse gas emission reductions.

Comment Number: 0554-9
Organization: Individual
Commenter: James Adcock

Plug-in hybrids. Given GM commitment to delivering a plug-in hybrid (Chevy Volt) in this time frame, NHTSA's assumption that plug-in technology will not exist during the regulatory period is troubling, and will lead to higher GHG.

Start/stop mild hybrid on small cars. NHTSA's assumption that this technology is not available for small cars is troubling given that it has already been implemented in Europe (Smart Fortwo mhd.) This assumption results in higher GHG.

Comment Number: 0557-11
Organization: The Natural Resources Defense Council
Commenter: Luke Tonachel, Brian Siu

NHTSA set arbitrary limits on technology availability in the Volpe Model, which biased toward setting a weaker fuel economy standard. Two specific examples include an arbitrary constraint on the use of lightweight materials substitution to improve fuel economy and the exclusion of plug-in hybrid electric vehicles from consideration in the Volpe Model.

Comment Number: 0559-7
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

We urge NHTSA to reevaluate its proposal, taking more of a technology forcing approach to setting standards. Further, we urge NHTSA to consider fuel consumption reducing technologies that by virtue of NHTSA's conservative cost-analysis approach have not been given due consideration. For example, NHTSA notes that "some manufacturers have made public statements regarding hopes to offer plug-in HEVs [hybrid electric vehicles] before MY 2015, but such vehicles are not represented in our analysis." We contend that the prospect for widespread deployment of plug-in HEVs in the near term is more than a simple hope. For example, both Toyota and Chevrolet have announced plans for plug-in HEVs to be available around 2010. [Footnote: See original comment document.]

Comment Number: 0572-18
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The potential technologies for improving fuel economy are unreasonably limited. The extent to which the technology is unreasonably limited is amply illustrated by the fact that the "technology exhaustion" alternative barely reaches the current fuel economy standards in Japan and Europe, much less the projected fuel economy standards in Europe and Japan for 2015. [Footnote: See original comment document.] A model that predicts maximal technology implementation to be unable to reach even current market standards in other countries is clearly not considering all available technologies.

Concrete examples of technologies that are unreasonably excluded are: electric vehicles, plug-in hybrids, and power-split hybrids. Electric vehicles are entirely excluded from the Volpe model. (73 *Fed. Reg.* at 24381, Table III-3) This is absurd considering that a major U.S. auto manufacturer produced and placed such vehicles on the road in the year 1996. [Footnote 6: See original comment document.] These vehicles were pulled from the market for commercial reasons over loud protests of drivers in 1999, and destroyed in 2003 (Biederman 2005). An auto manufacturer's commercial decision does not render a technology unsuitable for implementation – the only concern should be physical capability, which has been clearly demonstrated. Plug-in hybrids are also categorically excluded on the basis that they are not "market-ready" (73 *Fed. Reg.* at 24381), despite the fact that Toyota is planning to introduce plug-in hybrids by MY 2010 (Maynard 2008). The major U.S. auto manufacturers are also planning to offer similar vehicles around the same time. (Maynard 2008) Power split hybrids, like the Toyota Prius, are considered advanced technology that will not be available under 2014. (73 *Fed. Reg.* at 24381, Table III-3) This assumption is ludicrous given that the Toyota Prius has been sold in the U.S. since MY 2001 and is a top-selling vehicle.

Other technologies that are not yet commercially available, but could be if economy standards were sufficiently high, include replacement of spark-plugs with laser-pulse injection systems and engines that can switch between two-stroke and four-stroke modes (Graham-Rowe 2008). Furthermore, the DEIS makes no mention of alternatives such as compressed-air vehicles (Green Car Congress 2008).

There are abundant potential technologies for improving fuel economy that have not been included in the Volpe model. This leads to misleading and factually incorrect outputs from the model, and a failure to disclose basic relevant information under NEPA.

Comment Number: 0598-5
Organization: Sierra Club
Commenter: Caroline Keicher

NHTSA should first use more accurate values for gasoline prices and carbon values and more realistic assumptions about hybrid penetration and an accelerated introduction of PHEVs and EVs – all of which will justify a standard of at least 35 mpg in 2015. NHTSA should then recalibrate its alternative scenarios to reflect these changes.

Comment Number: TRANS-06-7
Organization: Public Citizen
Commenter: Lena Pons

All of the regulatory alternatives that are considered in the draft environmental impact statement are the result of modeling using the Volpe model. This is problematic because the Volpe model does not completely look at all of the available technologies. It does not look at, and it applies various optimization factors which do not reflect what the most aggressive possible control regulations would be.

Additionally, the Volpe model bars certain types of techniques, such as down weighting and performance reduction, which may seem like strange things to do, because we've traditionally considered them to be problematic. However, given the significant dangers to the environment as a result of global warming, it's important to consider these things as well.

Comment Number: TRANS-08-14
Organization: Sierra Club
Commenter: Ann Mesnikoff

The proposed rule and the PRIA both show that the gas prices are major forces in setting fuel economy. NHTSA short changes America by using gas price assumptions that are far too low, a price for carbon that is randomly selected, and artificially constraining technologies.

Comment Number: TRANS-08-4
Organization: Sierra Club
Commenter: Ann Mesnikoff

NHTSA should first use more accurate values for gasoline prices and other inputs to justify a 35 in 2015 standard, and increases beyond that with greater hybrid penetration, accelerated introduction of plug-in electric hybrid vehicles, and other technologies.

The DEIS is premised upon a flawed proposed standard and the scenarios that must be addressed should be fixed before a final standard is issued and a final EIS is issued.

Comment Number: TRANS-20-7
Organization: Sierra Club
Commenter: Caroline Keicher

NHTSA proposes to raise fuel economy of cars and light trucks to a combined average of 31.6 miles per gallon for model year 2015. While this increase is more than half of what is required to meet the floor set by the EISA, NHTSA fails to take full advantage of the fuel saving technologies, and fails to fully and fairly evaluate the benefits of greenhouse gas emission reductions.

Comment Number: TRANS-39-2
Organization: American Jewish Committee
Commenter: Ami Greener

In proposing a combined average of 31.6 miles per gallon for model year 2015, NHTSA is failing to acknowledge the current technology that could safely and cost effectively make all vehicles reach state-wide fuel economy average of at least 35 miles per gallon by that year.

Comment Number: TRANS-15-4
Organization: Individual
Commenter: Marissa Knodel

In order to reduce oil use and reach the goal of an 80 percent reduction in greenhouse gas pollution by 2050, we can increase fuel economy standards, make sure hybrid and plug-in electric vehicles are available and affordable

Comment Number: 0575-24
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

One of the peculiar findings of the NPRM is light trucks' lack of sensitivity compared to that of passenger cars. The sensitivity analysis using high fuel prices, for example, yields up to a 6.7 mpg difference from NHTSA's proposed scenario for cars, and only a 0.8 mpg difference from the proposed scenario for light trucks. The only explanation given by NHTSA for this lack of truck sensitivity is that marginal technologies for trucks are too expensive to "bring them over the cost-benefit threshold." (NPRM, p. 364-365).

However, that explanation is inconsistent with the technology costs laid out in Table III-1 of the NPRM. Even the 2002 National Academies study, on which NHTSA claims to have based some of its technology costs, show only slightly (approx. 15% to 25%) lower technology expenses for passenger cars than for light trucks [Footnote: See original comment document.] Moreover, given that incremental energy savings are greater at the low end of the fuel economy spectrum (i.e., that a 1 mpg increase from 14 to 15 mpg saves more energy than a 1 mpg increase from 24 to 25 mpg), one would presume that trucks would have an even *easier* time making the marginal cost-effective case.

Based on the opaqueness of the cost-effective judgment criteria, UCS cannot determine with certainty what might be constraining application of fuel saving technologies to light trucks in the Volpe model. However, the explanation provided by NHTSA that light truck technology has tapped out its cost-effectiveness seems highly unlikely.

Comment Number: 0576-33
Organization: Public Citizen
Commenter: Joan Claybrook

This approach to vehicle weight ignores the role of advanced materials to reduce vehicle weight without compromising safety, it discourages manufacturers from considering more aggressive vehicle redesigns, which could achieve a broad range of fuel economy and safety goals, and it preserves the dangerous incompatibility between the heaviest and lightest vehicles. In setting aggressive new fuel economy standards, the agency should encourage manufacturers to rethink how vehicles are built. New standards should promote innovation that drives safety and fuel economy forward. Instead, with the Volpe Model's approach of merely requiring that the industry do what it was planning to do, there is little to no motivation to make much-needed bold shifts.

Comment Number: 0588-6
Organization: New York State Department of Transportation
Commenter: Stanley Gee

As global warming trends continue, NYSDOT encourages NHTSA to work with the industry to expedite the production of more fuel efficient vehicles, as well as those capable of using alternative fuels, such as compressed natural gas (CNG), liquefied natural gas (LNG), and advanced biofuels. NHTSA should also promote hybrid-electric, battery electric, cleaner diesel, and fuel cell technology.

Comment Number: 0575-21
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

The source of the data for NHTSA's manufacturer-specific learning curves is not provided and the approach appears fundamentally flawed. First, by applying learning curves on a manufacturer-specific basis, NHTSA ignores the fact that many manufacturers engage in joint-venture efforts to produce new technologies. The recent 2-mode hybrid technology enabling more fuel efficient trucks, for example, was the product of a joint venture between Chrysler, General Motors, and BMW. Even when joint ventures are not in practice, manufacturers learn from each other through the standard practice of tearing down competitors products. NHTSA's proposed learning curve methodology does not account for any of these practices.

Further, treating car and truck sales volumes separately when estimating learning curves makes little sense. While certain components will invariably be unique to cars or light trucks separately, that is far from an industry-wide rule of thumb. It makes little sense to assume that the experience gained from, for example, the use of lower cost materials would not subsequently be used in other products. This is especially true today where many "trucks" are, in fact, car-like crossover vehicles with shared components of many sedans and wagons.

In its technical report, *Cost and Effectiveness Estimates of Technologies Used to Reduce Light-duty Vehicle Carbon Dioxide Emissions*, EPA suggests use of a learning curve factor of 20%, with the limited exception of diesel. [Footnote: See original comment document.] UCS recommends that NHTSA remedy the flaws associated with its learning curve assumptions, and adopt EPA's suggestion of a 20% learning factor, to help account for the market realities noted above.

Comment Number: 0559-12
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

Information from a 2004 NESCCAF (NESCCAF is the Northeast States Center for a Clean Air Future, an affiliate organization of NESCAUM) study entitled "Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles" is cited in the NHTSA proposal. Some of this information is reported in a way that is either confusing or incorrect. For example, NHTSA applies a 1.5 retail price equivalent (RPE) factor to the manufacturer costs presented in Appendix C of the NESCCAF report, and at other times uses a 1.4 RPE — and presents both costs as NESCCAF costs. In the report, NESCCAF only used a 1.4 RPE. The reporting of costs using the 1.5 multiplier as NESCCAF costs is incorrect and leads to uncertainty as to how the costs were developed. A specific case is the cost of a turbocharger. NHTSA states the NESCCAF turbocharger cost is $600. In this case, NHTSA applied a 1.5 RPE factor to manufacturer costs presented in Appendix C of the NESCCAF report to arrive at the $600 cost. This is different from the cost that NESCCAF developed. Conversely, on page 24369 of the Federal Register notice, NHTSA accurately states the NESCCAF cylinder deactivation costs ranged from $161 to $210. This cost accurately reflects manufacturer costs presented in Appendix C of the NESCCAF report, multiplied by the 1.4 retail price equivalent used by NESCCAF.

In some cases, information about what specific components were included in the NESCCAF study assumptions is reported incorrectly by NHTSA. For example, the NESCCAF study did not conclude that an air pump is required as part of a turbocharged system, in contrast to NHTSA's statement that NESCCAF assumed a $90 air pump is needed with the turbocharger.

Another example is the statement on p. 24375 of the *Federal Register* notice that the NESCCAF study included costs for high efficiency generators ($56) but failed to account for costs for the electrification of other accessories. In reality, Appendix C of the NESCCAF report assigns a cost of $70 for electrified accessories for a total cost of $126, which is within the range of costs for these technologies cited from a National Academy of Sciences report and used by NHTSA.

We recommend that all reported costs and benefits, attributed to NESCCAF by NHTSA, be reviewed carefully for errors and amended accordingly.

Comment Number: 0572-16
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Fleet mix is a central component of average fuel economy and yet is absent from the Volpe model cost-benefit analysis. For instance, the Volpe model "does not attempt to account for…intentional over-compliance…" Another possibility NHTSA and Volpe staff have considered but do not yet know how to analyze, is the potential that manufacturers might "pull ahead" the implementation of some technologies in response to CAFE standards that they know will be steadily increasing overtime." Proposed CAFE Standards MY 2011-2015 at 73 *Fed. Reg.* 24352, 24393 (May 2, 2008).

Comment Number: 0575-19
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

In Table 111-3, the NPRM specifies "year of availability" assumptions for various technologies. (NPRM, p. 112) It is unclear where the hybrid technology assumptions come from. Further, the assumptions used do not appear to make sense. All hybrid technologies—ranging from start/stop-based systems to the 2-mode and power-split "full" hybrid systems-are assumed not to appear until 2014, despite the fact that these technologies are on the road today (*i.e.*, Saturn VUE "mild" hybrid, GMC Yukon "2-mode" hybrid, and Toyota Prius "full" hybrid). It is unrealistic to assume, as it appears NHTSA has done, that automakers have cleared their product plans of any other hybrid models until the 2014 model year. This is especially egregious considering that the Toyota Prius is the 9th best selling car in the U.S.

Hybrid Adoption Rates

UCS is concerned about the technology phase-in caps or, as described by NHTSA, "overall constraints on the rates at which each technology can penetrate a manufacturer's fleet." (NPRM, p. 131-132) While many of the caps range from a 4-6 year fleet penetration, NHTSA assumes that hybrid and diesel technologies would see phase-ins as low as 3 percent.

UCS sees no valid reason to assume it will take 33 years for hybrid technology to become ubiquitous. First, and most fundamental, NHTSA applies the same cap to all types of hybrids, from mild start-stop hybrids to full PHEVs alike, despite the fact that the cap is employed “to reflect the major redesign efforts and capital investments required to implement these technologies.” (NPRM, p. 132) In contrast, an EPA technical report on which NHTSA relied said the following about integrated starter-generators with idle-off: “their low cost and easy adaptability to existing powertrains and platforms can make them attractive for some applications.” [Footnote: See original comment document.]

While hybrids currently only account for about three percent of the U.S. market, they are seeing a dramatic increase in interest from consumers seeking ways to find relief from high gas prices. Furthermore, with more than 10 years of experience from leading manufacturers, hybrids can no longer be considered niche technology. UCS (among numerous other groups and market analysts) expects significant growth in the hybrid market over the coming years.

It appears that, lacking any support to back their decision, NHTSA’s hybrid adoption rate was arbitrarily selected, as opposed to based on specific technological findings. Given the fuel savings potential of hybrid-electric technology, limiting its application in this manner is inappropriate. UCS recommends that NHTSA accelerate its hybrid technology adoption rate to 5-7 percent, equivalent to a 15-20 year full market penetration.

Comment Number: TRANS-19-9
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

The recent proposed notice rulemaking actually assumed that hybrids wouldn’t be on the road until 2014. Let me just reiterate that. Despite the fact that there are more than 1 million hybrids on the road today, despite the fact that the Toyota Prius is the ninth best selling car in America, the announcements that NHTSA used assume hybrids won’t be on the market until 2014.

People are not sitting around waiting for a hybrid to show up on a dealer’s lot in six years. They’re on six month waiting lists, as we heard today, because they are already that popular.

Comment Number: TRANS-28-3
Organization: Individual
Commenter: Jim Pierobon

I hope you’ll recognize how fuel efficient hybrids, as one dramatic example, are becoming more valuable and how quickly and efficiently they can deeply penetrate, especially the consumer automobile market.

Comment Number: TRANS-34-4
Organization: Individual
Commenter: Fred Teal, Jr.

I disagree with your belief that we’re not going to have any substantial amount of hybrid vehicles introduced until 2014. They’ve been around for years, and Ford and General Motors, Honda, Toyota, are making them and selling them today in large quantity. I disagree with your assumption that the rate of adoption of hybrids is going to be as low as you say it is.

Comment Number: 0572-7
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

As discussed in our July 1, 2008 comments on the NPRM, the Volpe model makes a number of assumptions that are unreasonable and conflict with the EPCA statutory scheme. For example, the NHTSA assumes that the U.S. fleet mix will not change in response to consumer demand for more fuel efficient vehicles or due to a change in regulatory requirements. (73 *Fed. Reg.* 24394) This assumption is particularly outrageous. First, auto manufacturers who have for decades deliberately manipulated the market with advertising, incentives, financing schemes, and other methods towards the least fuel efficient vehicles, continue to do so. (See, *e.g.* Chevrolet Tahoe Hybrid website; GreenCar.com 'Chevrolet Tahoe Hybrid Green Car of the Year;' Chrysler $3 gas banner; KCRA.com 'Chrysler $3 gas;' Ford Escape Hybrid website; Lyons 'Ford Guilt Free SUV.') Consumer preferences, nonetheless, are now shifting dramatically towards more fuel efficient vehicles in response to higher gas prices. (Cooper 2008). For a manufacturer to change its fleet mix in response to regulation is a method of compliance that must be considered in both the EPCA and NEPA analyses. Any precedent to the contrary is inapposite.

The NHTSA also assumes that manufacturers will not update their vehicle models more frequently than once every 5 years, and, "in most instances" has simply "accepted the projected redesign periods from the companies who provided them through MY 2013" (73 *Fed. Reg.* 24386) In other words, the underlying analysis for a fuel economy standard which is supposed to conserve energy by pushing manufacturers to develop new technology and innovate to meet challenging standards which may even "appear impossible" today, is constrained by the assumption that manufacturers will do <u>nothing other than what they are already doing</u>, at least for a period of five years. This clearly violates both EPCA and NEPA.

Comment Number: 0576-30
Organization: Public Citizen
Commenter: Joan Claybrook

For this rulemaking, NHTSA has added two more factors that impede transparency, and erode consumer confidence in the Volpe Model: technology phase-in caps and manufacturer learning curves. Public Citizen acknowledges that manufacturers cannot deploy all technologies in all vehicles at once, and that lead-time is necessary for manufacturers to make necessary changes. However, the agency's decision to gear technology additions to the redesign and refresh cycle is unnecessarily lenient. The agency has given the industry over two years of lead time before the 2011 model year. [Footnote: See original comment document.] EISA only requires only 18 months of lead time. For the 2012 to 2015 model years, the agency will have provided ample lead time for automakers to adjust. The industry is already changing plans, and closing plants or stopping work to adjust to changing consumer demand. [Footnote: See original comment document.]

NHTSA claims that it relaxed phase-in caps based on rising fuel prices and rising forecast fuel prices. (PRIA V-50). The agency should re-evaluate the assumptions about phase-in caps, especially with regard to technologies that require a more substantial redesign. NHTSA has given ample lead time for the industry to reconsider its redesign schedule to reflect tumultuous changes in consumer preferences. Public Citizen suggests that NHTSA not constrain the use of technology to achieve the maximum feasible fuel economy level.

Comment Number: 0576-41
Organization: Public Citizen
Commenter: Joan Claybrook

Public Citizen requests that NHTSA rethink its position on dealing with "outliers," or vehicles that get vastly better fuel economy. The agency position is that excluding hybrid electric vehicles "yields initial curves of shapes similar to those proposed, but displaced slightly in the direction of lower fuel consumption. The similarity of the shapes of these curves suggests that optimization against the full fleet (with HEVs) would produce standards whose stringency is similar to that of those proposed today." (73 *FR* 24440) However, automakers will be credited for producing hybrid vehicles which will count for compliance, but not in the stringency of how the curves are set. In an economy-wide standard, the pressure from manufacturers that build more efficient vehicles set the stringency of the economy-wide level of standards. Removing that pressure by excluding highly-efficient vehicles undercuts the maximum feasible level of fuel economy.

Comment Number: 0572-8
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Volpe model generally does not apply a new technology until a given vehicle is due for a "redesign or refresh," and assumes that some technologies, such as hybrid vehicles, already in use today cannot yet be adopted. (73 Fed. Reg. 24386)

Comment Number: 0575-20
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

Vehicle Redesign Rates

NHTSA assumes that vehicles will be redesigned on five-year cycles, which is inconsistent with recent trade publication information. As reported in Ward's Automotive. Ford intends to shorten its redesign period to three-year cycles. [Footnote: See original comment document.] Given this and past performance from other automakers, NHTSA's product cycle duration assumptions are too long. UCS recommends that NHTSA shorten its modeled redesign period to three-year cycles.

Comment Number: TRANS-02-3
Organization: Lee Auto Malls
Commenter: Adam Lee

The new technologies are coming down in price.

Comment Number: 0572-64
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

both the Volpe model and the economic analyses fail to account for the potential for technologies developed within the automobile industry to be exported to other economic sectors. This exclusion overlooks the potential for technologies developed in the automobile industry to bring significant benefits to the larger economy, resulting in financial returns to the developers of the technologies within the automobile industry, as well as the multiplied economic benefits of increased efficiency in other sectors, and the social and economic benefits of the greenhouse gas reductions. These considerations, by incorporating additional benefits to both society and to the automakers, would significantly alter the calculation of the CAFE standards and the cost-benefit analyses.

Response

Many commenters stated that NHTSA failed to take full advantage of available fuel saving technologies and that optimization factors used in technology application do not reflect the most aggressive possible regulations. NHTSA specifically sought comment on the estimates, which it had developed jointly with EPA, of the availability, applicability, cost, and effectiveness of fuel-saving technologies, and the order in which the technologies were applied, as well as cost learning curves. See 73 FR 24352, 24367. While NHTSA asked manufacturers to submit such information in the request for product plans, the agency also conducted its own independent analysis of the all the comments and data – including comments and information from entities outside the automobile manufacturing community – received through the rulemaking process. This involved hiring an international engineering consulting firm that specializes in automotive engineering, and that was used by the EPA in developing its recent Advance Notice of Proposed Rulemaking to regulate greenhouse gas emissions under the Clean Air Act.[14]

NHTSA and its consultants undertook a thorough review of the NPRM technology assumptions and all comments received on those assumptions, based on both old and new public and confidential manufacturer information. NHTSA and its consultants reviewed and compared comments on the availability and applicability of technologies, and the logical progression between them. NHTSA also reviewed and compared the methodologies used for determining the costs and effectiveness of the technologies as well as the specific estimates provided. Relying on the expertise of its consultants and taking into consideration all the information available, NHTSA revised its estimates of the availability and applicability of many technologies, and revised its estimate of the order in which the technologies were applied. In addition, the agency and its consultants generally agreed with commenters who said that in several cases, the technology related costs used in the NPRM and DEIS were underestimated and benefits were overestimated. The agency also agreed with commenters that both sets of estimates were not well differentiated by vehicle class and that the technology decision trees needed to be expanded and refined. Relying on the expertise of its consultants and taking into consideration all the information available, NHTSA revised its technology and effectiveness estimates and used them in analyzing all of the alternatives and scenarios presented in this FEIS. The agency believes that the representation of technologies—that is, estimates of the availability, applicability, cost, and effectiveness of fuel-saving technologies, and the order in which the technologies were applied, as well as cost learning curves—used in this action is the best available.

NHTSA appreciates NESCAUM's attention to detail on the retail price equivalents and component inclusion. NHTSA has noted the inaccuracies NESCAUM identified, and will correct them in the final rule.

As to the multitude of comments on hybrid penetration/phase-in rates, there is a general misperception that the technology is cost-effective. The waiting lists for popular hybrid cars are due to limitations in the supply chain, especially in battery production. At present, manufacturers are not able to produce numbers that justify the cost of production. The model incorporates technologies when they are expected to reach the point of cost-effectiveness, but this does not prevent manufacturers from applying the technologies if they choose to do so.

NHTSA has considered comments that we should include advanced materials and allow manufacturers to downweight vehicles; however, NHTSA's analysis still supports our position that

[14] 73 FR 44354 (July 30, 2008).

downweighting vehicles under 5,000 pounds carries unacceptable risks to public safety. See Section 10.3.6.4 for detailed responses to downweighting and safety comments.

Regarding levels of fuel economy in other countries, there are several important reasons why a direct comparison to U.S. standards is not possible. First, the United States, the European Union (EU), and Japan all use different testing methods to determine a vehicle's mpg. Second, the EU standard is voluntary, and the Japanese fines are minimal. Third, the Japanese standard is weight-based (a practice the United States moved away from for safety reasons). Fourth, the fleet mix is different. Fuel taxes and other incentives are credited with shrinking the average vehicle size in both the EU and Japan, so higher fuel economy standards cannot be attributed to technology alone, as the commenter appears to suggest. Fifth, the EU and Japanese emissions standards are not as stringent as those in the United States with respect to some pollutants (e.g., NO_x). To facilitate the fast penetration of diesel vehicles into its market, Europe made a policy decision not to require fast reductions in NO_x emissions. Diesel vehicles in the United States are more costly because of the higher emissions requirements and the need for installing pollution abatement devices, which are not required in Europe.

10.2.2.5 Fleet Turnover

Comments

Comment Number: 0574-10
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

As Attachment #14 to its substantive comments on NHTSA's CAFE NPRM for MY 2011-2015 (NHTSA Document ID: NHTSA-2008-0089-0170.1), the Alliance submitted the June 15, 2007 study performed by NERA, Sierra Research, and Air Improvement Resource ("AIR") entitled *Effectiveness of the California Light Duty Vehicle Regulations as Compared to Federal Regulations*, which was originally submitted to EPA in connection with its consideration of whether to grant California a waiver of preemption under the Clean Air Act for that State to set its own greenhouse gas emission standards for new vehicles. This study demonstrates how increases in fuel economy standards can, through the fleet turnover effect, delay new vehicle purchases, thereby prolonging the period that vehicles emitting greater levels of traditional criteria and toxic pollutants will be driven on the roads. [Footnote: See original comment document.]

The NERA/Sierra/AIR [Air Improvement Resources, Inc.] study compared the real-world emissions control levels achieved by the California program to the federal program for light-duty vehicles. The analysis compared emissions of the five key pollutants (VOC, NO_x, $PM_{2.5}$, CO, and SO_x), plus effects on an aggregation of five air toxics (acetaldehyde, benzene, 1,3 butadiene, formaldehyde, and acrolein) under the two programs from 2009 through 2023. The study concluded that increases in the relative stringency of fuel economy standards as adopted by California would significantly drive up most criteria pollutant and air toxics emissions levels.

By contrast, NHTSA's analysis in its DEIS concludes that the more stringent CAFE standards become, the fewer criteria pollutants and air toxics are emitted from the vehicle fleet. See DEIS at 2-15 (Table 2.5-2) (moving from right to left on that table, which corresponds to increased CAFE stringency, criteria and toxic emissions generally are shown to decrease). This can only be inconsequence of NHTSA failing to properly take account of the fleet-turnover effect. Failure to rectify this error would be arbitrary and capricious. See *Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 43 (1983) ("agency rule would be arbitrary and capricious if the agency has . . . offered an explanation for its decision that runs contrary to the evidence . . . .").

Indeed, NHTSA's discussion in the DEIS makes clear that the agency is refusing to consider fleet-turnover effects. See DEIS at 1-18 ("As these issues [including fleet turnover] raised by the AAM . . . do not relate to the effects on the physical environment, they are not addressed in this document."). This entirely misunderstands the NERA/Sierra/AIR study and the nature of the fleet turnover effect. This effect will cause NHTSA's proposed CAFE standards to increase various criteria pollutant and air toxic emissions. These are direct physical effects on the environment. It is difficult to understand what NHTSA means when it attempts to call the effect on pollutant levels caused by the fleet turnover effect a non-physical effect on the environment. If NHTSA means that it can ignore some physical effect on the environment whenever such an affect occurs based on economic cause and effect, then NHTSA surely errs. If that were the case, NHTSA's use of the Volpe model in connection with NEPA analysis would also be flawed, because the Volpe model is intended as a cost-benefit tool for comparing different fuel economy mandates, and the Volpe model is integral to NHTSA's NEPA analysis.

In fact, agencies are often compelled to consider environmental outcomes resulting from behavioral changes due to economic factors. See *generally Mid States Coalition for Progress v. STB*, 345 F.3d 520, 548-49 (8th Cir. 2003) (STB erred by failing to consider claimed increases in CO_2 emissions by power plants associated with the STB's approval of a new rail line based on a lengthy chain of economic reasoning to the effect that the new rail line would lower the price and increase the availability of low-sulfur coal, and thereby increase emissions from power plants expected to consume the coal being carried). In the case of EISA, the consideration of economic factors is a particularly critical element of the statutory design. It would be nonsensical for NHTSA to ignore technically sound studies demonstrating a direct connection between the economic effects of CAFE standards and resulting environmental impacts.

Comment Number: 0574-5
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

NHTSA finds that more stringent CAFE standards will reduce criteria pollutant and air toxics emissions. Such a conclusion is demonstrably incorrect and ignores the fleet-turnover effect and the study of that effect submitted by the Alliance to EPA in 2007 to explain how California CO_2 emissions standards that represent increases in stringency over the MY 2010 CAFE baseline would increase emissions of most criteria pollutant and air toxics. NHTSA has a duty to consider that submission and revise its analysis accordingly.

Comment Number: TRANS-01-5
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

[T]he draft EIS incorrectly disregards the environmental impact of the fleet turnover effect, and this was explained in our scoping comments. The Alliance asks NHTSA to consider the fleet turnover effect, and the air quality impacts that will result from heightened CAFE standards. Instead, NHTSA is treating this as an economic impact and an indirect one, which we don't think is appropriate.

Response

Under NHTSA's analysis, any effect of higher vehicle prices resulting from stricter CAFE standards on fleet turnover is not likely to have substantial consequences for criteria pollutant emissions. First, NHTSA's research indicates that prices for new vehicles are only one of many factors that vehicle buyers consider in their purchase decisions. Others are likely to include fuel prices, vehicle maintenance and repair costs, household income levels, loan rates for financing new-vehicle purchases, and *macroeconomic cycles. Because all of these factors are likely to change in the future, the potential effect of higher prices for new vehicles on fleet turnover is difficult to anticipate.*

Second, there is evidence that manufacturers cannot pass on to buyers the full costs of complying with higher CAFE standards, which would limit their effect on fleet-wide emissions of criteria pollutants. Finally, the dramatic reduction in the rates of tailpipe emissions for late-model vehicles that has resulted from technological advances in emissions controls has substantially narrowed the differences in emissions rates between new and older vehicles, and further reductions emissions rates in new-vehicles will continue to do so over the foreseeable future.[15] *This continued narrowing of the difference between emissions from older vehicles and the new vehicles with which they would be replaced has substantially reduced the likely impact of any slowing in fleet turnover on fleet-wide emissions.*

10.2.2.6 Consumer Demand/Behavior

Comments

Comment Number: 0564-1
Organization: Consumer Federation of America
Commenter: Mark Cooper

In light of the new evidence on the swift changes by consumers to embrace more fuel- efficient vehicles, we believe that the standard should be set at the highest level in NHTSA's analysis that was economically practicable. (This is the point in the initial analysis where total benefits equal total costs. When NHTSA corrects the many flaws in its approach benefits from this level of fuel economy will far exceed the costs.) This would raise the standard for 2011 to 30.6 miles per gallon, from the proposed level of 27.8 mpg. The attached report shows that consumers are more than willing to purchase such vehicles and the dramatic changes that the automakers have announced in their product plans indicate they can deliver the vehicles necessary to achieve this level of fuel economy.

Comment Number: 0564-3
Organization: Consumer Federation of America
Commenter: Mark Cooper

NHTSA's approach to setting fuel economy standards is to start with automaker product plans, assert that consumers undervalue fuel economy by demanding unrealistic economic returns from fuel saving technologies and assume that automakers are severely constrained in their ability to incorporate new fuel-saving technology into the vehicle fleet. Neither the product plans, nor the assumptions about consumer and automaker behavior relied on in NHTSA's analysis bear any relationship to reality.

- Consumers are looking for higher mileage in the new vehicles today than NHTSA has mandated for seven years from now.

- The product plans on which NHTSA based its rule seven years into the future have already been torn up by the automakers who have belatedly recognized the strong shift in consumer behavior.

[15] *In 1990, for example, NHTSA's estimates indicate that average VOC emissions for a 10-year-old gasoline automobile were 4.75 grams per mile larger than those for a new model-year 1990 car, but by 2005 this difference had narrowed to 1.31 grams per mile; it is projected to decline to 0.23 grams per mile by 2015. These emissions factors were computed using EPA's MOBILE6.2 motor vehicle emissions factor model using the procedures described elsewhere in this FEIS.*

- The mix of cars and trucks that NHTSA projects bears no relationship to the vehicles that consumers are buying.

- Not only did NHTSA assume that consumers are unwilling to buy fuel economy beyond a very narrow economic assumption, but it also assumed that higher fuel economy has no value in the marketplace (particularly in resale value), which is contrary to what is happening in the market.

Our market behavior analysis and public opinion polling show that consumers want more fuel-efficient cars than the automakers are offering them.

Comment Number: 0564-8
Organization: Consumer Federation of America
Commenter: Mark Cooper

The attached study of consumer attitudes and auto market behavior prepared by the Consumer Federation of America has a series of findings that call into question the fundamental approach that NHTSA took to set the standard and compel NHTSA to thoroughly reconfigure its analytic approach before it issues a final rule.

Consumers are deeply concerned about rising gasoline costs and the national security implications of our dependence on foreign oil and are prepared to take actions to remedy these problems. Neither the auto industry in its marketing plans nor NHTSA in its proposed rule has fully comprehended the current state of consumer attitudes toward fuel efficiency and the state of the auto market.

- Eighty-four percent of respondents say they are concerned about rising gasoline prices (70 percent very concerned) and eighty-four percent say this rise in price has placed a financial burden on their household budgets (63 percent say severe).

- Seventy-four percent of respondents say they are concerned about Mid Eastern oil imports (57 percent very concerned).

- Among those who drive and intend to purchase a vehicle, the current average fuel economy of their vehicle is reported at about 24.1 mpg, but they intend to get 32.7 mpg in their next vehicle.

- Thus, the average goal for consumers in the market today is 32.7 mpg above the standard of 31. 6 mpg that NHTSA has set for 2015.

- There is a huge mismatch between consumer demand and models offered by automakers in 2008. Whereas 59 percent of the respondents say they want to get more than 35 mpg in their next vehicle, only 1 percent of the models offered by automakers in the first half of 2008 achieve that mileage.

- About 60 percent of the poii respondents say they are willing to consider major changes to achieve higher fuel economy, including switching to four cylinder engines, small cars and hybrids.

Moreover, as the attached report shows, consumers are not merely considering these measures to achieve higher fuel economy; they are acting on their attitudes.

- Four cylinder engines have increased their market share dramatically.
- Smaller cars are in exceptionally high demand, while trucks and SUVs languish on the lots.
- Hybrids are flying out of the show rooms.

However, in direct contradiction to these market trends, NHTSA's proposed rule restricts the level of the standard because it makes assumptions about consumer behavior or automaker ability to incorporate fuel-saving technology that fail to reflect this market reality. NHTSA refuses to consider vehicle downsizing or different performance characteristics as a means of increasing fuel efficiency. NHTSA's underlying assumptions are so out of touch with reality that they are arbitrary and capricious, resulting in a rule that is unreasonable.

The change in consumer attitudes and purchasing patterns has deeply affected the resale value of vehicles, yet NHTSA's proposed rule does not recognize the impact of fuel economy on the resale value of vehicles. NHTSA erroneously assumes that a gas guzzling SUV has the same resale value (as a percentage of the original purchase price) as a fuel sipping small car.

- Contrary to this assumption, SUVS and pickups are piling up on dealer lots across the country.

- SUVs and trucks, both new and used, have plummeted in value, while small cars have increased sharply.

- The Big 3 U.S. automakers announced plans to discontinue leasing these vehicles precisely because the value at the end of a lease is so much lower than the price they have to pay.

The faulty assumptions on resale value play a critical role in NHTSA's analysis by undervaluing fuel efficiency in its consumer payback analysis and preventing NHTSA from including more fuel savings in the fleet in its evaluation of standards.

The analysis of auto market behavior in the attached report shows that these consumer attitudes and trends were not a sudden development in the early part of 2008. They have been evident and progressing for several years. The auto industry and NHTSA have simply ignored the clear evidence.

- The shift in sales was not sudden, nor is it only the result of a shift from trucks to cars. Consumers have also been demanding greater fuel economy within vehicle categories.

- The structural shift to fuel economy occurred in 2004 for trucks and 2006 for cars.

- The effect has built over time so that by the first half of 2008, the level of fuel economy of a car model accounts for over 40 percent of the variance in the change in sales.

- Simply put, it did not take $4/gallon gas to cause the change in consumer behavior, it started at least three years ago when gas was $2.50 per gallon and has been growing progressively.

The automakers not only missed the shift in consumer behavior, they actually tried to resist it by continuing to pump out gas-guzzlers and trying to bribe consumers to buy them with rebates and low interest. However, the trend has proven too powerful and fundamental to resist. Now that the automakers have recognized that they must change, they are rapidly shifting their operations, retooling plants and adopting new technologies at a pace that is far greater than NHTSA had assumed possible. Thus, NHTSA's auto market model erroneously assumes a slow incorporation of fuel savings technology into the vehicle fleet for several reasons. Not only were the product plans on which NHTSA based its proposed rule thoroughly outdated, but also the ability of automakers to change was vastly underestimated by NHTSA. A rule based on data that is so out of touch with reality is arbitrary and capricious and unreasonable.

Comment Number: 0575-23
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

As one of the components in assessing sales impacts of increased fuel economy, NHTSA estimates the 5-year resale value of vehicles. First, NHTSA's explanation for choosing five years as the evaluation timeline, namely that "this is the average length of time of a financing agreement" (PRIA, p. VII-41), is unfounded—as that would presume that consumers sell their vehicles as soon as their car and truck loans are paid off.

Moreover, NHTSA computes the resale value of a vehicle as a flat 32.8% of its original value. This assumption ignores the fact that fuel efficient vehicles are valued more than inefficient vehicles on the used vehicle market. According to a 2008 Congressional Budget Office study:

"Average prices of fuel-efficient used vehicles have been rising, and those of less-efficient vehicles have been falling. That is as expected: In both [new and used vehicle markets, consumers' preferences for fuel-efficient vehicles should be similarly affected by rising gasoline prices—which should affect prices similarly in both markets." [Footnote: See original comment document.]

UCS recommends that NHTSA modify its resale value estimate to reflect greater consumer preference for fuel efficient vehicles in the new and used vehicle markets.

Comment Number: 0572-17
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

A recent report by the Consumer Federation of America indicates that the NHTSA's assumed fleet mix does not represent what consumers are actually buying (Cooper 2008). Furthermore, the average consumer desires a car that gets at least 32.7 mpg today (Cooper 2008), yet even the "technology exhaustion" alternative would only require an average fuel economy of 31.1 mpg in 2011.Including this shift in consumer demand in the Volpe model is essential to properly assess the potential for increased fuel economy in the U.S.

The NHTSA does not address the potential implications of a changing automobile market and to embrace its technology forcing mandate. The possibility that increasing consumer demand for more fuel efficient vehicles may affect the calculation of an individual automaker's CAFE under Reformed CAFE, and the opportunities available for individual automakers to take advantage of those changing demands through CAFE credits. (73 Fed. Reg. at 24393 & 24443). However, the proposed CAFE standards completely fail to consider the significant market advantage experienced by automakers that "pull ahead" to offer higher-efficiency vehicles.

In such a market, "over-compliance" can result in significant gains in market share and economic returns for innovative automakers. By failing to consider shifting consumer demand, NHTSA and the Volpe model significantly underestimate the economic benefits of increased efficiency vehicles, and artificially and inappropriately skew the cost-benefit analysis of developing and implementing efficiency technologies. Stated another way, NHTSA has illegally constrained its analysis by locking itself into the assumption that a manufacturer's fleet mix need not, and will not, change in response to the nation's need to conserve energy.

Comment Number: 0572-46
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The inadequacy of the proposed CAFE standards is perhaps most clearly seen in comparison to vehicles already available on the market today with fuel efficiencies of 35 mpg and higher. The NPRM, on page 24394, states that the Volpe model, in the development of the CAFE standards, does not account for shifting demand by consumers for higher efficiency vehicles. Thus, the proposed CAFE standards were developed within the context of the automakers current product lines and business plans, and thus rejected or delayed larger increases in fuel efficiency in deference to previous business decisions the automakers have made that have favor lower efficiency vehicles.

Comment Number: 0572-51
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

NHTSA, on page 24393 of the NPRM, states that the Volpe model does not attempt to account for…intentional over-compliance....Another possibility NHTSA and Volpe staff have considered but do not yet know how to analyze, is the potential that manufacturers might "pull ahead" the implementation of some technologies in response to CAFE standards that they know will be steadily increasing over time."

These statements display NHTSA's fundamental failure to understand the potential implications of a changing automobile market and to embrace its technology forcing mandate. The NPRM on page 24393 and 24443 mentions the possibility that increasing consumer demand for more fuel efficient vehicles may affect the calculation of an individual automaker's CAFE under Reformed CAFE, and the opportunities available for individual automakers to take advantage of those changing demands through CAFE credits. However, the proposed CAFE standards completely fail to consider the significant market advantage experienced by automakers that "pull ahead" to offer higher-efficiency vehicles. In such a market, "over-compliance" can result in significant gains in market share and economic returns for innovative automakers. By failing to consider shifting consumer demand, NHTSA and the Volpe model significantly underestimate the economic benefits of increased efficiency vehicles, and artificially and inappropriately skew the cost-benefit analysis of developing and implementing efficiency technologies. Stated another way, NHTSA has illegally constrained its analysis by locking itself into the assumption that a manufacturer's fleet mix need not, and will not, change in response to the nation's need to conserve energy.

Comment Number: 0576-14
Organization: Public Citizen
Commenter: Joan Claybrook

The Volpe model does not estimate market shifts, and therefore cannot predict the experience of recent months, where sales of light trucks have plummeted and sales of small cars have skyrocketed in response to high oil prices (73 FR 24394). The vehicles automakers are offering do not achieve a level of fuel economy consumers want, and vehicles that comply with the 2011-2015 standards will not achieve a level of fuel economy that consumers want. [Footnote: See original comment document.] NHTSA's failure to effectively regulate the industry has resulted in a market that offers too few choices to consumers, and the

Volpe model will exacerbate this problem rather than correct it, by relying on outdated information from the automakers.

Comment Number: 0576-16
Organization: Public Citizen
Commenter: Joan Claybrook

This country is in crisis because of high gas prices, the attendant rise in the price of food and other goods, and the looming prospect of catastrophic consequences of global warming. Failure by the agency to adequately plan for future predictable fuel price increases has contributed to the current fuel price situation. NHTSA must not exacerbate this condition further by failing to ask for the most aggressive implementation of available technology to give consumers the fuel economy they want and need." [Footnote: See original comment document.] In a March 2008 survey, "[s]ixty-one percent of those interviewed said lawmakers should require better fuel efficiency for new cars, trucks and SUVs; 56 percent said the government should increase funding for alternative fuel research." [Footnote: See original comment document.] This came just three months after Congress passed a law to raise fuel economy standards and expand research funding for alternative fuels. This is a strong signal to NHTSA to reconsider the pace and level of these new standards, which will, of course, inform the standards set for model years 2016-2020 and beyond.

Comment Number: TRANS-02-4
Organization: Lee Auto Malls
Commenter: Adam Lee

Consumers have changed their habits and their view of the future.

Comment Number: TRANS-04-3
Organization: National Automobile Dealers Association
Commenter: David Westcott

Importantly, CAFE standards equate the greenhouse gas emissions in that CAFE compliance is measured by capturing greenhouse gases emitted by regulated motor vehicles. Thus the draft EIS appropriately suggests that model year 2011 through '15 proposal likely will result in the overall motor vehicle greenhouse gas emission reduction below what will occur without standards.

Of course, this conclusion assumes that purchasers will buy new vehicles covered by CAFE proposal, and hereby bring them into the fleet at the rate assumed by NHTSA and that once introduced into the fleet, they will be driven to the same degree that NHTSA has assumed.

To that extent, purchasers do not buy – to the extent that purchasers do not buy vehicles regulated by the CAFE proposal and bring them into the fleet as predicted, whether due to their higher cost or lack of desirability, the CAFE proposal will necessarily fail to achieve this hoped for level of environmental performance.

This jalopy affect phenomenon recently was demonstrated by the failed introduction of the '07 model year medium and heavy-duty truck rules governed by the new EPA emissions mandates that increase their costs and arguably compromise their fuel economy and reliability.

Comment Number: TRANS-05-7
Organization: Consumer Federation of America
Commenter: Mark Cooper

Consumers are looking for higher mileage in new vehicles today than NHTSA has mandated for seven years from now. The product plans on which NHTSA based its rule seven years in the future have already been torn up by the automakers, but belatedly recognize the shift in consumer behavior.

The mix of cars and trucks that NHTSA projects, there's no relationship to the vehicles that consumers are buying. Rules that are not connected to reality violate the act and the administrative procedures act.

If you don't think that people will buy and drive more fuel efficient vehicles, you must be living under a rock.

Comment Number: TRANS-18-5
Organization: Individual
Commenter: Pamela Woodward

And you also need to understand how many people would be interested in buying fuel efficient vehicles, were they both accessible and affordable. The technology exists. There are companies that are using successfully, and other companies should be encouraged to develop the technology even further.

Comment Number: TRANS-23-6
Organization: Greater Washington Interfaith Power and Light
Commenter: Tara Morrow

Given the recent soaring gas prices, we are seeing a change in the market by consumer demand for vehicles with greater fuel economy. However, I think the American people are ready for bold action, at least my generation is, and moving forward will take more than responding to market research.

Comment Number: TRANS-41-5
Organization: Individual
Commenter: Catherine Easton

With the price of gas over $4 a gallon, consumers are looking for fuel efficient vehicles.

Comment Number: 0575-23
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

As one of the components in assessing sales impacts of increased fuel economy, NHTSA estimates the 5-year resale value of vehicles. First, NHTSA's explanation for choosing five years as the evaluation timeline, namely that "this is the average length of time of a financing agreement" (PRIA, p. VII-41), is unfounded—as that would presume that consumers sell their vehicles as soon as their car and truck loans are paid off.

Moreover, NHTSA computes the resale value of a vehicle as a flat 32.8% of its original value. This assumption ignores the fact that fuel efficient vehicles are valued more than inefficient vehicles on the used vehicle market. According to a 2008 Congressional Budget Office study:

"Average prices of fuel-efficient used vehicles have been rising, and those of less-efficient vehicles have been falling. That is as expected: In both [new and used vehicle markets, consumers' preferences for fuel-efficient vehicles should be similarly affected by rising gasoline prices—which should affect prices similarly in both markets." (Congressional Budget Office, 2008. Effects of Gasoline Prices on Driving Behavior and Vehicle Markets, p. 20.)

UCS recommends that NHTSA modify its resale value estimate to reflect greater consumer preference for fuel efficient vehicles in the new and used vehicle markets.

Response

NHTSA considers product plans and other data from auto manufacturers, which it believes to be the most accurate source of information about manufacturer capability and future production. In NHTSA's judgment, there is no more accurate source for this information. <u>See</u> *the response in Section 10.2.2 for more information. Many factors are considered in these product plans, including fuel-price projections and shifts in buyers' preferences toward higher fuel efficiency. Commenters who pointed to NHTSA's use of out-of-date product plans can be reassured that the recently revised Volpe model relies on updated product plans received after publication of the NPRM.*

Regarding comments that the popularity of fuel-efficient vehicles among consumers is justification for promulgating more stringent standards, commenters fail to recognize the influence of economic practicability. The demand might exist, but the supply might not exist if manufacturers cannot realistically be expected to meet it.

While higher fuel prices are currently affecting consumer behavior, NHTSA's assumptions about consumer undervaluation of fuel economy are well supported by peer-reviewed literature. The study that the Consumer Federation of America used to support its arguments relies on a survey in which the consumers are not actually purchasing a vehicle, and that likely overvalues consumer preferences.

Regarding resale value, estimates of resale value are used, not in the Volpe model but in the Regulatory Impact Analysis, to try to predict how the increase in price and fuel economy of vehicles would affect sales. These estimates of resale value have no direct impact on the levels of the CAFE standard, and their indirect impact was negligible because NHTSA did not find a large impact on sales.

Further, NHTSA does not presume that consumers would all sell their cars at the end of the loan period, an average of 5 years. NHTSA uses that as a proxy measure of how consumers make purchasing decisions; that is, how do consumers value increased fuel economy? NHTSA assumes that the average purchaser thinks about how much money he might save in fuel over a 5-year period. In the Regulatory Impact Analysis, NHTSA conducts a marginal cost-benefit analysis. This commenter appears to imply that resale value would increase by more than 32.8 percent of incremental costs because of the improved fuel economy. This implies that first purchasers believe that a second purchaser would place a value on the improvement in fuel economy over the remaining life (beyond the initial first 5 years) of the vehicle. If NHTSA made this assumption, then for the first purchaser who keeps a vehicle, we should value fuel economy savings over the lifetime of the vehicle (or some period longer than 5 years), not just over the first 5 years. However, NHTSA does not believe that the average consumer thinks about payback periods past 5 years; that is, a first purchaser would not consider the second purchaser's payback period. When NHTSA performs the Volpe model cost-benefit analysis, considering costs and benefits from a societal perspective, NHTSA uses fuel economy savings over the lifetime of the vehicle.

However, NHTSA does not believe that the average consumer thinks about payback periods past 5 years; that is, a first purchaser would not consider the second purchaser's payback period. When

NHTSA performs the Volpe model cost-benefit analysis, considering costs and benefits from a societal perspective, the agency uses fuel economy savings over the lifetime of the vehicle.

10.2.2.7 Fleet Composition Assumption

Comments

Comment Number: 0575-22
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

As shown in Figure 3, the assumption of a near-term (i.e., in 2011-2015) increase in light truck market share appears unfounded. While UCS recognizes that computer models and computed projections require assumptions often based upon historical data, UCS requests that NIITSA in general (*i.e.*, across all modeling efforts) check their results and assumptions compared to the changing vehicle market.

Comment Number: 0575-5
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

NHTSA assumed light trucks would grow in market share, but between 2005 and 2008 the market share of light trucks sold from January to May dropped from 54% to 48%.

Response

NHTSA assumes future fleet composition based on manufacturer product plans, for reasons explained in Section 10.2.2. The product plans have been updated in response to NHTSA's request for updated information released concurrent with the NPRM. See 73 FR 24190. These updated product plans showed a shift in the fleet composition along the lines highlighted by Union of Concerned Scientists. It was quite clear from the manufacturers' submissions that they have accounted for the recent market trends and the new requirements in EISA.

10.2.2.8 Discount Rate

Comments

Comment Number: 0557-9
Organization: The Natural Resources Defense Council
Commenter: Luke Tonachel, Brian Siu

NHTSA fails to adhere to standard economic practice and governmental guidelines when it used a discount rate of 7 percent. The agency should use a discount rate that does not exceed 3 percent and should conduct sensitivity analysis for even lower values.

Comment Number: 0559-11
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

NHTSA's stated intent is to use a 7 percent rate for discounting future benefits from increased CAFE standards. We believe this rate is too high and therefore inappropriately devalues the technologies designed to achieve increased fuel economy. In contrast, for the rulemaking on Tier 2 Motor Vehicle

Emissions Standards (*FR*/Vol. 65, No. 28, February 10, 2000). EPA used a discount rate of 5 percent. We recommend that NHTSA use a discount rate of no greater than 5 percent and perhaps consider an even lower discount rate if appropriate.

Comment Number: 0564-10
Organization: Consumer Federation of America
Commenter: Mark Cooper

Discounted the value of fuel savings at an unnecessarily high rate; *i.e.*, after identifying two possible discount rates: 1) a high rate based on the automaker view of capital costs and 2) a low rate based on the consumer view of consumption expenditures. NHTSA failed to choose a rate between the two, instead applying the high "capital" rate.

Comment Number: 0572-13
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

One of the primary flaws is the use of a 7% discount rate. The DEIS acknowledges that discount rate and gasoline price have a significant impact on the cost-benefit analysis. Yet the DEIS adopts a 7% discount rate and does not present even the results for a 3% or lower discount rate. The significant influence of discount rate alone is reflected in the fact that the "optimized" fuel economy standard with a 3% discount rate is more than 50% higher than the "optimized" alternative presented in the DEIS. (PRIA Appx. A at A-2, Table A-1) This important information is only available in the Preliminary Regulatory Impact Assessment (PRIA), which is insufficient. *Grazing Fields Farm v. Goldschmidt*, 626 F.2d 1068,1072 (1st Cir. 1980) ("no indication in the [NEPA] statute that Congress contemplated that studies or memoranda contained in the administrative record, but not incorporated in any way into an EIS, can bring into compliance with NEPA an EIS that by itself is inadequate").

The choice of a 7% discount rate is not supported by the evidence. As the DEIS states, OMB suggests the use of both 3% and 7% discount rates, with the 3% discount rate appropriate where the costs of regulations are likely to be passed on to consumers. (DEIS at 3-60) The Volpe model assumes that costs will be passed to consumers. For instance, the cost of new technology is limited by consumer pay-back periods and willingness to pay higher vehicle prices. See, *e.g.*, DEIS 2-1 (discussing "retail price equivalent"); DEIS Appx. C at V11-41 (discussing impact of higher costs on sales).

Other agencies have assumed discount rates of 3% in similar analyses. The EPA in its recent advance notice of proposed rule making for regulating greenhouse gas emissions under the Clean Air Act noted that changes in GHG emissions are "essentially long-run investments" that "yield returns in terms of avoided impacts over a period of one hundred years and longer. Furthermore, there is a potential for significant impacts from climate change, where the exact timing and magnitude of these impacts are unknown. These factors imply a highly uncertain investment environment that spans multiple generations." [73 Fed. Reg. 44354, 44414 (July 30, 2008)] When there are important benefits or costs that affect multiple generations of the population, EPA and OMB allow for low but positive discount rates (*e.g.*, 0.5–3% noted by U.S. EPA, 1–3% by OMB)."

In recent testimony before the House of Representatives Energy Committee, Sir Nicholas Stern notes the inappropriateness of pure-time discounting in which future generations are valued less than the current generation (Stern 2008). He goes on to distinguish between current market rates, which reflect only near-term benefits, versus the value of "young or unborn" generations.

The DEIS thus makes several crippling errors in its choice of discount rate. First, the NHTSA assumes that a substantial portion of the costs of the regulation will come from foregone capital investments by the auto industry. This is simply incorrect. All capital costs will be passed onto consumers in short order. Furthermore, the largest costs from the regulation come in the form of impacts from catastrophic climate change. This will most certainly be felt by consumers, both in this generation and the next. The choice of a 7% discount rate is based in part on assumptions regarding loan rates. (DEIS Appx. C at VIII-2). Yet, this short-sighted context is entirely inappropriate. Given that the impacts of the alternatives are analyzed out to year 2100, the discount rate must also reflect this long time horizon for impacts.

Comment Number: 0572-50
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The NPRM, on page 24393 and footnote 7 on page 24355, describes using a 7% and 3% discount rate for societal benefits. While essentially conceding that the 7% discount rate is far too high, NHTSA then appears to use the 7% figure in calculations for the proposed rule. However, the NPRM on page 24393, discusses the Volpe model calculation of societal costs and benefits without identifying which discount rate is used.

In fact, both the 7% and 3% are too high, artificially reducing the value of the future benefits of increasing fuel efficiency. For example, Stern (2007) sets the rate at lower than 1% per year. NHTSA proposes 3% versus 7%. For the purposes of the rulemaking, any calculations performed under a selected discount rate for societal benefits must be compared to the same calculations under standard inflationary discount, but without discounting societal benefits to future generations.

The discount rate is an extremely important factor in determining the "socially optimal" fuel economy level as defined by NHTSA. Use of a 3% discount rate would have resulted in fuel economy standards 2 mpg higher than the proposed standards in MY 2015. NHTSA should have run the calculations with a reasonable range of values and disclosed the outcomes, and should have selected a lower discount rate for primary use in its analysis.

Comment Number: 0575-12
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

As noted in comments from UCS to NHTSA on the 2006 light truck rule, the discount rate used to calculate the present value of future costs and benefits is among the most important factors in determining a fuel economy target. NHTSA's use of a 7% discount rate to determine the proposed standards is inappropriate and contrary to OMB recommendations. A discount rate of 3%, corresponding to the social rate of time preference, should instead be used. While OMB Circulars A-4 and A-94 direct that the default interest rate should be 7%, Circular A-4 advises that:

"The effects of regulation do not always fall exclusively or primarily on the allocation of capital. *When regulation primarily and directly' affects private consumption (e.g., through higher consumer prices for goods and service), a lower discount rate b appropriate*. The alternative most often used is sometimes called the "social rate of time preference." . . . *Over the last thirty years, this rate has averaged around 3 percent in real terms on a pre-tax basis.*" (Office of Management and Budget, 2003. Circular A-4)

This guidance is cited by NHTSA multiple times throughout the NPRM and PRIA, and indeed NHTSA itself acknowledges that "direct benefits to consumers, including fuel savings" account for 84%-85% of the gross consumer benefits resulting from increased passenger car and light truck CAFE. (PRIA, p. VIII-36 and VIII-37).

A smaller effect of the proposed regulation will be for automakers to invest capital to build cars with more advanced technologies. While automakers will need to allocate some capital to help meet the proposed regulations, the amounts involved will be markedly smaller than the benefits realized by private consumers. The primary effect of the regulation, therefore, will be on private consumption.

It is clear that the proposed regulation will directly affect private consumption of vehicle fuels, and that this benefit is by far the primary effect. Since the regulation "primarily and directly affects private consumption," much more so than the allocation of capital, the regulation should be based on discounting using the social rate of time preference. UCS recommends that a real rate of 3% – as noted in Circular A-4 – be employed.

Comment Number: 0588-2
Organization: New York State Department of Transportation
Commenter: Stanley Gee

NHTSA should also correct several errors in its analysis that artificially reduce the stringency of the proposed CAFE standards by underestimating benefits arid overestimating costs. In particular, NHTSA inflates costs relative to benefits by failing to apply a discount rate to future costs.

Comment Number: 0588-5
Organization: New York State Department of Transportation
Commenter: Stanley Gee

In its analysis, NHTSA discounts economic benefits, but not costs. In any cost-benefit analysis, both future benefits and costs should be discounted using the same discount rate, or time-value of money, to correct for the difference in the value of money in hand today versus money in the future, based on the interest rate and inflation. The Office of Management and Budget specifically instructs NHTSA to discount both costs and benefits, and provides recommended interest rates for that purpose.

Comment Number: 0595-2
Organization: Environmental Protection Agency
Commenter: Susan Bromm

NHTSA uses a 7 percent discount rate to future benefits in determining the "optimized" fuel economy standard. The sensitivity analysis performed in the DEIS using a discount rate of 3 percent shows that a lower discount rate has a substantial effect on future carbon dioxide reductions. As such, using a 3 percent discount rate significantly increases the projected societal benefits, as shown in Section IX of the PRIA, indicating a higher "optimized" fuel economy standard. EPA recommends that NHTSA consider using a 3 percent discount rate for GHG benefits as part of its primary analysis. While a 7 percent discount rate may be reasonable to apply to the cost savings realized by consumers who invest in fuel economy, EPA questions whether such a high discount rate can be justified for the long-term benefits associated with GHG reductions.

Response

Discounting represents the conversion of the economic values of expected future benefits and costs to their equivalent values today, or present values. Discounting is intended to account for the fact that most individuals attach lower values to economic outcomes that are not expected to occur until some *future date, than to equivalent outcomes that are expected to occur sooner. It is particularly important to discount the future values of benefits or costs when they are expected to vary from year to year, or when the time profiles of benefits and costs are not expected to be similar. Discounting enables a consistent comparison of benefits to costs across time, and enables consistent comparison of expected future costs or benefits to those in the present.*

In proposing CAFE standards for MY 2011-2015, NHTSA employed a rate of 7 percent to discount future benefits and costs resulting from increased fuel economy to their present values. Discounting the value of future fuel savings and other benefits that result from higher fuel economy, and future costs from added driving due to the fuel-economy rebound effect, accounts for the fact that they will occur over the future lifetimes of MY 2011-2015 vehicles. The discount rate expresses the rate at which the value of these future benefits and costs, as viewed from today's perspective, declines for each year they are deferred into the future.

NHTSA received many comments on the discount rate it employed in analyses in the NPRM and DEIS. Many of these comments suggested that NHTSA use a rate as low as 3 percent to discount future benefits from reduced fuel consumption, and that even lower rates be used to discount the reductions in the future costs of climate change expected to result from reduced emissions of GHGs from fuel production and consumption. In contrast, other comments argued that vehicle buyers discount the value of future fuel savings resulting from higher fuel economy at rates of 12 percent or higher, and suggested that NHTSA should employ a similarly high discount rate to evaluate the fuel savings and other benefits resulting from higher CAFE standards.

In response to these comments, NHTSA has carefully reviewed published research and Office of Management and Budget (OMB) guidance on appropriate discount rates, including "inter-generational" discount rates that should be applied to benefits that are expected to occur in the distant future and, thus, be experienced mainly by future generations. On the basis of this review, NHTSA has have elected to apply separate discount rates to the benefits resulting from reduced emissions of CO_2 *and other GHGs, which are expected to reduce the rate or intensity of climate change that will occur 100 or more years in the future, and the economic value of fuel savings and other benefits resulting from lower fuel consumption that will be experienced in the comparatively near future.*

In support of this decision, NHTSA notes that OMB guidance on discounting permits the use of lower rates to discount benefits that are expected to occur in the distant future (OMB 2003). The main rationale for doing so is that although most individuals demonstrate a clear preference for current consumption over consumption they expect to experience later within their own lifetimes, it might not be appropriate for society to exercise a similar preference for present over distant-future consumption when developing actions that affect the relative income levels of present and future generations. In addition, while market interest rates provide useful guidance about the rates that should be used to discount future benefits that will be received by present generations, no comparable market rates are available to guide the choice of rates for discounting benefits to be received by future generations.

Specifically, NHTSA has elected to use a rate of 3 percent to discount the benefits resulting from reduced emissions of CO_2 *and other GHGs projected to result from decreased fuel production, distribution, and consumption. These benefits, which include reductions in the expected future economic damages caused by increased global temperatures, a rise in sea levels, and other projected impacts of climate change, are anticipated to extend over a period from approximately 50 to 200 or more years in the future.*

The 3-percent rate is consistent with those used to develop many of the estimates of the economic costs of future climate change that form the basis for NHTSA's estimate of the economic value of *reducing CO_2 emissions (see Section 10.2.2.3) (Tol 2008). Of the 125 peer-reviewed estimates of SCC included in Tol's 2008 survey, which provides the basis for NHTSA's estimated value of reducing CO_2 emissions, 83 used assumptions that imply discount rates of 3 percent or higher. Moreover, the 3-percent rate is consistent with widely used estimates of the appropriate rate-of-time preference for present versus distant-future consumption, expected future growth in real incomes, and the rate at which the additional utility provided by increased consumption declines as income increases.[16]*

The remaining future benefits and costs anticipated to result from higher fuel economy are projected to occur primarily within the lifetimes of vehicles affected by the CAFE standards for MY 2011-2020 vehicles, which extend up to a maximum of 35 years from the date they are manufactured. Thus, a conventional or intra-generational discount rate is appropriate to use in discounting these benefits and costs to their present value when analyzing the benefits and costs of establishing higher CAFE standards.

The correct discount rate to apply to these nearer-term benefits and costs depends on how the costs to vehicle manufacturers of CAFE compliance will ultimately be distributed. If manufacturers are unable to recover their costs for increasing fuel economy in the form of higher selling prices for new vehicles, those outlays will displace or alter other productive investments that manufacturers could make. In this case, the appropriate discount rate is their opportunity cost of investment capital. OMB estimates that the real before-tax rate of return on private capital investment in the U.S. economy averages approximately 7 percent per year, and recommends this figure for use as a real discount rate in cases where the primary effect of a regulation is to displace private capital investment (OMB 2003).

However, if vehicle manufacturers are able to raise selling prices for new vehicles to recover their costs for improving fuel economy, those costs will ultimately affect private consumption rather than capital investment. Under this assumption, a lower discount rate might be appropriate. Specifically, the rate-of-time preference for current versus future consumption, or the annual rate at which consumers must be compensated for deferring current consumption to the future, will be the appropriate rate for discounting future benefits from improved fuel economy.

OMB notes that the real rate of return on long-term government debt, which has averaged about 3 percent over recent decades, provides a reasonable measure of the rate at which typical savers discount future consumption (OMB 2003). The 3-percent rate reflects consumers' average rate-of-time preference, and thus provides an appropriate rate for discounting future benefits of higher CAFE standards if manufacturers are able to recover their costs for complying with those standards by charging higher prices for new vehicles.

Uncertainty about future developments in the international oil market, the U.S. economy, and the U.S. market for new cars and light trucks make it extremely difficult to anticipate the extent to which vehicle manufacturers will be able to recover costs (in the form of higher prices for new vehicles) for complying with higher CAFE standards. If buyers of new vehicles expect fuel prices to remain higher than those NHTSA used to establish CAFE standards for MY 2011-2015, they might be willing to pay the

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[16] The Ramsey discounting rule is widely employed in studies of potential economic damages from climate changes in the distant future; see Tol (2008, p. 3). The Ramsey rule states that $-r = \delta + \eta g$, where r is the consumption discount rate, δ is the pure rate of time preference (the marginal rate of substitution between current and future consumption under the assumption that they are initially equal), g is the expected (percentage) rate of growth in future consumption, and η is the elasticity of the marginal utility of consumption with respect to changes in the level of consumption itself. Commonly used values in climate studies appear to be $\delta = 1$ percent per year, $\eta = -1.0$, and g = 2 percent per year, which yield a value for r of 3 percent per year.

higher prices necessary for manufacturers to recover their costs for complying with those standards.[17] *However, potential buyers who expect future fuel prices to be lower than these levels are likely to resist manufacturers' efforts to raise new vehicle prices sufficiently to recover their costs for compliance with CAFE standards.*

From the manufacturer's perspective, the current financial condition of some car and light-truck producers suggests that they are likely to find it difficult to absorb the costs of complying with higher CAFE standards. Some analysts speculate that because CAFE standards apply to all manufacturers, establishing higher standards provides a ready opportunity for all producers to raise prices for cars and light trucks. However, this opportunity might be restricted if producers that face very low compliance costs (because of higher CAFE standards in their planned model offerings) compete aggressively with others that face substantial costs for increasing their fuel-economy levels in their product plans to comply with higher CAFE standards.

Because the ultimate incidence of the costs for complying with higher CAFE standards is inherently uncertain, NHTSA has employed both the 3-percent and 7-percent rates to discount future benefits from higher CAFE standards other than those benefits resulting from lower CO_2 emissions. Accordingly, NHTSA has analyzed the mpg stringencies associated with varying combinations of discount rates. See Table 2.3-6.

10.2.2.9 Creation of a Backstop

Comments

Comment Number: 0575-15
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

The Ninth Circuit Court of Appeals ruled that, in their recent fuel economy rulemaking for 2008-2011 light trucks, NHTSA was "arbitrary and capricious" in failing to set a backstop, a mechanism that would ensure that the benefits NHTSA's standards provide would not be eroded by a shift in sales to larger, lower fuel economy vehicles. The court also found that the agency failed to address petitioners' "well-founded concerns (given the historical trend) that a floating fleet-mix-based standard would continue to permit upsizing—which is not just a function of consumer demand, but also a function of manufacturers' own design and marketing decisions." [*Center for Biological Diversity v. National Highway Traffic Administration*. No. 06-7 1891 (9th Cir. 2007).]

In NPRM documentation, NHTSA argues that no further action is required of the agency with respect to backstops, as Congress has spoken directly on this issue, and called for an attribute-based system.

It is true that the 35 mpg minimum standard required in 2020 is a backstop of sorts. However, if maximum feasible fuel economy levels are found to exceed 35 mpg, the legislated minimum will not ensure those levels (and, thus, maximum feasible energy savings) are achieved. In essence, the same concerns of the Ninth Circuit court persist, and NHTSA can not be too deferential to the market in the setting of fuel economy standards.

[17] *Whether they will be willing to do so, however, depends partly on how the combined value of the economic and environmental externalities used to determine the standards compares to current fuel taxes. It also depends on whether buyers of new vehicles consider the value of fuel savings resulting from higher fuel economy over the entire expected lifetimes of the vehicles they purchase, or over only some part of that lifetime (such as the period they expect to own new vehicles).*

It is also true that Congress implied an interim-year backstop by requiring ratable increases in the average fuel economy standard from 2011 through 2020. However, it is NHTSA's obligation to ensure that these interim-year backstops are instituted. In effect, NHTSA has failed to follow through on its legal obligations, because while the proposed average fuel economy standards appear to be at or above a ratable level, there is no mechanism to ensure the market does not undermine those standards. For these reasons, UCS recommends that NHTSA implement a regulated backstop that addresses the concerns first raised by the Ninth Circuit Court of Appeals.

Comment Number: 0576-34
Organization: Public Citizen
Commenter: Joan Claybrook

Congress mandated a *minimum* increase in fuel economy standards for passenger cars and light trucks to 35 mpg; however, Congress entrusts the agency to determine the maximum feasible level of fuel economy for cars and trucks. In *Center for Biological Diversity v. NHTSA*, the court held that NHTSA must set a backstop to prevent the erosion of fuel savings due to up sizing of vehicles and manipulation of the fleet mix. (*Center for Biological Diversity v. NHTSA*. at 14841). NHTSA says "[a] relatively flat standard for larger vehicles acts as a de facto 'backstop' for the standard in the event that future market conditions encourage manufacturers to build very large vehicles. Nothing prevents manufacturers from building larger vehicles. With a logistic curve, however, vehicles upsizing beyond some limit face a flat standard that is increasingly difficult to meet." (73 *FR* 24418). Public Citizen is not convinced this approach is sufficient, particularly since NHTSA has chosen not to reevaluate the regulatory definitions.

Response

A "backstop," as NHTSA described it in the NPRM, is a minimum fixed CAFE standard that does not change in response to changes in a manufacturer's vehicle mix. As noted in the NPRM, Congress' enactment of EISA resolved the backstop issue by, among other things, requiring each manufacturer to meet a minimum fuel economy standard for domestically manufactured passenger cars in addition to meeting the standards set by NHTSA. The minimum standard "shall be the greater of (a) 27.5 miles per gallon; or (b) 92 percent of the average fuel economy projected by the Secretary [of Transportation] for the combined domestic and non-domestic passenger automobile fleets manufactured for sale in the United States by all manufacturers in the model year…." 49 U.S.C. § 32902(b)(4). Congress expressly mandated that CAFE standards for automobiles be attribute based. That is, they must be based on an attribute related to fuel economy (e.g., footprint), and they must adjust in response to changes in vehicle mix. Taken by itself, this mandate precludes NHTSA from adopting a fixed minimum standard. The only exception to that mandate is the provision in which Congress mandated a fixed and flat minimum standard for one of the three compliance categories. It required one for domestic passenger cars, but not for either non-domestic passenger cars or light trucks. Congress could have, but did not, enact one for foreign passenger cars or light trucks. Congress was aware of this issue from the MY 2008-2011 light-truck CAFE rulemaking and the Ninth Circuit Center for Biological Diversity case, but it chose not to act.

Given the clarity of the requirement for attribute-based standards and the equally clear narrow exception to that requirement, NHTSA reasonably concludes that had Congress intended backstops to be established for either of the other two compliance categories, it would have specified them. Absent explicit statutory language that provides NHTSA authority to set flat standards, we continue to believe that setting a supplementary minimum flat standard for the other two compliance categories would be contrary to the requirement under EISA to set an attribute-based standard.

NHTSA notes that the minimum 35-mpg requirement in and of itself serves as a backstop. Indeed, the Union of Concerned Scientists concedes in its comments that "[i]t is true that the 35 mpg minimum standard required in 2020 is a backstop of sorts." Under this backstop, NHTSA must set the standards high enough to ensure that the average fuel economy level of the combined car and light-truck fleet achieves the statutory requirement of at least 35 mpg by 2020. If we find that this requirement might not be achieved, we may set standards for MY 2016-2020 early enough (consistent with EPCA's 18-month lead time requirement), and at the appropriate level of stringency to ensure reaching the 35-mpg requirement.

Regarding NHTSA's discussion of why the attribute-based standards would make a backstop unnecessary even without Congress' having spoken to this issue, UCS and Public Citizen appear to argue that the statutory requirement of a combined fleet fuel economy of at least 35 mpg in MY 2020, combined with NHTSA's anti-backsliding measures for the target curves and the inherent lower asymptotic bound of the target curves for each model year, are not sufficient to guarantee that manufacturers will either (1) achieve fuel economy levels higher than 35 mpg in 2020 or (2) be prevented from upsizing their vehicles.

NHTSA reiterates, however, that the 35-mpg minimum statutory requirement for 2020 is absolute. Even if manufacturers so drastically change their fleet mix (by upsizing most or all of their vehicles to gain the benefits of lower targets) to achieve substantially lower fuel economy levels for the model years covered by this rulemaking, NHTSA must still set maximum feasible standards for MY 2016-2020 such that the combined fleet reaches at least the 35-mpg minimum requirement in 2020. Further, NHTSA has the authority to revise standards set in the current rulemaking if necessary to ensure that requirement is met, as long as the statutory minimum lead-time of 18 months is observed. See 49 U.S.C. § 32902(c).

10.2.2.10 Oil Import Externalities

Comments

Comment Number: 0557-10
Organization: The Natural Resources Defense Council
Commenter: Luke Tonachel, Brian Siu

The economic value of military security to protect oil supplies should be non-zero and positive. When NHTSA used zero it ignored the U.S. military security-related benefits of reduced oil consumption, such as enhanced flexibility to respond to supply threats and move the country in the direction of oil being a non-strategic resource.

Comment Number: 0564-5
Organization: Consumer Federation of America
Commenter: Mark Cooper

NHTSA takes a fundamentally flawed approach to its externality analysis. This was evident in the analysis of the military and strategic externalities in the proposed rule, where NHTSA engaged in reasoning that can, at best, be described as blind incrementalism.

Rather than see improvements in fuel economy as a part of a broader solution to the national oil addiction, NHTSA argues that because this rule alone cannot solve the problem, it does not deserve to be counted as making a contribution to the solution.

Implementing a law entitled the Energy Independence and Security Act, NHTSA concluded that oil consumption has no military or strategic value whatsoever.

Comment Number: 0575-4
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

NHTSA left out the military and strategic costs of America's oil addiction.

Comment Number: TRANS-43-3
Organization: Individual
Commenter: Charles Yoder

I've noticed that your EIS puts your actions, proposed actions and alternatives in the context of the world. That was addressed by someone as I came into the hall earlier, in the context of the entire planet, not just in terms of the U.S. If you choose to do that, then I think we need to look at the implications of our national addiction to oil in a world context, in a world wide context. Our country invests enormous treasure and enormous numbers of lives ensuring our access to oil.

Comment Number: 0576-22
Organization: Public Citizen
Commenter: Joan Claybrook

Public Citizen also objects to the zero valuation of military security costs associated with oil consumption. NHTSA states "that while costs for U.S. military security may vary over time in response to long-term changes in the actual level of oil imports into the U.S., these costs are unlikely to decline in response to any reduction in U.S. oil imports resulting from raising future CAFE standards for passenger cars and light trucks." (See PRIA V-90 and 73 *FR* 24411.) NHTSA justifies this claim by stating that there are other national security and foreign policy objectives served by military actions in the Middle East. NHTSA used similar logic to justify assigning zero value to reducing CO_2 emissions in the light truck rule. The Ninth Circuit Court of Appeals rejected this justification in *Center for Biological Diversity v. NHTSA*, finding that uncertainty about how to assign a value was not a justification for setting the value at zero. [*Center for Biological Diversity et al., v. NHTSA*. 508 F. 3d 508 (November 15, 2007).]

Comment Number: TRANS-03-4
Organization: Individual
Commenter: Dennis McGinn

Our continued dependency on oil constitutes a clear and present danger to our national security, economically, militarily, and diplomatically. These dangers involve real, quantifiable costs, and these costs do not appear to be adequately included in your assumptions for the proposed fuel economy rule.

As a result, your draft environmental impact statement is at best incomplete, and more importantly, fundamentally flawed by its reliance on outdated data and unsupported assumptions about the real costs of this nation's ever growing consumption of oil. Erroneous assumptions based on old data inevitably leads to fundamentally flawed conclusions.

Ignoring these costs is just not a mistake. It is a threat to our national security because it precludes fuel savings our citizens and nation critically need at this moment in our history.

Our burgeoning demand for oil weakens U.S. diplomatic leverage around the globe, burdens our armed forces, and leaves the United States' economy vulnerable to unpredictable price spikes and an ever growing trade imbalance.

Taken together, these dynamics create a daunting national security challenge that must be met immediately. With oil at over $130 dollars a barrel, over a million dollars each minute is draining out of our economy, increasing our trade deficit, creating huge opportunity costs, and most significantly, putting money in the hands of regimes that are hostile to our interests.

OPEC [Organization of Petroleum Exporting Countries] recently warned that prices, oil prices would experience an unlimited increase in the event of a military conflict involving Iran over its nuclear program. A very real consequence of such confrontation is that Iran, in a bid to preempt or respond to U.S. military action would close the Straight of Hamus through which 20 percent of the world's oil supply passes. The impact would be swift and sure. Unprecedented spikes in oil costs, and a deep and lasting effect on the U.S. and world economy.

The ongoing impact of our oil dependency already threatens our national security economically. We lose over 35 billion dollars from our economy every month, and oil imports now account for over half of our annual trade deficit. We are exposed on a daily basis to oil price shocks and supply disruptions.

Regardless of how they are caused, by global market dynamics, natural disasters, terrorist attacks, or politically motivated oil embargos, the trends of our growing oil demand in a business as usual mode will make those price shocks much more frequent, deeply felt, and longer lasting.

In addition, there are national security costs and risks involved in addressing climate change. Last year top retired three and four star military leaders in a report from the Center on Naval Analysis, global warming poses a "serious threat to America's national security," acting as a threat multiplier for instability in some of the world's most volatile regions, adding tension to stable regions, worsening terrorism, and likely dragging the U.S. into fights over water and other resource shortages.

Comment Number: TRANS-05-3
Organization: Consumer Federation of America
Commenter: Mark Cooper

The second problem in the draft environmental impact statement stems from the fact that NHTSA takes a fundamentally flawed approach to its externality analysis. This was evident in the analysis of the military and strategic externalities in the proposed rule. There NHTSA engaged in reasoning that can at best be described as blind incrementalism.

Rather than see improvements in fuel economy as part of a broader solution to the national oil addiction, NHTSA argues that the cost to rule alone cannot solve the problem, it does not deserve to be counted as making a contribution to the solution.

Implementing a law entitled the Energy Independence and Security Act NHTSA arrived at the outrageous conclusions that oil consumption has no military or strategic value whatsoever.

Comment Number: TRANS-43-2
Organization: Individual
Commenter: Charles Yoder

But if the U.S. is going to continue our addiction to oil, then we need to address the impacts on a worldwide basis, and the environmental costs of any standard other than the strictest possible standard are enormous simply because there are powerful nations, not just the U.S., there are many powerful nations seeking access to a limited supply of a resource that overwhelmingly is located in an unstable part of the world.

And I think it's only reasonable to assume that there will be additional conflicts over the next generation, and that those conflicts will have enormous environmental impacts.

So if you're going to consider things in a world context, you need to consider the environmental impact of future wars, and those impacts must weight on the balance as you make your decision of the alternatives available to you in this rulemaking process.

Comment Number: TRANS-44-3
Organization: Individual
Commenter: Emily Spear

My second main concern is about America's dependence on oil, as it is a national security issue. Our country feeds off of foreign oil, which causes us to be in the pockets of many non-democratic governments. Increasing our fuel economy standard to 35 miles per gallon by 2015 would save us 300,000 gallons of oil per day by 2020.

Taking this simple and achievable action would help us decrease our dependence on oil, would allow us to take back control, and would help stabilize some issues with security.

Response

One possible component of the external economic costs of importing oil into the United States includes government outlays for maintaining a military presence to secure the supply of oil imports from potentially unstable regions of the world.[18]

In the NPRM, NHTSA tentatively concluded that:

> *[W]hile the costs for U.S. military security may vary over time in response to long-term changes in the actual level of oil imports into the U.S., these costs are unlikely to decline in response to any reduction in U.S. oil imports resulting from raising future CAFE standards for passenger cars and light trucks. U.S. military activities in regions that represent vital sources of oil imports also serve a broader range of security and foreign policy objectives than simply protecting oil supplies, and, as a consequence are unlikely to vary significantly in response to changes in the level of oil imports prompted by higher standards.*

73 FR 24352, 24411. Some commenters took issue with this tentative conclusion, and recommended that NHTSA assign a value to the reduction in military spending or other costs related to energy security that is likely to result from lower U.S. petroleum imports. NHTSA disagrees with commenters who asserted that there is a measurable relationship among higher CAFE standards, U.S. petroleum imports, and energy security costs.

The objective of "U.S. energy security," that reductions in U.S. petroleum imports might help to achieve is primarily a reduction in national political and military risks associated with a failure to adequately defend the Persian Gulf. Although NHTSA agrees that by reducing fuel consumption and U.S. petroleum imports from the Persian Gulf region, higher CAFE standards might reduce these military and political risks to some degree, the agency does not believe there is convincing evidence that this would reduce U.S. military expenditures in the Persian Gulf (or elsewhere). No commenter has presented any

[18] *Oil import externalities encompasses military security costs. For further discussion of what constitutes "oil import externalities," see page 24410 of the NPRM.*

evidence that this would occur, nor do any of the references included in their comments provide such evidence.

NHTSA does not agree with Public Citizen's analogy between energy security and "global warming costs." Although the economic valuation of climate-related benefits from reducing carbon dioxide emissions is uncertain, there is nevertheless a direct causal link between changes in U.S. oil consumption and changes in U.S. carbon dioxide emissions. In contrast, no such causal link – either scientific or empirical – exists between changes in U.S. oil consumption or imports, and changes in U.S. military expenditures in the Persian Gulf or anywhere in the world.

Although one recent economic analysis cited widely by commenters did estimate the value of U.S. military spending attributable to securing oil imports from the Persian Gulf region, this study does not estimate the extent to which U.S. military spending is likely to vary in response to changes in U.S. imports of Persian Gulf oil. Nor does it estimate the potential savings in U .S. military outlays that might result from reductions in U.S. oil imports of the magnitude likely to result from higher CAFE standards.[19]

The study argues that its purpose is to develop "the military cost of highway transportation." Broadly, the authors attempt to do this in four steps:

- *Estimate the amount spent annually to defend all U.S. interests in the Persian Gulf;*
- *Deduct the cost of defending interests other than oil in the Persian Gulf;*
- *Deduct the cost of defending against the possibility of a worldwide recession due to the effects of an oil price shock or supply interruption originating in the Persian Gulf on other countries; and*
- *Deduct the cost of defending the use of oil in sectors of the U.S. economy other than highway transportation.*

This analysis yields an estimate of the annual "military cost of oil use by motor vehicles" in the United States ranging from $5.8 billion to $25.4 billion in 2004. The authors then divide these figures by 2004 U.S. gasoline and diesel consumption by on-road motor vehicles, to arrive at an average "military cost of highway transportation" ranging from $0.03 to $0.15 per gallon of fuel.[20]

However, the authors do not argue that U.S. military spending would be reduced by this – or any other – amount as a consequence of incremental reductions in domestic consumption of transportation fuels. Instead, they describe their estimate in the following terms: "The bottom line of our analysis is that if all motor vehicles in the US (light-duty and heavy-duty) did not use oil, Congress might reduce defense spending by $6–$25 billion annually in the long run. This amounts to about $0.03–$0.15 per gallon ($0.01–$0.04 per liter) of all gasoline and diesel motor fuel in 2004." Id.

Thus, the values they report are clearly intended as estimates of the total and average per-gallon costs of U.S. military activities in the Persian Gulf that might reasonably be related to petroleum consumption by U.S. motor vehicles, and not as estimates of the extent to which those costs might be reduced as a consequence of lower fuel consumption by U.S. motor vehicles. The authors speculate that the proportional reduction in these outlays might be larger than any proportional reduction in U.S. petroleum imports from the Persian Gulf region, but provide no empirical support for this hypothesis.[21]

[19] *See Mark A. DeLucchi & James J. Murphy, US Military Expenditures to Protect the Use of Persian Gulf Oil Imports, 36 Energy Policy 2253 (2008) (assigning a cost of between $0.03 and $0.15 per gallon).*
[20] *Delucchi and Murphy, p. 2260.*
[21] *Delucchi and Murphy, pp. 2261-62.*

Nor does this study attempt to demonstrate any causal or empirical linkage between domestic consumption of transportation fuels and the level of U.S. military activities or spending in the Persian Gulf (or elsewhere). As the authors clearly acknowledge, achieving any reduction in U.S. military spending that might be facilitated by lower U.S. oil imports would require specific actions by Congress, and would not result automatically or necessarily. However carefully their analysis might be done, defining some fraction of U.S. military expenditures as being allocated to the defense of oil interests in the Persian Gulf, and then dividing the resulting figure by some quantity of petroleum, does not demonstrate any causal linkage between changes in the numerator and denominator of this calculation.

The analysis described above is irrelevant to NHTSA's analysis of fuel economy standards, because NHTSA's cost-benefit analysis is properly concerned with comparing two alternative states of the world: (1) the world as the agency expects it to exist over the next few years, in the absence of any new CAFE standards, compared with (2) an alternative world that is identical in every respect except that new CAFE standards are in place. NHTSA should, therefore, consider how U.S. defense expenditures might vary between these two states of the world. The relevant question for a cost-benefit analysis is: How much would U.S. military expenditures change if U.S. passenger-car and light-truck fuel consumption is several percent lower in the next decade than it otherwise would have been?

Neither the Congress nor the Executive Branch has ever attempted to calibrate U.S. military expenditures, force levels, or deployments to any oil market variable, or to some calculation of the projected economic consequences of hostilities in the Persian Gulf. Instead, changes in U.S. force levels, deployments, and thus military spending in that region have been largely governed by political events, emerging threats, and other military and political considerations, rather than by shifts in U.S. oil consumption or imports. NHTSA thus concludes that the levels of U.S. military activity and expenditures are likely to remain unaffected by even relatively large changes in light duty vehicle fuel consumption.

Nevertheless, the agency decided to conduct a sensitivity analysis of the potential effect of assuming that some reduction military spending would result from fuel savings and reduced petroleum imports in order to investigate its impacts on the standards and fuel savings. Assuming that the preceding estimate of total U.S. military costs for securing Persian Gulf oil supplies is correct, and that approximately half of these expenses could be reduced in proportion to a reduction in U.S. oil imports from the region, the estimated savings would range from $0.02 to $0.08 (in 2007 dollars) for each gallon of fuel savings that was reflected in lower U.S. imports of petroleum from the Persian Gulf. If the Persian Gulf region is assumed to be the marginal source of supply for U.S. imports of crude petroleum and refined products, then each gallon of fuel saved might reduce U.S. military outlays by $0.05 per gallon, the midpoint of this range.

This FEIS analyzes the stringencies of alternative CAFE standards, the resulting fuel savings, and their associated environmental impacts that would result from assuming that each gallon of fuel saved as a consequence of higher fuel economy would reduce U.S. military outlays by $0.05 per gallon, representing the midpoint of the estimated savings range in 2007 dollars. These results are included as part of the Sensitivity Analysis reported in Section 3.4.4.2 of this FEIS.

10.2.3 ALTERNATIVES

10.2.3.1 Introduction

NHTSA received a substantial number of comments related to the choice of the range of alternatives analyzed in the DEIS. These comments are related enough to provide a general response, but also unique enough to warrant individual attention. For this reason, the following paragraphs review *and generally respond to a common element in the comments regarding NEPA alternatives in the context of this rulemaking under EPCA. Following this section, NHTSA provides responses to individual comments.*

Commenters specifically suggested that NHTSA did not consider a reasonable range of alternatives. Commenters also suggested that NHTSA use different estimates of various economic inputs to the Volpe model when developing CAFE standards. Several commenters stated that the No Action Alternative was not properly selected. Some commenters also suggested that the Optimized Alternative did not accurately reflect the point at which marginal costs equal marginal benefits because incorrect economic assumptions were input into the Volpe model. In addition, commenters recommended that NHTSA select the Total Costs Equals Total Benefits Alternative as its Preferred Alternative. Commenters also criticized NHTSA's Technology Exhaustion Alternative. As a new alternative, commenters suggested that NHTSA consider GHG regulations as potential alternatives under CAFE. In addition, some commenters stated that NHTSA needs to survey consumer demand and dictate what vehicle fleets manufacturers offer based on those trends. Some commenters further stated that the agency must adopt the "environmentally preferable" alternative as its preferred alternative. Other commenters stated that NHTSA must take into account the looming threat of global warming on the environment and assign further emphasis to energy conservation, thereby setting the CAFE standards at a higher level. Some commenters also asserted that NHTSA did not prioritize the need of the United States to conserve energy. Finally, NHTSA received comments urging the adoption of more "aggressive" fuel economy standards.

Where there is a federal action requiring an EIS, NEPA requires an agency to develop "alternatives to the proposed action." 42 U.S.C. § 4332(2)(C)(iii). CEQ regulations state that consideration of alternatives is the "heart" of an EIS. 40 CFR § 1502.14. However, under CEQ regulations and applicable case law, NHTSA is not required to include every conceivable "alternative" in an EIS, nor necessarily other hypothetical "alternatives" submitted by commenters. Rather, an agency is to consider "reasonable" alternatives. The purpose of and need for the rulemaking determines the range of reasonable alternatives under NEPA. As one circuit court has framed the issue, "an agency must look at every reasonable alternative, with the range dictated by the nature and scope of the proposed action, and sufficient to permit a reasoned choice." Alaska Wilderness Recreation and Tourism Ass'n v. Morrison, 67 F.3d 723, 729 (9th Cir. 1995). NHTSA believes its NEPA analysis of alternatives satisfies this standard.

The CEQ regulations state that the alternatives "should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public." 40 CFR § 1502.14. CEQ guidance also instructs that "[w]hen there are potentially a very large number of alternatives, only a reasonable number of examples, covering the full spectrum of alternatives, must be analyzed and compared in the EIS." Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026, 18027 (March 23, 1981). The CEQ regulations for EISs further provide that the alternatives section must:

(a) Rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated.

(b) Devote substantial treatment to each alternative considered in detail including the proposed action so that reviewers may evaluate their comparative merits.

(c) Include reasonable alternatives not within the jurisdiction of the lead agency.

(d) Include the alternative of no action.

(e) Identify the agency's preferred alternative or alternatives, if one or more exists, in the draft statement and identify such alternative in the final statement unless another law prohibits the expression of such a preference.

(f) Include appropriate mitigation measures not already included in the proposed action or alternatives.

40 CFR § 1502.14.

As noted above, courts have held that an agency is not required to include every conceivable alternative in NEPA environmental documents. Instead, agencies are required to examine "reasonable" alternatives, and not those that are unlikely or are a "worst case scenario." Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 354-55 (1989). An agency is not required to consider alternatives "whose effect cannot be reasonably ascertained, and whose implementation is deemed remote and speculative." Headwaters, Inc. v. Bureau of Land Management, Medford District, 914 F.2d 1174, 1180 (9th Cir. 1990) (quoting Life of the Land v. Brinegar, 485 F.2d 460 (9th Cir. 1973), cert. denied, 416 U.S. 961 (1974)). An agency is also not required to consider alternatives that are "infeasible, ineffective, or inconsistent with the basic policy objectives" of the proposal. Id. (citing California v. Block, 690 F.2d 753, 767 (9th Cir. 1982)).

Courts have upheld the appropriateness of an agency relying on statutory objectives as a guide for the purpose and need of a project. See Westlands Water Dist. v. U.S. Dep't of Interior, 376 F.3d 853, 866 (9th Cir. 2004) ("Where an action is taken pursuant to a specific statute, the statutory objectives of the project serve as a guide by which to determine the reasonableness of objectives outlined in an EIS."). See also City of New York v. U.S. Dep't of Transp., 715 F.2d 732, 743 (2d Cir. 1983) (statutory objectives provide a "sensible compromise" between unduly narrow objectives and "hopelessly broad societal objectives"); City of Alexandria v. Slater, 198 F.3d 862, 867-68 (D.C. Cir. 1999) (upholding agency's analysis of highway expansion project where purpose and need statement was focused upon factors required by the applicable, substantive statute).

CEQ guidance on this point is similar. "Reasonable alternatives include those that are practical or feasible from the technical and economic standpoint and using common sense, rather than simply desirable from the standpoint of the applicant." Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026, 18027 (March 23, 1981) (emphasis added).

The "rule of reason" also guides the choice of alternatives and the extent to which the EIS must discuss each alternative. See, e.g., City of Carmel-by-the-Sea v. U.S. Department of Transportation, 123 F.3d 1142, 1155 (9th Cir. 1997). See also American Rivers v. FERC, 201 F.3d 1186, 1200 (9th Cir. 2000) (same, quoting City of Carmel-by-the-Sea, 123 F.3d at 1155). Under the rule of reason, an agency "need not consider an infinite range of alternatives, only reasonable or feasible ones." Id. (citing 40 CFR § 1502.14(a)-(c), as set forth above). "[F]or alternatives which were eliminated from detailed study, [an EIS must] briefly discuss the reasons for their having been eliminated." American Rivers v. FERC, 201 F.3d 1186, 1200 (citing 40 CFR § 1502.14(a)) (emphasis in original).

With this understanding, and as explained in the NPRM and the DEIS, EPCA requires the Secretary of Transportation to establish average fuel economy standards for each model year at least 18 months before the beginning of that model year and to set them at "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year." When *setting "maximum feasible" fuel economy standards, the Secretary is required to "consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need of the United States to conserve energy." NHTSA construes EPCA's statutory factors as including environmental issues and permitting the consideration of other relevant societal issues, such as safety. "Congress did not prescribe a precise formula by which NHTSA should determine the maximally-feasible fuel economy standard, but instead gave it broad guidelines within which to exercise its discretion." Competitive Enterprise Institute v. NHTSA, 901 F.2d 107, 121 (D.C. Cir. 1990) (citing Public Citizen v. NHTSA, 848 F.2d 256, 265 (DC Cir. 1988)). See also Center for Auto Safety v. NHTSA, 793 F.2d 1322, 1340 (DC Cir. 1986) (same); Competitive Enterprise Institute v. NHTSA, 901 F.2d 107, 121 (D.C. Cir. 1990) (Wald, J.) (same). Thus, EPCA does not require the agency to establish fuel-economy standards at any chosen level, but instead confers on NHTSA broad discretion to balance these factors when setting an appropriate standard.*

Although NHTSA has used the Volpe model to inform its consideration of potential CAFE standards, the Volpe model does not determine the CAFE standards NHTSA will propose or promulgate as final regulations. NHTSA considers the results of analyses conducted by the Volpe model and analyses conducted outside the Volpe model, including analysis of the impacts of CO_2 and criteria pollutant emissions, analysis of technologies that might be available in the long term and whether NHTSA could expedite their entry into the market through these standards, and analysis of the extent to which changes in vehicle prices and fuel economy might affect vehicle production and sales. Considering all of this information—not solely that from the Volpe model—NHTSA considers the governing statutory factors, along with environmental issues and other relevant societal issues, such as safety, and promulgates the maximum feasible standards based on its best judgment on how to balance these factors.

This FEIS complies with NEPA and EPCA by informing decisionmakers and the public of the reasonable alternatives and the environmental impacts associated with each alternative. While mindful that EPCA's overall purpose is energy conservation, NHTSA sought to balance the EPCA statutory factors when proposing its Preferred Alternative in the DEIS. After careful consideration of all comments, NHTSA concludes that the Optimized Alternative remains the agency's Preferred Alternative. It is the point at which net benefits are maximized. Further, by limiting the standards to levels that can be achieved using technologies that provide benefits that at least equal their costs, the net benefit maximization approach provides a strong assurance of the marketability of the manufacturers' vehicles and thus economic practicability of the standards. This assurance assumes increased importance in view of current and anticipated conditions in the industry in particular and the economy in general.

With this understanding of the applicable standards for NEPA alternatives in the context of this rulemaking under EPCA, NHTSA turns now to the comments the agency received regarding alternatives. The comments fell into several subcategories, which are set forth below along with NHTSA's response.

10.2.3.2 Reasonable Range of Alternatives

Comments

Comment Number: 0564-2
Organization: Consumer Federation of America
Commenter: Mark Cooper

The analysis underlying the proposed rule is so fundamentally flawed that the agency has not considered an appropriate range of policy options, for which the environmental impact should be evaluated. Erroneous assumptions about market fundamentals have led NHTSA to center its analyses on a level of fuel economy that is so low that it sheds little light on what the environmental impact of a reasonable fuel economy standard would be. NHTSA has based the proposed rule on flawed assumptions and data on:

- Consumer behavior and attitudes toward fuel economy;
- Automaker capabilities to incorporate fuel savings technologies; and
- The price and value of energy.

Comment Number: 0572-10
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Even were the Volpe model not fundamentally rigged to provide an unreasonably low result, the inputs used by NHTSA ensured that the fuel economy levels that resulted were artificially low, again resulting in NHTSA failing to analyze a reasonable range of alternatives.

Comment Number: 0572-59
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The IPCC (2007) provides an extensive description of the different environmental impacts projected under different levels of greenhouse gas emission levels, as summarized in the Synthesis Report, Summary for Policymakers (Bernstein (2007). NHTSA refers to IPCC (2007) repeatedly, as on page 24357 of the NPRM, regarding the need to “take actions to reduce greenhouse gas emissions,” and starting on page 24413 of the NPRM, regarding the projection of “specific climate impacts.” The IPCC report Bernstein (2007) categorizes global greenhouse gas emission levels into quantitative emissions scenarios with impacts associated with particular levels of emissions. The proposed rule must analyze the impacts of the proposed CAFE standards in relation to the emissions scenarios and their associated impacts.

Comment Number: 0576-1
Organization: Public Citizen
Commenter: Joan Claybrook

To this aim, NHTSA has neither sharply defined the issues, nor has it provided a clear basis for choice among the options. Furthermore, NHTSA has not fulfilled the obligation to “rigorously explore and objectively evaluate all reasonable alternatives,” “[i]nclude reasonable alternatives not within the jurisdiction of the lead agency,” or “[i]nclude appropriate mitigation measures not already included in the proposed action or alternatives.” [Footnote: See original comment document.] NHTSA’s range of alternatives is unreasonably constrained by the Volpe model’s assumptions regarding the inputs, and NHTSA does not consider other reasonable alternatives out of its jurisdiction.

Comment Number: 0576-4
Organization: Public Citizen
Commenter: Joan Claybrook

The agency also does not include a technology-forcing alternative as required by Energy Policy and Conservation Act (EPCA). [Energy Policy and Conservation Act. Pub. L. 94-163 (Dec. 22, 1975).] While EPCA does not provide explicit guidance, NHTSA has been chided in its interpretation of the balance of the four factors in the statute. In *Center for Biological Diversity v. NHTSA*, the Ninth Circuit Court of Appeals found that NHTSA’s weighing the value of consumer choice over the “need of the nation to conserve energy” was arbitrary and capricious. The courts have affirmed the idea that technology-forcing statutes can impose standards that are at the technology horizon — levels which only the most advanced facilities in an industry may only achieve some of the time." [Footnote: See original comment document.]

Comment Number: 0576-5
Organization: Public Citizen
Commenter: Joan Claybrook

Consideration of alternatives not within the jurisdiction of the lead agency and mitigation measures not included in the proposed action or alternatives are particularly important in addressing the implications of fuel economy standards on reducing greenhouse gas emissions. NHTSA must therefore consider actions that fall outside the scope of the proposed action, and outside of the agency's jurisdiction — something it specifically failed to do when it stated in the draft EIS: "NHTSA emphasizes to the reader of this DEIS that the proposed action does not directly regulate the emissions from passenger cars and light trucks. NHTSA does not have that authority." [Footnote: See original comment document.]

Comment Number: TRANS-05-6
Organization: Consumer Federation of America
Commenter: Mark Cooper

The underlying analysis is so fundamentally flawed that the agency has not considered an appropriate range of policy options for which the environmental impact should be evaluated.

Erroneous assumptions about market fundamentals, about consumer behavior and attitudes towards fuel economy, auto making capabilities to incorporate fuel savings technologies, and the price and value of energy have led NHTSA to center its analysis on a level of fuel economy that is so low that it sheds little light on what the environmental impact of a reasonable fuel economy standard would be.

Comment Number: TRANS-06-1
Organization: Public Citizen
Commenter: Lena Pons

The first is the range of alternatives does not constitute the range of alternatives envisioned under the National Environmental Policy Act, and does not meet the requirements under the regulation.

Under the regulation set forth under the National Environmental Policy Act, agencies are required to consider a range of alternatives that include all reasonable regulatory alternatives. The regulatory alternatives that are considered in this proposal effectively are a confidence bound around the optimized scenario proposed in the regulation.

Response

Commenters state that NHTSA did not consider a reasonable range of alternatives. As noted in detail in the response at 10.2.3, under the applicable standards, NHTSA is not required to include every conceivable alternative in NEPA documents, nor necessarily the alternatives submitted by commenters. See *40 CFR § 1502.14(a). The content and scope of alternatives to the proposed action depends on the purpose and need for the action.*

Here, NHTSA considered the environmental impacts of alternatives ranging from taking no action to Technology Exhaustion. The environmental impacts stem from the mpg standard implemented by the decisionmaker. As such, the agency considered a broad spectrum of alternative actions and the *accompanying environmental impacts. Moreover, throughout the NEPA process, NHTSA has sought to give the decisionmaker and the public a thorough understanding of the range of environmental impacts of diverse CAFE standard setting, which is what is meant by a "reasonable range of alternatives" under NEPA. NHTSA has discussed and analyzed in the DEIS and this FEIS a broad spectrum of alternatives. NHTSA's range of alternatives, which analyze the setting of higher CAFE standards, is sufficiently broad to include the likely environmental impacts of potential greenhouse gas regulation approaches, including those proposed by the California Air Resources Board (CARB), other states, and other federal agencies. An analysis of such "other" potential alternatives would not present environmental impacts that fall outside the range of impacts resulting from the analysis of alternatives in this FEIS. Under NEPA's rule of reason, it would not serve a purpose to require NHTSA to evaluate in this FEIS other alternatives, the environmental impacts of which NHTSA has already considered and analyzed for the benefit of the decisionmaker and the public. NHTSA believes it has complied with the letter and the spirit of NEPA by considering a wide range of alternatives that informs the decisionmaker and the public of the potential environmental impacts associated with this rulemaking.*

10.2.3.3 Different Economic Inputs to the Volpe Model

Comments

Comment Number: 0572-11
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The NHTSA also abuses its discretion to balance the four EPCA factors by using inaccurate and unreasonably constrained values in the Volpe model. As discussed below, in each and every instance when NHTSA faced a choice of inputs, it chose the level that would minimize the resulting fuel economy level. Even if one or more of the NHTSA's choices were otherwise lawful under EPCA and the Administrative Procedures Act (APA), which they are not, the NHTSA's failure to disclose in the DEIS the impact of these input choices, and to provide an alternative based on choosing higher input numbers, violates NEPA as well.

Comment Number: 0572-21
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

In summary, in each and every instance discussed above, NHTSA unreasonably chose an input level that would depress the fuel economy level that resulted from the modeling. Then, NHTSA disclosed in the DEIS only the results of the modeling runs using these unreasonable input figures. NHTSA's modeling is arbitrary and capricious and violates NEPA (as well as the EPCA, as described throughout and in our July 1, 2008 comments on the proposed rule). Even if NHTSA's use of the Volpe model were otherwise valid (which it is not, as described above), at a minimum, NHTSA was required to consider alternatives based on modeling with reasonable inputs. In other words, NHTSA should also have disclosed the level of its so called "optimization" and "technology exhaustion" alternatives had the model been run with inputs that would have led to higher fuel economy outputs. NHTSA failed to do so.

Response

Commenters suggested that NHTSA use different data inputs to the Volpe model when developing CAFE standards. While NHTSA continues to report the "Reference Case," the agency recognizes that the commenters' suggested inputs could reflect potential future conditions, depending on the economic situation in the future. Therefore, in response to those comments, and in the interest of informing the *decisionmaker and the public, this FEIS explores what CAFE standards could result when inputting different values into the Volpe model. This FEIS also evaluates the environmental impacts resulting from use of the different economic assumptions. See Section 10.2.2 of this FEIS for discussions of NHTSA's reasoning behind the use of the different economic assumptions. This FEIS now analyzes potential impacts of the alternatives resulting from the Volpe model's use of two separate sets of assumptions: the Reference Case Volpe model inputs and the "High Scenario" Volpe model inputs. NHTSA carefully selected the various economic assumptions used in the Reference Case, and described those values and the process for selecting each of them in detail in Section 7 of Chapter V of the NPRM, and in Chapter VIII of the PRIA. Section 3.4.4.2.2 of the DEIS and Section 10.2.2 of this FEIS also briefly discuss the values assigned to the Volpe model economic assumptions. Specifically, NHTSA calculated and analyzed mpg standards and environmental impacts associated with each alternative under both the Reference Case for key model inputs, which uses the EIA's Reference Case fuel price forecast, a domestic SCC, and a 7 percent discount rate; and under the High Scenario, which uses the EIA High Case for fuel price forecast, a global SCC, and a 3 percent discount rate. NHTSA also examined two additional input scenarios (Mid-1 and Mid-2) to show how various combinations of economic-assumption input values between those used in the Reference Case and High Scenario result in average mpg levels that fall between the required mpg standards associated with the Reference Case and High Scenario input values. See Table 2.3-6 (listing input assumptions for Mid-1, Mid-2 and High Scenarios). Sections 3.4 and 4.4 describe the environmental impacts of the Reference Case and High Scenario alternatives. Appendix B shows the analysis results for the Mid-1 and Mid-2 Scenarios. Because this FEIS analyzes the environmental impacts of the alternatives at different values for Volpe model input assumptions, the decisionmaker and the public are presented with the full range of environmental impacts resulting from the alternatives' range of stringencies, which is derived using varying sets of economic assumptions, some of which were suggested by commenters. Even varying these economic inputs into the Volpe model, the environmental impacts of the resulting CAFE standards still fall within the range of impacts between the No Action Alternative (Alternative 1) and the Technology Exhaustion Alternative (Alternative 7).*

The Center for Biological Diversity (CBD) suggested that NHTSA disclose the level of stringency associated with technology exhaustion "had the model been run with inputs that would have led to higher fuel economy outputs." CBD's comment indicates that CBD misunderstands the Technology Exhaustion Alternative. As set forth in the NPRM and the DEIS, the Technology Exhaustion Alternative represents the level at which vehicle manufactures apply all feasible technologies by progressively increasing the stringency of the standard in each model year until every manufacturer (among those without a history of paying civil penalties) exhausts technologies estimated to be available during MY 2011-2015. Except for phase-in constraints, this analysis was performed using the same technology-related estimates (e.g., incremental costs, incremental fuel savings, availability, applicability, and dependency on vehicle freshening and redesign) as used for other alternatives, such as those that maximize net benefits and those that produce total benefits approximately equal to total costs. For the Technology Exhaustion Alternative, NHTSA removed phase-in constraints in order to develop an estimate of the effects of fuel economy increases that might be achieved if manufacturers could apply as much technology as theoretically possible, while recognizing that some technology must still be installed as part of a vehicle freshening or redesign. Thus, the Technology Exhaustion Alternative is not (and could not be under any set of different model data inputs) affected by the economic assumptions used in the Volpe model.

As to CBD's larger point regarding alternate economic inputs, this has been addressed in the FEIS through use of the High, Mid-1 and Mid-2 scenarios, which use different economic inputs from the Reference Case.

10.2.3.4 Alternative 1 (No Action)

Comments

Comment Number: 0572-30
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The NHTSA compounds the other errors in its analysis by presenting the effect of its action only as an improvement over the "no action" alternative, which NHTSA defines as leaving fuel economy standards unchanged. The true "no action" alternative is the technologically achievable fuel economy level. NHTSA's "action" is to reduce this level, based on its consideration of the other statutory factors. Therefore, NHTSA was required to disclose in the DEIS the additional greenhouse gas emissions that will result from its decision to set fuel economy standards far lower than the technologically feasible level. The NHTSA failed to do so, instead continuing to portray its rulemaking merely as an improvement over the status quo, when in fact the opposite is true: it has proposed standards that are far lower than what is achievable with today's and future technology, and far lower than current levels in other countries. The true effects of this decision must be disclosed.

Comment Number: 0574-11
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

Under the case of *Department of Transportation v. Public Citizen*, 541 U.S. 752(2004), commonly referred to as the "Mexican Trucks" decision—a case in which NHTSA's parent Cabinet Department prevailed unanimously in the Supreme Court—the Court held that NEPA analysis must be framed based on directives from Congress, and must be performed only to the extent that a particular agency has discretion:

> We hold that where an agency has no ability to prevent a certain effect due to its limited statutory authority over the relevant actions, the agency cannot be considered a legally relevant "cause" of the effect. Hence, under NEPA and the implementing CEQ regulations, the agency need not consider these effects in its EA [Environmental Assessment] when determining whether its action is a "major Federal action." Because the President, not FMCSA [Federal Motor Carrier Safety Administration], could authorize (or not authorize) crossborder operations from Mexican motor carriers, and because FMCSA has no discretion to prevent the entry of Mexican trucks, its EA did not need to consider the environmental effects arising from the entry. (*Department of Transportation v. Public Citizen*, 541 U.S. 752 (2004) at 770.),

NHTSA never explains why the Mexican Trucks decision should not alter the no-action alternative the agency proposes, which imagines counterfactually that NHTSA can leave CAFE standards unchanged, contrary to Congress's directives in EISA. Instead, to justify continuing with its own view of how to define the no-action alternative, NHTSA states in a circular fashion that "NHTSA must analyze a scenario where NHTSA does not take this action [i.e., takes no action to increase fuel economy standards]." (DEIS, at 1-11) That assertion is non-responsive to the Alliance's NEPA scoping comments. NHTSA clearly cannot specify a "no action" alternative that incorrectly assumes that the agency has no duty to carry out EISA's directives. Instead, NHTSA must specify a "no action" alternative that is formulated with the congressionally ordered baseline of achieving at least 35 mpg by MY 2020 in mind. Given the time period over which NHTSA is proposing to establish standards (i.e., for half of the model years between MY 2011 and MY 2020), the simplest way for NHTSA to specify a proper baseline is to use the fuel economy level in MY 2015 that makes half of the progress necessary to achieve the 35 mpg target in MY 2020, and then judge all of its alternatives against that halfway mark. There may also be other defensible ways of defining a "no action" alternative, but pretending that EISA does not exist is not one of them.

Moreover, this debate over how to define the no-action alternative is no tan arid one lacking in practical significance. Properly specifying the baseline for analysis of regulatory alternatives that fall within NHTSA's discretion under EISA is vital. If NHTSA sets the baseline too high, then it will underestimate the benefits of a given set of fuel economy standards. If NHTSA sets the baseline too low, as it has done here by specifying a baseline that falls short of the congressional mandate in EISA, then it will *overestimate* benefits. For instance, using MY 2010 CAFE standards as the no-action alternative, NHTSA might conclude that the agency's preferred set of CAFE standards will reduce the global concentrations of CO_2 that might otherwise obtain by 1 ppm. By contrast, it might find that if the no-action alternative instead were defined to take as a given mandated increases in fuel economy by Congress in EISA, then the same agency-preferred set of CAFE standards might reduce global concentrations of CO_2 by only 0.1 ppm. These numbers are purely illustrative. The point is that by mis-specifying the no-action alternative, NHTSA improperly exaggerates the environmental benefits that its discretionary choices appear to achieve. Furthermore, if NHTSA corrects this error, it would provide further directional support for concluding the NEPA process with an EA/FONSI [Environmental Assessment/Finding of No Significant Impact] (primarily, or in the alternative), as opposed to concluding that process with a final EIS.

Comment Number: 0574-6
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

NHTSA continues to misidentify the so-called "no action" alternative. NHTSA's persistence in making comparisons against a "no action" alternative that uses MY 2010 CAFE standards as a baseline counter factually assumes that EISA was never passed and is based on circular reasoning.

Comment Number: 0576-7
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA has also influenced the context by choosing a baseline that is too low. The agency's baseline is the no action alternative; however, the agency assumes fuel economy levels of 27.5 mpg for passenger cars and 23.5 mpg for light trucks. [Footnote: See original comment document.] NHTSA's most recent report on the level of fuel economy performance of vehicles estimates that passenger cars are getting 31.2 mpg and light trucks are getting 23.4 mpg. [Footnote: See original comment document.] However, even this level of fuel economy is unlikely to capture a real baseline, considering the intense shift in consumer demand for fuel efficient vehicles and the auto industry's scrambling to produce and market more efficient vehicles. [Footnote: See original comment document.]

Comment Number: TRANS-01-1
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

The first issue relates to NHTSA's inclusion of a no action alternative in its array of options. In our scoping comments, the Alliance noted that the 2007 energy bill does not allow for a no action option. Instead the energy bill sets a clear trajectory for increasing fuel economy standards for the span of a decade, and requires at least steady progress toward a 35 mile per gallon goal in model year 2020. We do not think it is appropriate for NHTSA to continue to rely on no action as its starting point.

Comment Number: TRANS-06-3
Organization: Public Citizen
Commenter: Lena Pons

Additionally, the no action alternative should not be considered to be an extension of the situation as it stands, but should be a reflection of what would happen were there no regulatory intervention.

Response

NHTSA received several comments contending that we improperly selected our No Action Alternative. In response to these comments, NHTSA clarifies that its No Action Alternative does not assume that NHTSA would issue a rule directing manufacturers to continue to achieve the MY 2010 CAFE standard (the DEIS incorrectly stated this assumption but the analysis was unaffected). Rather, the No Action Alternative simply assumes that NHTSA would not issue a rule regarding CAFE standards. The No Action Alternative assumes that average fuel economy levels in the absence of CAFE standards beyond 2010 would equal the higher of a manufacturer's product plans or the manufacturer's required level of average fuel economy for MY 2010. The MY 2010 fuel economy level represents the standard NHTSA believes manufacturers would continue to achieve, assuming NHTSA does not issue a rule.

Some commenters asserted that the No Action Alternative is not legally available for selection. Other commenters stated that NHTSA did not use the proper fuel-economy standard for the No Action Alternative. NHTSA recognizes the commenters' concern that the current average fuel economy of automobiles and light trucks is rising due to high energy costs and a shifting market.

These commenters misunderstand the NEPA process. Although EISA's recent amendments to EPCA direct NHTSA to increase CAFE standards and do not permit the agency to take no action on fuel economy, CEQ regulations mandate analysis of a no action alternative. See 40 CFR § 1502.14(d). Indeed, CEQ has explained that:

> *[T]he regulations require the analysis of the no action alternative even if the agency is under a court order or legislative command to act. This analysis provides a benchmark, enabling decision makers to compare the magnitude of environmental effects of the action alternatives. It is also an example of a reasonable alternative outside the jurisdiction of the agency which must be analyzed. [See 40 CFR § 1502.14(c).] … Inclusion of such an analysis in the EIS is necessary to inform the Congress, the public, and the President as intended by NEPA. [See 40 CFR § 1500.1(a).] Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026 (1981) (emphasis added).*

Thus, "[i]n requiring consideration of a no-action alternative, the [CEQ] intended that agencies compare the potential impacts of the proposed major federal action to the known impacts of maintaining the status quo." Custer County Action Assoc. v. Garvey, 256 F.3d 1024, 1040 (10th Cir. 2001) (citing Association of Public Agency Customers v. Bonneville Power Administration, 126 F.3d 1158, 1188 (9th Cir. 1997), and 46 FR 18,026, 18,027 (1981)). Consistent with CEQ regulations, the baseline model year 2010 levels in NHTSA's No Action Alternative represent the level at which manufacturers are meeting the CAFE standards already in effect. Manufacturers are obligated under EPCA to either meet the current CAFE standards or pay a penalty for falling below those standards. Manufacturers are not, however, *mandated to reach a fleet-wide average fuel economy level above 27.5 mpg for passenger automobiles or 23.5 mpg for non-passenger automobiles. Therefore, NHTSA believes that it would be speculative to set the baseline No Action Alternative at a level of fuel economy stringency that not all manufacturers are currently mandated, or able, to meet. In NHTSA's view, a different or modified No Action Alternative is not reasonable and would not aid the decisionmaker or the public in understanding the environmental impacts of the alternatives, because the alternatives would simply be measured from a different reference point. Therefore, this FEIS has maintained the baseline No Action Alternative as set forth in the DEIS. It is consistent with CEQ regulations and applicable law, and provides a logical reference point that serves the purpose of displaying to the decisionmaker and the public the difference between no action (maintaining the status quo) and each of the six action alternatives.*

10.2.3.5 Alternative 3 (Optimized Scenario)

Comments

Comment Number: 0559-3
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

Despite these developments which call for bold policy steps to actively pursue significant improvements in fuel economy, NHTSA has chosen to pursue a very conservative course in setting near-term standards. We made this point in our comments submitted on the Proposed Rule, noting NHTSA's initial consideration of seven different fuel economy stringency scenarios (ranging from no-action to technology exhaustion alternatives), and ultimate choice of an "optimized" alternative that maximized net benefits from an economic standpoint. In settling on this alternative for which there is little to no impetus for forcing technology, NHTSA's actions will have a dampening effect on progress toward long term improvements to fuel economy and by extension to progress addressing the environmental impacts brought about by climate change.

Comment Number: 0572-12
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Moreover, even if NHTSA's choice of the "optimized" alternative were otherwise lawful, the use of incorrect inputs in the model results means that even by the NHTSA's own twisted definitions, this alternative does not actually represent the point at which marginal benefits equal marginal costs. The NHTSA's inaccurate claim that it does violates NEPA's requirement to provide accurate information to the public.

Comment Number: 0576-19
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA's sensitivity analysis shows that the level of fuel economy standards is highly sensitive to the price of gasoline. The agency's estimate for the high price scenario would set the car standard at 37.4 mpg in 2011, almost 20 percent higher than the agency's "optimized" scenario, and at almost exactly the same level as NHTSA's total costs balance total benefits (TC=TB) scenario. (PRIA A-2) The light truck standards are less responsive to changes in economic assumptions, which NHTSA attributes to a lack of "cost effective" technologies available to raise fuel economy above the level reached in the optimized scenario." (PRIA at IX-10-IX-13)

Response

As noted in the DEIS and in this FEIS, the Optimized Alternative is the agency's Preferred Alternative. This alternative reflects standards based on applying technologies until net benefits are maximized. For a more detailed discussion of the Optimized Alternative, see Section 2.3.4 of the FEIS; Section 2.3.3 of the DEIS; Section X of the NPRM; and Section III-1 of the PRIA.

Commenters suggested that the Optimized Alternative does not accurately reflect the point at which marginal costs equals marginal benefits because incorrect economic assumptions were input into the Volpe model. As noted above, in response to these comments, this FEIS explores what CAFE standards could result from inputting different values into the Volpe model. This FEIS also evaluates the environmental impacts resulting from the use of the different economic assumptions in these alternatives through the High, Mid-1 and Mid-2 Scenarios. See Chapters 3 and 4. Thus, the environmental analysis has been expanded to include the environmental impacts of the alternatives at different values for Volpe model input assumptions. NHTSA selected the various economic assumptions to be used in the Volpe model carefully, and described those values and the process for selecting each of them in detail in Section 10.2.2 of this chapter. Chapter 2 of this FEIS also provides a brief discussion of the values assigned to the Volpe model economic assumptions. Because this FEIS analyzes the environmental impacts of the alternatives at different values for Volpe model input assumptions, the decisionmaker and the public are presented with the full range of environmental impacts resulting from the alternatives' range of stringencies, which is derived using varying sets of economic assumptions, some of which were suggested by commenters.

10.2.3.6 Alternative 6 (Total Costs Equal Total Benefits)

Comments

Comment Number: 0564-13
Organization: Consumer Federation of America
Commenter: Mark Cooper

We believe that the TC=TB [total costs equal total benefits] approach is the proper way to recognize "the need of the nation to conserve energy."

At a minimum, an approach that would reasonably consider "the need to conserve energy" would balance the economic and conservation concerns and set the standard between the two extremes.

NHTSA did not do so. It simply chose to set the standard at the lower level with no consideration of the enormous energy conservation cost of that decision.

Comment Number: 0575-14
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

An MC=MB [maximum costs equal maximum benefits] analysis produces noticeably more conservative findings for maximum cost-effective fuel economy levels. The MC=MB approach is also very sensitive to different valuations of the benefits, making it more error prone. It is therefore critical to accurately identify and account for the benefits associated with fuel-saving technologies. An MC=MB analysis that excludes or undervalues even some of the benefits—such as avoided carbon emissions, reduced oil dependence, or high gas prices—is fundamentally flawed.

Unfortunately, this NPRM contains numerous flaws including undervalued gasoline and carbon prices, among others (see Sections 1 and 2), which vastly underestimate consumers' economic and social savings from reduced fuel use. While NHTSA must fix these flaws, UCS suggests that NUTSA use a TC=TB analysis to determine maximum feasible U.S. fuel economy standards. Such an analysis would reduce the impact of any inaccurate monetizing of the benefits of reduced fuel consumption, such as improved energy security and reduced heat-trapping emissions, and ensure that the agency is doing the most possible to address these issues without negative consequences to U.S. consumers. As shown in Table 1 below, NHTSA's own analysis indicates that employing a TC=TB analysis would increase the economically practicable fleet average between 2.8 and 5.7 miles per gallon. This greater application of technology also produces higher lifetime societal benefits, as noted by NHTSA. Depending on discount rate selected (3% or 7%), opting for a TC=TB analysis over NHTSA's proposed standard would yield between $46.2 and $57.6 billion in additional lifetime benefits over the proposed standard. (Computed from PRIA Tables IX-2a and IX-2b, Passenger Cars and Light Trucks Combined (2006 dollars).]

Table 1: Required Fleet Average MPG Levels [See original comment document.]

NHTSA's decision to base deployment of fuel saving technology on the marginal, rather than total benefits, by definition, fails to reach the maximum feasible fuel economy level needed to address the Department of Transportation's legal requirements. The use of a TC=TB analysis, which would maximize the need to conserve energy while ensuring consumers are as well off as they are today, is a far more pragmatic economic assessment, and one that better meets the intent of Congress in raising fuel economy standards. UCS suggests that NHTSA use a TC=TB analysis to determine maximum feasible U.S. fuel economy standards.

Comment Number: 0575-6
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

NHTSA based its rulemaking on costs and benefits on the margin rather than the total costs and benefits of improved standards.

Response

Another alternative NHTSA evaluated in the DEIS is the Total Costs Equals Total Benefits Alternative (Alternative 6). As an initial matter, the Union of Concerned Scientists and other commenters suggested the Total Costs Equals Total Benefits Alternative during NHTSA's CAFE rulemaking for MY 2008-2011 for light trucks. This alternative reflects standards based on manufacturers applying technologies until total costs equal total benefits, yielding zero net benefits. The Total Costs Equal Total Benefits Alternative is the second most stringent set of mpg standards examined in this FEIS, after the Technology Exhaustion Alternative (which yields negative net benefits). For a more detailed discussion of the Total Costs Equal Total Benefits Alternative, <u>see</u> *Section 2.3.7 of the FEIS, Section X of the NPRM, and Section III-1 of the PRIA.*

Commenters suggested that NHTSA select the Total Costs Equals Total Benefits Alternative as its Preferred Alternative, arguing that it properly recognizes the need of the nation to conserve energy and is a far more pragmatic economic assessment that better meets the intent of Congress in raising fuel economy standards. Upon a considered analysis of all information available, including all information raised to NHTSA in comments, NHTSA concludes that the Optimized Alternative remains the agency's Preferred Alternative. It is the point at which net benefits are maximized. Further, by limiting the standards to levels that can be achieved using technologies that provide benefits that at least equal their costs, the net benefit maximization approach provides a strong assurance of the marketability of the *manufacturers' vehicles and thus economic practicability of the standards. This assurance assumes increased importance in view of current and anticipated conditions in the industry in particular and the economy in general.*

10.2.3.7 Alternative 7 (Technology Exhaustion)

Comments

Comment Number: 0572-6
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

NHTSA's "technology exhaustion" would result in average fuel economy of 31.1 mpg in 2011 to 41.4 mpg in 2015. It is clear that this cannot, by any stretch of the imagination, be equated with what is "technologically feasible." First, cars on the road in the U.S. today already achieve approximately the same or better gas mileage than what NHTSA has defined as the combined fleet "technology exhaustion" for model year 2015. These include the Toyota Prius (48/45; city/highway) and the Honda Civic Hybrid (40/45; city/highway). [Footnote: See original comment document.] Even more vehicles cars already achieve the "technology exhaustion" standard for the combined fleet in MY 2011: smartcar (33/41; city/highway); Mini Cooper(28/31); Toyota Yaris (29/36); Toyota Corolla (28/37); Nissan Altima Hybrid (35/33); Toyota Camry Hybrid (33/34); Hyundai Accent (27/32); Kia Rio (27/32); Mazda Tribute Hybrid 2WD (34/30); and Honda Fit (28/34). [Footnote: See original comment document.]

Second, NHTSA's "technology exhaustion" alternative results in fuel economy standards, even in 2015, which are below current standards in many other countries, and far below Japanese standards for 2015. In contrast, Europe and Japan had average fuel economy standards of approximately 40 mpg in 2006—over 15 mpg higher than U.S. standards (ICCT 2007). Both Europe and Japan are predicted to continue increasing their fuel standards; even their high standards are not the technology maximum. That other countries have achieved higher fuel standards indicates that there are eminently feasible technology options available today that have not been included in the DEIS. (We note the substantial overlap in manufacturers of the European fleet and U.S. fleet (ICCT 2007:13), and that at least one manufacturer, Ford, has already declared its intention to "make big changes to the vehicles it sells domestically" and bring "six small cars made in Europe to the North American market (Smith 2008).")

Figure 1. [See original comment document.]

By contrast, NHTSA's definition of "technology exhaustion" is the level that would "require every manufacturer to apply every feasible fuel saving technology to their MY 2011-2015 fleet." (DEIS at 2-2) By what sleight of hand does NHTSA transform what is "technologically feasible" into something called "technology exhaustion" that is so much lower? The answer lies in the unlawful constraints of the Volpe model itself.

Comment Number: 0574-2
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

The Alliance agrees with much of the analysis presented in the DEIS. For instance, NHTSA's analysis of the fuel economy impacts associated with mandating higher levels of fuel economy under the alternatives studied leads to the conclusion that even if NHTSA were to adopt the so-called "technology exhaustion" alternative, NHTSA would be able to reduce global mean surface temperatures in 2100 by only an additional 0.006°C as compared to the temperature reductions associated with the "optimized" alternative

NHTSA favors in its notice of proposed rulemaking ("NPRM"). [Footnote: See original comment document.]. See DEIS 2-16 (Table 2.5-4 (comparing "Reduction from No Action" for the "Optimized" and "Technology Exhaustion" scenarios). This is obviously a very small change, and is less than both the natural variability in temperature on an annual basis and the error in measuring temperatures from year to year. [Footnote : See original comment document.]

Comment Number: 0588-9
Organization: New York State Department of Transportation
Commenter: Stanley Gee

Tables 3.2-2 and 3.2-3 indicate that the technology exhaustion alternative will yield more incremental benefits for light trucks than it yields for passenger vehicles. Figure 4.2-2 also indicates that the technology exhaustion alternative will yield a significant incremental benefit for light trucks. Certain sections of the DEIS suggest that if the CAFE standards are set too stringent, manufacturers may opt to pay noncompliance penalties rather than meet or exceed the standard. If this is the case, wouldn't the more aggressive alternatives (3-7) yield less benefit than the preferred alternative? The FEIS should explain this in more detail and clearly describe how the Volpe model and other models treat this issue for alternatives 3-7.

Response

NHTSA disagrees with the Center for Biological Diversity's (CBD) comment suggesting that the Technology Exhaustion Alternative is not truly "exhaustive" because some cars sold in the United States achieve higher fuel economy than the fleetwide average NHTSA estimated would be achieved under the technology exhaustion alternative NHTSA performed for MY 2011 and MY 2015. Other commenters contend that NHTSA did not fully explore what is technologically feasible.

As an initial matter, NHTSA developed the Technology Exhaustion Alternative by progressively increasing the stringency of the standard in each model year until every manufacturer (among those without a history of paying civil penalties) exhausted technologies estimated to be available during MY 2011-2015. Except for phase-in constraints, this analysis was performed using the same technology-related estimates (e.g., incremental costs, incremental fuel savings, availability, applicability, and dependency on vehicle freshening and redesign) as used for other alternatives, such as those that maximize net benefits and those that produce total benefits approximately equal to total costs. For the Technology Exhaustion Alternative, NHTSA removed phase-in constraints in order to develop an estimate of the effects of fuel economy increases that might be achieved if manufacturers could apply as much technology as theoretically possible, while recognizing that some technology must still be installed as part of a vehicle freshening or redesign.

In each year, NHTSA increased the stringency until the first manufacturer exhausted available technologies; beyond this stringency, NHTSA estimated that the manufacturer would be unable to comply (NHTSA is precluded from considering manufacturers' ability to use CAFE credits) and would be forced to pay civil penalties. NHTSA then increased the stringency until the next manufacturer would be unable to comply, and continued to increase the stringency of the standard until every manufacturer was unable to apply enough technology to comply.

NHTSA did not, as CBD appears to suggest, estimate the stringency that would force every manufacturer to apply to every single vehicle every theoretically applicable technology. This approach would completely ignore product planning cycles and real constraints on the pace at which technologies can even conceivably be added to manufacturers' fleets. Rather, as mentioned above, NHTSA applies constraints related both to vehicle engineering and to vehicle freshening and redesign schedules.

The Center for Biological Diversity further argues that NHTSA's Technology Exhaustion Alternative is not truly "exhaustive" because other countries achieve higher fuel economy levels. This argument ignores the fact that the United States does not, even setting aside technological differences, have the same fleet profile as other countries, and that average fuel economy is strongly dependent on fleet profile. EPCA requires NHTSA to set maximum feasible CAFE standards for passenger cars and light trucks produced for sale in the United States, not to set standards that force manufacturers to make the U.S. vehicle market have a profile like that of any other country.

In response to the comment suggesting that this FEIS explain how the Volpe model considers manufacturers' election to pay noncompliance civil penalties rather than meet the prescribed CAFE standard, Sections 3.1.4, 3.4.3.1, 3.4.4.2.2, and 4.4.3.1 of this FEIS illustrate how the estimated penalty rate is accounted for in the Volpe model. For additional discussion of how noncompliance civil penalties are accounted for in the Volpe model, see page III-13, V-55-56 of the PRIA.

10.2.3.8 New Alternatives

Comments

Comment Number: 0572-23
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The EPCA is a "technology-forcing" statute, whereby a challenging standard encourages technological innovation. The EIS must consider alternatives in light of EPCA's technology-forcing character. As the court in *Center for Auto Safety v. Thomas* noted, "[t]he experience of a decade leaves little doubt that the congressional scheme in fact induced manufacturers to achieve major technological breakthroughs as they advanced towards the mandated goal." (847 F.2d 843, 870 (D.C. Cir. 1988) (overruled on other grounds); *see also Green Mt. Chrysler Plymouth Dodge Jeep v. Crombie*, 508 F. Supp. 2d 295, 358-359 (D. Vt. 2007) (discussing technology-forcing character of EPCA and the use of increased fuel efficiency to augment performance rather than mileage). As explained by the court in *Kennecott Greens Creek Min. Co. v. Mine Safety and Health Admin*., "when a statute is technology forcing, "when a statute is technology forcing, the agency can impose a standard which only the most technologically advanced plants in an industry have been able to achieve-even if only in some of their operations some of the time." (476 F.3d946, 957 (D.C. Cir. 2007) (quoting *United Steel Workers of America, AFL-CIO-CLC v. Marshall*, 647F.2d 1189, 1246 (D.C. Cir. 1980)). With regard to a similarly technology-forcing statute, the Clean Air Act, legislative history indicates that the primary purpose of the Act was not "to be limited by what is or appears to be technologically or economically feasible," which may mean that "industries will be asked to do what seems impossible at the present time." (116 Cong. Rec. 32901-32902 (1970), 1 Legislative History of the Clean Air Amendments of 1970 (Committee Print compiled for the Senate Committee on Public Works by the Library of Congress), Ser. No. 93-18, p. 227 (1974); *see also Whitman v. American Trucking Associations*, 531 U.S. 457, 491 (2001)).

Due to the technology-forcing nature of the statutory scheme, the NHTSA was required to include one or more technology-forcing alternatives in the DEIS. Such an alternative would include standards that may appear impossible today, but that would force innovation as industry strives to meet a challenging standard. NHTSA's "technology exhaustion" alternative, defined by the criteria "whether a particular method of improving fuel economy can be available for commercial application in the MY for which the standard is being established" (DEIS at 1-2) clearly cannot substitute for consideration of a technology-forcing alternative.

While NHTSA will likely argue that it was not required to consider a technology-forcing alternative because it has pre-determined that it would not select such an alternative, it is clear that all reasonable alternatives, even those falling outside the lead agency's jurisdiction, must be considered. *Natural Resources Defense Council. v. Morton*, 458 F.2d 827, 834 (D.C. Cir. 1972). Because EPCA is a technology-forcing statute, the failure to include a technology-forcing alternative was unreasonable and unlawful.

Having failed to include such an alternative, the NHTSA then failed to analyze the environmental impacts of a technology-forcing standard. This omission is particularly significant because such a technology forcing standard would have environmental benefits that not only amplify the ability of automakers to meet higher standards in later years, but that also ripple through the economy. NHTSA's failure to consider this important aspect of the analysis renders the DEIS inadequate.

Comment Number: TRANS-06-2
Organization: Public Citizen
Commenter: Lena Pons

Additionally, under the regulations, agencies may consider regulatory alternatives that are not in the jurisdiction of the lead agency, which would include more protective types of regulations such as greenhouse gas regulations for motor vehicles, such as those envisioned by the State of California and other states, and also part of the EPA's proposed greenhouse case, economy-wide greenhouse gas regulations.

Response

While NHTSA recognizes that under Section 1502.14 of the CEQ NEPA implementing regulations, an agency may consider alternatives not within its jurisdiction, we disagree with commenters who suggested that NHTSA consider the regulation of GHGs as potential alternatives under CAFE. NHTSA can issue CAFE standards, which necessarily have the effect of regulating CO_2*, just as EPA can issue* CO_2 *standards, which necessarily have the effect of regulating CAFE. Indeed, in the Advance Notice of Proposed Rulemaking, EPA published in response to the* Massachusetts v. EPA *ruling on the regulation of* CO_2*, vehicle efficiency ranges are comparable to the ranges in NHTSA's proposed rulemaking because both were based on product plans available to both agencies at the time of the analyses.*[22] *Because regulating CAFE is tantamount to regulating* CO_2*, it would add nothing to the alternatives to include* CO_2 *regulations.*

Section 1502.14 of the CEQ regulations authorizes an agency to "include reasonable alternatives not within the jurisdiction of the lead agency." An agency, however, need not consider alternatives that are outside its power to implement. See Sierra Club v. Babbitt, 65 F.3d 1502, 1513 (9th Cir. 1995); see also Citizens Against Rails-To-Trails v. Surface Transportation Board, 267 F.3d 1144, 1151 (D.C. Cir. 2001). An agency is also not obligated to consider an alternative that would "override and redefine" the stated purpose of the project. See Crutchfield v. County of Hanover, 325 F.3d 211, 221-223 (4th Cir. 2003). NEPA does not require discussion of an alternative that is not reasonably related to a project's purpose(s). Native Ecosystems Council, 428 F.3d at 1245-1247 (EA case); City of Richfield v. FAA, 152 F.3d 905, 907 (8th Cir. 1998); Citizens Against Burlington, Inc. v. Busey, 938 F.2d 190, 195-196 (D.C. Cir. 1991); Northern Alaska Environmental Center v. Kempthorne, 457 F.3d 969, 978 (9th Cir. 2006) (agency need not discuss alternatives that are infeasible, ineffective, or inconsistent with the objectives of the project).

[22] *73 FR 44354, 44442-43 (July 30, 2008).*

The CBD relies on Natural Resources Defense Council. v. Morton, 458 F.2d 827, 834 (D.C. Cir. 1972) for the proposition that "all reasonable alternatives, even those falling outside the lead agency's jurisdiction, must be considered." This case from the early 1970's must be read in light of more recent Supreme Court and federal case law. In light of Vermont Yankee Nuclear Power Corp. v. Natural Resources Defense Council, Inc., 435 U.S. 519 (1978), and subsequent case law, the District of Columbia Circuit itself has stated that Morton stands only for the proposition that a reasonable alternative is defined by reference to a project's objectives. City of Alexandria v. Slater, 198 F.3d 862, 869 (D.C. Cir. 1999), cert. denied sub nom., Alexandria Historical Restoration and Preservation Com'n v. Federal Highway Admin., 531 U.S. 820 (2000).

Indeed, the District of Columbia Circuit has noted that "[w]e doubt the continuing vitality of the rather expansive view of NEPA we expressed in Morton, since subsequent Supreme Court cases have directly criticized us for overreading that statute's mandate." City of Alexandria, 198 F.3d at 869 n. 4 (citing, among other authorities, Baltimore Gas and Elec. Co. v. Natural Resources Defense Council, Inc., 462 U.S. 87, 97 (1983) and Vermont Yankee, 435 U.S. at 554).

Where, as here, "an action is taken pursuant to a specific statute, the statutory objectives of the project serve as a guide by which to determine the reasonableness of objectives outlined in an EIS." Westlands Water Dist. v. U.S. Dep't of Interior, 376 F.3d 853, 866 (9th Cir. 2004). The purpose and need of this rulemaking is to set maximum feasible average fuel economy levels under EPCA. NHTSA does not have the statutory authority to reduce the total amount of GHGs emitted by all vehicles driven, because NHTSA, under its statutory authority conferred by EPCA, cannot control how many miles citizens elect to drive. Nevertheless, NHTSA appreciates the fact that, despite the complex global nature of the problem, we still have an obligation to take a "hard look" under NEPA and analyze the effects of this rulemaking on global warming within the context of the other actions that affect global warming. Thus, NHTSA believes that the range of alternatives – including that of the Technology Exhaustion Alternative at the highest level of stringency – fully informs the decisionmaker and the public about the environmental impacts of any other reasonable CAFE standard, including climate-change issues.

Moreover, as noted above, NHTSA has discussed and analyzed in the DEIS and in this FEIS a broad spectrum of alternatives. NHTSA's range of alternatives, which analyze the setting of higher CAFE standards, is sufficiently broad to include the likely environmental impacts of potential GHG regulation approaches, including those proposed by the California Air Resources Board (CARB), other states, and other federal agencies. An analysis of such "other" potential alternatives would not present environmental impacts that fall outside of the range of impacts resulting from the existing analysis of the alternatives.

Finally, in response to the CBD's comment that NHTSA did not include a technology-forcing alternative, NHTSA states that other than the No Action Alternative, all of the analyzed alternatives induce manufacturers to implement new technologies to increase the fuel efficiency of their vehicles and are, therefore, technology-forcing. For a discussion of the alternatives, see Section 2.3 of the DEIS and this FEIS, Section X of the NPRM, and Section III-1 of the PRIA. For example, the Technology Exhaustion Alternative represents the level at which vehicle manufactures apply all feasible technologies without regard to costs. NHTSA removed phase-in constraints, in order to develop estimates of fuel economy increases that might be achieved if manufacturers could apply as much technology as theoretically possible, while recognizing that some technologies must still be installed as part of a vehicle freshening or redesign.

10.2.3.9 Alternatives Relationship to Maximum Feasible Fuel Economy Standard

Comments

Comment Number: 0557-6
Organization: The Natural Resources Defense Council
Commenter: Luke Tonachel, Brian Siu

The Draft Environmental Impact Statement is inaccurate because [it] evaluates an unlawful NHTSA CAFE proposal. As explained in NRDC's comments to the proposed rule, NHTSA failed to meet its statutory directive to set the maximum feasible fuel economy levels. [Footnote: See original comment document.] In calculating the required fuel economy level, NHTSA used erroneous assumptions for key input parameters and NHTSA set arbitrary limits on the availability of key vehicle technologies that could significantly improve fuel economy. These assumptions inaccurately characterized technologically feasible and economically practicable fuel economy in NHTSA's NPRM for both the proposed rule and the alternatives and therefore similarly skew the findings in the DEIS.

Comment Number: 0564-14
Organization: Consumer Federation of America
Commenter: Mark Cooper

NHTSA chose to define "feasibility" and "practicability" in a manner that lets the least fuel-efficient automakers drive down the standard. It protects the least capable automakers rather than requiring them to rise up to the level that the industry as a whole could achieve. Ironically, by setting a lower standard, in the face of dramatically rising consumer expectations, the Administration is creating an environment of failure for those companies who are driving down the standard. NHTSA allows the laggards in the industry, who have been trailing farthest behind the shift in consumer behavior, to pull the standard down.

Comment Number: 0564-4
Organization: Consumer Federation of America
Commenter: Mark Cooper

The crucial role of a higher fuel economy standard is to push the automakers to deliver what the public wants and deliver the maximum feasible fuel economy, but NHTSA has failed to do so.

Comment Number: 0572-1
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The NEPA analysis must be conducted in a way that is both meaningful and appropriate given the underlying statutory scheme. The EPCA requires that NHTSA set fuel economy standards for each model year at the "maximum feasible" level, taking into account four factors: technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy. (49 U.S.C. § 32902(f)). The EPCA is a "technology-forcing" statute, whereby a challenging standard encourages technological innovation. [Footnote: See original comment document.] As part of the statutory balancing, NHTSA must necessarily determine what is "technologically feasible." The NHTSA has discretion to set standards somewhere below that level based on its consideration of the three other statutory factors, <u>if it is reasonable to do so.</u>

In December 2007, Congress passed the Energy Independence and Security Act of 2007 (Pub. L.11-140, 121 Sat. 1492 (Dec. 18, 2007) (EISA)). The EISA eliminates the previous 27.5 mpg standard for passenger cars with a mandate that NHTSA set separate passenger car and light truck standards annually at the "maximum feasible level," with a minimum fleet wide fuel economy of 35 mpg by 2020.

Comment Number: 0572-20
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Manufacturers not only manipulate market demand as discussed above, but also respond to it. When economics demand, a manufacturer would certainly implement a change outside a normal development cycle. Similarly, if regulations required, automakers could make changes outside a normal development cycle. Development cycles are a product of commercial convenience, not practicability. As a result, they have no bearing on the considerations of technology implementation within the cost benefit analysis.

Comment Number: 0572-45
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The proposed CAFE standards fail to comply with the EPCA's mandate to set the CAFE standards at the "maximum feasible" level that the automakers can achieve for each model year. While the EPCA does authorize the agency to consider technological feasibility and economic practicability when deciding maximum feasible average fuel economy standards, it does not authorize NHTSA to set standards that maximize net economic benefits at the expense of fuel savings that are feasible, practicable, and necessary to meet the nation's acute conservation needs. In fact, the EPCA mandates that NHTSA must maximize feasible fuel savings, even if these fuel savings are not "optimal" by an incremental parsing of costs and benefits. 49 U.S.C. § 32902(a),(f). See also, *Center for Biological Diversity v. National Highway Traffic Safety Administration*, 508 F.3d 508 (9th Cir. 2007).]

Overall, the proposed rule systematically manipulates the analysis, assumptions and modeling inputs such that NHTSA selects proposed CAFE levels far below the statute's technology forcing mandate. The methodologies used by NHTSA in the development of these CAFE standards do not consider the maximum feasible level of fuel efficiency. The Volpe model and economic cost-benefit analyses defer overwhelmingly to the automakers and prioritize the economic benefit of the automakers. In doing so, NHTSA artificially and inappropriately constrained the analysis to exclude available and feasible efficiency technologies, assign low priorities and delayed implementation schedules for individual technologies, and ultimately limit the range of potential efficiency increase analyzed and adopted.

NHTSA defers overwhelmingly to auto manufacturer's preferences and convenience in violation of EPCA's technology forcing mandate. For example, the Volpe model generally does not apply a new technology until a given vehicle is due for a "redesign or refresh." (73 *Fed. Reg.* 24386) The assumption that the manufacturers need apply new technologies only when it is most convenient to do so is completely at odds with the statutory mandate to set fuel economy at the maximum feasible level. NHTSA's use of this and other such assumptions to systematically reduce the maximum feasible fuel economy level violates the statute.

Comment Number: 0572-47
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

NHTSA has manipulated the definition of "technological feasibility" to such an extent that it bears no relation to the plain meaning of those words. This manipulation and artificial constraint of the analysis leads to the perverse result that the "maximum technology" alternative considered by NHTSA of 37.5 mpg in 2011 is far below the fuel economy of many cars on the road today. (73 *Fed. Reg.* 24466) NHTSA's limitation of the regulatory universe to scenarios in which manufacturers' fleet mix remains the same is arbitrary and capricious in light of the nation's urgent need to conserve energy and slow global warming.

Comment Number: 0572-5
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

As part of the statutory balancing, NHTSA must necessarily determine what is "technologically feasible." While NHTSA has discretion to set standards somewhere below that level based on its consideration of the three other statutory factors, if it is reasonable to do so, NHTSA violates both EPCA and NEPA by failing to even consider or disclose what is truly "technologically feasible." An essential component of the DEIS must be disclosure of the "technologically feasible" fuel economy level, along with the environmental impact of choosing this level of fuel economy as compared to the NHTSA's preferred alternative and a reasonable range of additional alternatives. The DEIS fails to provide both the basic starting point for this analysis and the proper analysis that must follow.

"Technologically" is defined by Merriam-Webster's Dictionary as "of or relating to a capability given by the practical application of knowledge." Merriam-Webster Online Dictionary (2008) (definition 1b for technology). "Feasible" is defined as capable of being done or carried out." *Id.* (definition 1). Therefore, NHTSA must disclose what practical application of the knowledge [in the area of engineering] is capable of being done or carried out. NHTSA has failed to do so.

Comment Number: 0575-7
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

NHTSA's own analysis confirms that simply using more realistic gas prices or switching to an analysis based on total benefits would have led them to propose a fleet wide average of at least 35 mpg by 2015—five years earlier than the required minimum. (PRIA Pages III-6, IX-12 and IX-13) Given the urgency of global warming, and the fact that removing CO_2 early on is essential to reducing the risks of dangerous climate change, NHTSA is significantly underestimating the potential environmental impact of increased fuel economy simply because they are failing to exercise their legal obligation to set standards at maximum feasible levels.

Comment Number: 0575-8
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

NHTSA's own analysis proves that technologically feasible and economically practicable fuel economy levels can go well beyond 35 mpg by 2020. In fact, NHTSA's analysis indicates that by employing more sound assumptions, fleet average fuel economy can exceed 35 mpg by even 2015, the final year covered by this rule, setting the stage for even further improvements in fuel economy between 2016 and 2020.

Comment Number: 0576-15
Organization: Public Citizen
Commenter: Joan Claybrook

The agency's mission under EPCA and EISA is to deliver the "maximum feasible" level of fuel economy in a given model year. (See 49 U.S.C. 32902(a).) It is not the agency's responsibility to take into account how the industry could most easily comply. Instead, NHTSA is required to set standards based on "technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy." (49 U.S.C. at 32902(f))

Comment Number: 0576-25
Organization: Public Citizen
Commenter: Joan Claybrook

The logic behind the restructured CAFE standards is to add the minimum amount of fuel saving technology to bring a manufacturer into compliance with the standard for a given year, with significant latitude given to individual manufacturers for compliance based on the specific fleet mix of a given manufacturer. This approach necessarily undercuts the maximum feasible level of fuel economy. In its November 2007 decision in *Center for Biological Diversity v. NHTSA* the Court of Appeals for the Ninth Circuit said: "the agency's cost-benefit analysis does not set the CAFE standard at the 'maximum feasible' level and fails to give due consideration to the need of the nation to conserve energy." (*Center for Biological Diversity et al., v. NHTSA*. 508 F. 3d 508. (November 15, 2007).)

NHTSA states in this notice on fuel economy standards: "In striking [a] balance [between costs and benefits], the agency was mindful of the growing need of the nation to conserve energy for reasons that include increasing energy independence and security and protecting the environment." (73 *FR* 24457) However, analysis of the Volpe Model suggests that the assumptions NHTSA uses to set the standards are not sufficiently mindful of the need to conserve energy or environmental protection.

Public Citizen recognizes that since the Ninth Circuit decision there have been changes to the Volpe Model since the 2006 light truck rule: "the set of technologies represented was updated, the logical sequence for progressing through these technologies was changed, methods to account for 'synergies' (*i.e.*, interactions) between technologies and technology cost reductions associated with a manufacturer's 'learning' were added, the effective cost calculation used in the technology application algorithm was modified, and the procedure for calibrating a reformed standard was changed, as was the procedure for estimating the optimal stringency of a reformed standard." (73 *FR* at 24396) But these changes have not corrected the problems with the model that prevent it from setting standards at the maximum feasible level. Although Congress authorized NHTSA to restructure the CAFE scheme for passenger cars, but it did not mandate the NHTSA use Volpe Model. There are other ways the agency could model fuel economy that would set targets at the maximum feasible level and would improve public participation in the process.

Comment Number: 0576-8
Organization: Public Citizen
Commenter: Joan Claybrook

The Volpe model for fuel economy is structured in such a way that it undercuts the maximum feasible level of fuel economy statutorily mandated by EPCA. This is because the model is designed to minimize the estimate of what is technologically feasible and economically practicable. The fuel economy targets set by the Volpe model are a direct product of the economic assumptions made in the inputs to the model. The model also constrains the level of fuel economy by excluding technologies judged not to be cost efficient, and applying phase-in caps on certain technologies, which skews the impacts across the entire range of alternatives.

Comment Number: 0585-1
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary Of The Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

Ultimately, therefore, the DEIS must disclose whether NHTSA has adequately considered the environmental impacts of its new CAFE rule, and determined whether the need to reduce GHG emissions is of such critical importance that it requires the Agency to place more emphasis on energy conservation and to set the CAFE standard at a significantly higher level than proposed. In this case, the higher level would be represented either by the 25% above optimized, 50% above optimized, total cost equal total benefits, or technology exhaustion level alternatives. [Footnote: See original comment document.] The DEIS does not answer this question.

Comment Number: 0596-7
Organization: Environmental Defense Fund
Commenter: Martha Roberts

The statutory mandate in the Energy Policy Conservation Act (EPCA) requires NHTSA to set the "the maximum feasible average fuel economy level" while considering "technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy." (49 U.S.C. 32902(a), 32902(f)) NHTSA's statutory task is to first determine the "maximum feasible" limits of achievable fuel economy. Then NHTSA has some discretion to require less than the maximum feasible standard if such standard is not "economically practicable," but the agency is not given discretion to balance these statutory factors in a manner that defeats the primary purpose of EPCA. Congress has not given NHTSA discretion to "undermine the fundamental purpose of the EPCA: energy conservation." (p. 14865 *Center for Biological Diversity*)

The EIS fails to properly weigh the statutory factors because it impermissibly relies upon the assumption that economic considerations may be used to reject the "maximum feasible" alternative without a showing that the economic costs associated with an alternative make that alternative not "economically practicable." Merely showing that the estimated mix of economic costs and benefits are optimized at one alternative level of the standard does not establish a basis for concluding that more stringent standards may be rejected as not "economically practicable."

Congress did not establish the optimization of costs and benefits as the controlling factor for setting the standard. The controlling statutory factor is the "maximum feasible" level, but in this rulemaking NHTSA has impermissibly substituted the level at which costs and benefits are optimized as the controlling factor for setting the standard. The statute only gives weight to economic factors to the extent that the maximum feasible standard is not economically practicable. Here, the EIS does not identify economic factors that make the maximum feasible standard not practicable, and fails to explain why alternatives more stringent than the economically optimized level of the standard are not "economically practicable." The failure of the EIS to explore the limits of what is economically practicable is fundamentally arbitrary and capricious because it fails to consider the factors made relevant by the statute.

Comment Number: 0596-9
Organization: Environmental Defense Fund
Commenter: Martha Roberts

The limited findings of the EIS suggest alternatives preferential to the "optimized" alternative. Any of the alternatives with higher fuel efficiency than that of the "optimized" alternative better minimize environmental impacts and foster energy conservation. For example, the "costs = benefits" alternative saves 5.5 billion gallons of fuel annually in 2020 compared to the "optimized" alternative. Furthermore, as described in section II, greater fuel efficiency will prevent thousands of premature deaths a year.

In summary, the EIS supports adoption of the most stringent CAFE standard rather than NHTSA' s preferred "optimized" standard. NHTSA must adopt the feasible standard that achieves the greatest reduction in fuel use because that standard is mandated by the primary objective of EPCA—energy conservation—, unless the agency can show that such standard is not economically practicable. NHTSA must accordingly revise its preferred CAFE alternative to one of greater fuel efficiency.

Comment Number: 0598-2
Organization: Sierra Club
Commenter: Caroline Keicher

NHTSA' s own analysis shows that between 2011 and 2015, significantly higher standards are technologically feasible and economically practicable when higher gas prices are used ($3.14 per gallon in 2016). NHTSA's final rule should be, at a minimum, consistent with the analysis provided in the PRIA. NHTSA's use of below-cost energy estimates is arbitrary and capricious and violates the agency's statutory charter to impose mandatory maximum feasible fuel economy standards based upon a review of economic and technological feasibility.

Comment Number: 0599-1
Organization: Center for Biological Diversity
Commenter: Multiple Signatories

You are required by law to set U.S. fuel-economy standards at the "maximum feasible level." Doing so requires an honest assessment of the real costs and benefits of these standards, but your agency has failed to do so.

Comment Number: 0599-3
Organization: Center for Biological Diversity
Commenter: Multiple Signatories

Your decision to set the "maximum feasible" fuel-economy standard for U.S. automobiles in 2015 at 31.6 mpg, far below what vehicles must achieve today in Europe, Japan, China, Australia, and elsewhere is not only illegal, but also an affront to American ingenuity and resourcefulness.

Comment Number: TRANS-05-8
Organization: Consumer Federation of America
Commenter: Mark Cooper

The crucial rule of higher fuel economy standards is to push the automakers to deliver vehicles that consumers want, and to push the auto industry to the maximum technologically feasible and economically practicable level. NHTSA has failed to do so.

Comment Number: TRANS-12-4
Organization: Individual
Commenter: Sam Blodgett

Failure to utilize the higher cost projection violates NHTSA's statutory charter to impose mandatory feasible fuel economy standards based on economic and technological feasibility.

Comment Number: TRANS-19-8
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

The second problem is with the announcements that the rule is based on. Recent UCS report indicates that auto makers can cut cost effectively their fleet wide average fuel economy of cars and trucks and improve it to 42 miles per gallon by 2020, and up to 50 and more than 50 by 2030, with a modest 25 percent penetration of hybrids by 2020.

Comment Number: TRANS-24-10
Organization: Individual
Commenter: Heather Moyer

NHTSA's own analysis shows that between 2011 and 2015 significantly higher standards are feasible and economically practical when higher gas prices are used. NHTSA's final rule should be, at a minimum, consistent with the analysis provided in the preliminary impact analysis that accompanied this proposed, this notice of proposed rulemaking.

Comment Number: TRANS-24-9
Organization: Individual
Commenter: Heather Moyer

It is time to put existing fuel saving technology to work by increasing fuel economy standards to the levels that reflect the maximum achievable standards for vehicles produced in 2011 and 2015.

Comment Number: TRANS-32-3
Organization: Environmental Defense Fund
Commenter: James Keck

We are also concerned that even though EDFCA requires NHTSA to select the maximum technically feasible fuel economy that is economically practicable, the administration has deviated from this mandate and instead selected the standard that supposedly maximizes economic benefits. This so called optimized standard falls below alternative standards that convey less net economic benefits, but are still economically practicable and better meet the other recognized statutory considerations of energy conservation, environmental, and human health protection.

Comment Number: TRANS-35-6
Organization: Individual
Commenter: Alina Fortson

If we are to take advantage of our best, and most feasible technology, we would be in a position to reduce our oil use, in addition to lessening the impact that the price of gasoline has on families like mine. NHTSA's current proposal hinders this potential.

Comment Number: TRANS-37-6
Organization: Individual
Commenter: Jaafar Rizvi

I am here because I am concerned for several reasons that the fuel economy standards that you all have proposed are not strong enough.

According to the DEIS, fuel economy standards should be set at the maximum feasible average that the Secretary of Transportation decides the manufacturers can achieve in that model year, while simultaneously considering technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need for the U.S. to conserve energy.

And I agree with those guidelines. I think they're good. But I fear that NHTSA didn't properly analyze each of those specifically. For example, when considering economic practicability, the report doesn't really go into all of the economic benefits of lowering emissions, as well as the moral issues, which I won't talk about right now.

Comment Number: TRANS-37-8
Organization: Individual
Commenter: Jaafar Rizvi

And I've heard environmental scientists talk about why they disagree with this report. And I haven't heard any argument about why they are wrong. So basically, I'm left with the position where I feel like something isn't right with the research that's been done here.

And that makes me skeptical about analysis on two of the other categories that were mentioned before, the need for the U.S. to conserve energy and technological feasibility.

Comment Number: TRANS-39-4
Organization: American Jewish Committee
Commenter: Ami Greener

The use of the low cost energy estimates violates the agency's charter to impose mandatory maximum feasible standards based upon a review of economic and technological feasibility. NHTSA must reconsider the proposed standards and use its authority to meet the urgent need of the U.S. to conserve oil and meet the growing demand of American consumers for vehicles that go farther on a gallon of gas.

Response

NHTSA notes that under EPCA, the role of fuel economy standards is to set maximum feasible fuel economy standards. EPCA requires NHTSA to consider "economic practicability," which, as set forth in the NPRM, we have interpreted as not permitting the CAFE standards to cause substantial economic hardship and job loss for automakers. See 49 U.S.C. § 32902(f). Additionally, NHTSA does not have the statutory authority to dictate vehicle fleets. The legislative history of EPCA also demonstrates that Congress was concerned that CAFE standards should not unduly limit consumer choice. See H.R. Rep. No. 94-340, at 87 (1975), reprinted in 1975 U.S.C.C.A.N. 1762, 1849 ("any regulatory program must be carefully drafted so as to require of the industry what is attainable without either imposing impossible burdens or unduly limiting consumer choice as to the capacity and performance of motor vehicles").

Some commenters stated that because specific vehicles currently in production can achieve a fuel economy equal to or greater than EISA's statutory goal of combined fleet fuel economy of 35 mpg by 2020, NHTSA should effectively raise the fuel economy standards to a level that creates innovation among these high-fuel-economy vehicles. These commenters misunderstand how NHTSA measures and calculates CAFE levels under EPCA. CAFE standards are not measured by the performance of a single vehicle in a manufacturer's fleet. Rather, as set forth in the NPRM, they are measured as the average of the manufacturer's fleet-wide fuel economy. As explained in detail in the NPRM, the actual CAFE standards for each manufacturer are a function of their product mix. Vehicles with a larger footprint have a lower fuel economy goal than vehicles with a smaller footprint. NHTSA has, and continues to, set CAFE standards while keeping in mind the preservation of consumer choice, by assuming that manufacturers' product plans reflect this variable. NHTSA uses the manufacturers' product plans to inform what manufacturers' capabilities and capacities will be for any given model year. As stated earlier, NHTSA updated its technology assumptions based on comments received and used these updated assumptions in the Volpe model. NHTSA continues to believe that more stringent standards result in a substantial number of manufacturers falling out of compliance with the standards. This goes to the issue of economic practicability – technological feasibility cannot be viewed independently of this and other EPCA factors. If, for example, a manufacturer chooses to pay civil penalties, NHTSA would not reach the necessary fuel savings goal of achieving a combined fuel economy average for MY 2020 of at least 35 mpg.

Some commenters are concerned with NHTSA's use of purportedly "low" energy costs. As noted above, this FEIS explores CAFE standards resulting when inputting a different fuel price into the Volpe model. This FEIS also evaluates the environmental impacts resulting from the use of other different economic assumptions. <u>See</u> FEIS Sections 3.4.4.2 and 10.2.2. ***.*** *Regarding NHTSA's selection of fuel price in the DEIS, we relied on the most recent fuel price projections from the U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO) for this analysis. Specifically, we used the AEO 2008 Early Release forecasts of inflation-adjusted (constant-dollar) retail gasoline and diesel fuel prices, which represent the most up-to-date estimate of the most likely course of future prices for petroleum products. Federal Government agencies generally use EIA's projections in their assessments of future energy-related policies. <u>See</u> 73 <u>FR</u> 24405, May 2, 2008. For a more detailed discussion, <u>see</u> Section 7 of Chapter V of the NPRM, and Chapter VIII of the PRIA. Section 3.4.4.2.2 of the DEIS and Section 3.4.5 of this FEIS also provide a brief discussion of the values assigned to the Volpe model economic assumptions.*

Regarding the comments that NHTSA must adopt the "environmentally preferable" alternative as its preferred alternative, neither EPCA nor NEPA require this. As noted above, "Congress in enacting NEPA . . . did not require agencies to elevate environmental concerns over other appropriate considerations." <u>Baltimore Gas and Elec. Co. v. Natural Resources Defense Council, Inc.</u>, 462 U.S. 87, 97 (1983). Instead, NEPA requires an agency to develop "alternatives to the proposed action" in preparing an EIS. 42 U.S.C. § 4332(2)(C)(iii).

Other commenters stated that NHTSA must take into account the looming threat of global warming on the environment and give further emphasis to energy conservation by setting the CAFE standards at a higher level. NHTSA's range of alternatives considers the effect of global warming on the environment. Moreover, the purpose of an EIS is to present the reasonably foreseeable environmental impacts of the agency's proposed action to the decisionmaker and to the public, not to force policymakers' decisions. The Supreme Court in <u>Public Citizen v. Department of Transportation</u> found that "NEPA itself does not mandate particular results" but rather, "NEPA imposes only procedural requirements on federal agencies with a particular focus on requiring agencies to undertake analyses of the environmental impact of their proposals and actions." 541 U.S. 752, 756-57 (2004) (citing <u>Robertson</u>

v. Methow Valley Citizens Council, 490 U.S. 332, 349-50 (1989). Accordingly, a normative determination that GHG emissions reduction are of critical importance is not the purpose of an EIS.

10.2.3.10 The Need of the United States to Conserve Energy

Comments

Comment Number: 0564-12
Organization: Consumer Federation of America
Commenter: Mark Cooper

NHTSA failed to give the "need to conserve energy" proper consideration in light of the clear, obvious, and painful national energy crisis currently facing all Americans. In speaking for the American public, Congress was very clear in its requirement that NHTSA set the fuel economy standard at the "maximum feasible level." In doing so, NHTSA was to take into consideration "the four statutory factors underlying maximum feasibility (technological feasibility, economic practicability, the effect of other standards on fuel economy, and the need of the nation to conserve energy)." NHTSA completely failed to give proper consideration to this last and most fundamental reason for the Act: "the need of the nation to conserve energy."

Comment Number: 0585-11
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary Of The Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

Ultimately, however NHTSA chooses to present the data, there must be some analysis that enables the Agency and the public to determine whether the proposed CAFE rule, when combined with other anticipated actions, is sufficiently stringent to reduce, over time, GHG emissions and stabilize CO_2 concentrations at levels that will prevent us from reaching the area of dangerous anthropogenic interference. If the proposed CAFE rule is not sufficiently stringent to reach those goals, then NHTSA has not properly considered whether our need to conserve energy and lower GHG emissions outweighs the remaining factors under EPCA, and requires a stricter CAFE standard and higher fuel economy.

Comment Number: TRANS-14-5
Organization: U.S. Public Interest Research Group
Commenter: Annie Chau

We fully support the comments of the Consumer Federation of American and we agree that NHTSA has failed to prioritize the need to conserve energy, has undervalued the benefits of increased vehicle fuel economy, and has kept standards too low for too long.

Response

Some commenters claimed that NHTSA did not prioritize the need to conserve energy. Throughout this rulemaking and the development of the DEIS and this FEIS, NHTSA did, and continues to, appropriately prioritize the need to conserve energy when balancing the EPCA factors, along with environmental issues and relevant societal issues, in an effort to set maximum feasible fuel economy standards. The extent of such prioritization is within NHTSA's discretion. Notably, "Congress did not prescribe a precise formula by which NHTSA should determine the maximally-feasible fuel economy *standard, but instead gave it broad guidelines within which to exercise its discretion." Competitive Enterprise Institute v. NHTSA, 901 F.2d 107, 121 (D.C. Cir. 1990) (citing Public Citizen v. NHTSA, 848 F.2d 256, 265 (D.C. Cir. 1988)). See also Center for Auto Safety v. NHTSA, 793 F.2d 1322, 1340 (D.C. Cir. 1986) (same); Competitive Enterprise Institute v. NHTSA, 901 F.2d 107, 121 (D.C. Cir. 1990) (Wald, J.) (same). Thus, EPCA does not require NHTSA to establish fuel-economy standards at any particular level, but instead confers on NHTSA broad discretion to balance these factors when setting an appropriate standard. However, in response to comments, NHTSA is presenting the CAFE stringencies and the resulting environmental impacts that would result from using the higher AEO forecast, which increases the value of fuel-saving technology. Thus, higher fuel prices produce model results that imply an increased emphasis on the need for the nation to conserve energy. In this way, NHTSA has acknowledged the commenters' concerns and addressed the scenario of increased need for the nation to conserve energy. For a more detailed discussion of NHTSA's balancing of EPCA's four factors, including the need to conserve energy, along with the environmental issues and relevant societal issues, such as safety, see Section 2.2 of this FEIS.*

10.2.3.11 More Aggressive Alternative

Comments

Comment Number: 0533-1
Organization: Individual
Commenter: Robert Burchard

Even the President now recognizes the reality of anthropogenic global warming. This threat to the biosphere combined with increasing acidity of the earth's oceans caused by increasing atmospheric CO_2 necessitates the need for early implementation of rigorous fuel economy standards independent of "paying-for-itself considerations. America's auto industry needs to have its feet held to the fire and quickly. If Japanese manufacturers can do it, why can't "Detroit"?

Comment Number: 0534-1
Organization: Individual
Commenter: Peggy Gilges

Please do the right thing by our great nation and mother earth now– insist on MUCH higher– already implementable – standards that dramatically increase fuel efficiency of U.S. vehicles in the near term.

Comment Number: 0536-1
Organization: Ceribon
Commenter: Unkown

I believe that all efforts should be made to produce an American car and imported car with the highest mpg possible, I don't mean 25, I mean what the Prius is touting 45 mpg. It is also possible to include technologies which can increase this further.

Comment Number: 0539-1
Organization: Individual
Commenter: John Schieber

The need for an aggressive reduction in fuel usage is not only about an attempt to keep the cost down – it's about the need to drastically conserve what remains for future generations.

Comment Number: 0544-1
Organization: Individual
Commenter: Michael Kirchner

I support real world fuel economy standards, and whole heartily support increasing these standards toward the goal of 100 mpg.

Comment Number: 0545-1
Organization: Individual
Commenter: Mary Hamilton

The sensible way to go in this global climate crisis is to increase miles per gallon.

Comment Number: 0547-1
Organization: Individual
Commenter: Fred Marshall

We need to raise cafe standards not erode them. It is insane to drill in environmentally sensitive areas when we can directly reduce demand for oil by mandating that all passenger cars get at least 40 mpg by 2012. It is so clear, double the mpg and you double the fuel supply.

Comment Number: 0548-1
Organization: Individual
Commenter: Carl Henne

The CAFE requirement should be at least 50 mpg for all cars and light trucks by 2018 and an equal proportional improvement for all trucks and busses.

Comment Number: 0550-5
Organization: Individual
Commenter: Sarah Larsen

Although there is no magic antidote to get us to an 80% reduction in CO_2 emissions by 2050, one of the single biggest step we can take in this country to reduce our global warming emissions is to make our cars and trucks go further on a gallon of gasoline. The technology exists today to safely and cost-effectively make all passenger cars and light trucks reach a fleet wide fuel economy average of at least 35 miles per gallon by 2015. Taking this step will achieve the goals of the new fuel economy law and as is most pertinent to this hearing will greatly reduce the global warming emissions from the transportation sector.

Comment Number: 0555-1
Organization: National Counsel of Churches and Christ
Commenter: Elizabeth McGurk

On behalf of the religious organizations we represent, we urge you to increase the Corporate Fuel Economy (CAFE) standards of America's vehicles

Comment Number: 0557-12
Organization: The Natural Resources Defense Council
Commenter: Luke Tonachel, Brian Siu

If NHTSA had used reasonable assumptions for their analysis, the fuel economy levels in the proposed rule and all cost-dependent alternatives would be higher. For example, based on NHTSA's *own* sensitivity analysis presented in the Preliminary Regulatory Impact Assessment, the MY2015 fuel economy standards should be set at least at the level that would result in a combined fleet average of 35 mpg by MY2015 if the fuel savings are more properly valued.

The potential additional public and private benefits of raising the standards to 35 mpg by MY2015 are enormous. Consumer pocketbooks, the nation's energy security, and the environment would all stand to benefit tremendously from a 35 mpg standard. We estimate by 2020, the U.S. would conserve 3 billion barrels of oil, 1.5 times more, if the MY2015 standard was set at a level that resulted in a combined 35 mpg instead of 31.6 mpg. The 35 mpg level in MY2015 also avoids 510 million metric tons of global warming pollution (see Figure 5). [See original comment document for Figure 5.]

The emissions reduction estimates are conservative, however. Beyond 2015, the fuel economy standards could continue to increase to over 40 mpg in 2020, which would result in even greater pollution reductions.

Comment Number: 0557-15
Organization: The Natural Resources Defense Council
Commenter: Luke Tonachel

In the DEIS, NHTSA characterizes the differences in the environmental impacts between the proposed standard and the other evaluated alternatives as small and difficult to distinguish. The fuel economy level proposed by NHTSA in the CAFE rule, referred to as the "Optimized" alternative in the DEIS, reaches a fleetwide fuel economy level of 31.6 mpg in for model year (MY) 2015. Other alternatives reach higher levels; for example the Total Cost Equals Total Benefits (TC=TB) alternative reaches 37.5 mpg for MY 2015. The DEIS concludes that there is almost no difference between the proposed standard and the TC=TB alternative, noting that the two alternatives differ by only 0.2 percent in terms of global warming emissions reductions in 2100. Our analysis of similar alternatives shows that NHTSA's characterization is misleading. In reality, more aggressive alternatives to the proposed rule can have very significant environmental benefits over the proposal. For example, a standard that reaches 35 mpg with MY 2015 instead of MY 2020 could save more than a billion barrels of oil and cut greenhouse gas (GHG) emissions by more than 510 million metric tons of CO_2-equivalent (MMT CO_2e) by 2020. A 35 mpg standard for MY 2015 would also pave the way for future fuel economy increases beyond 2015; these increases would put the U.S. on a path to achieve at least 40 mpg by 2020 and provide further oil and GHG savings not envisioned by the current DEIS.

Comment Number: 0559-6
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

As a general observation, we note that NHTSA has taken a rather conservative approach towards setting fuel economy standards. The proposal emphasizes "available technologies" for achieving fuel economy improvements and reflects a rather strong preoccupation with the ability of individual auto manufacturers to meet more stringent standards, compared to what is proposed. Further, NHTSA's optimized standards are couched almost exclusively in economic terms; emphasizing a perceived need for "maximizing net societal benefits... where the estimated benefits to society exceed the estimated cost of the rule by the highest amount." NHTSA appears very reluctant to propose more ambitious standards if the effect would be to reduce the consumer payback by any amount.

Comment Number: 0572-52
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

These findings are merely the most recent in a growing body of literature that is refining the scientific understanding of the need to quickly and drastically reduce our greenhouse gas emissions to minimize the impacts of global climate change. This represents a significant advance in the scientific understanding of global climate change, which previously has included the assumption that global atmospheric concentrations of CO_2 must be contained below 450 to 550 parts per million (ppm) in order to avoid the worst impacts of climate change. NHTSA fails to refer to or consider this essential information in the proposed rule. The urgency of the climate crisis and the need to immediately and rapidly reduce greenhouse gas emissions in order to avoid catastrophic climate changes, clearly tops the list of reasons that our nation needs to conserve energy. NHTSA's complete failure to address this information violates the law.

Comment Number: 0575-1
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

Instead of doing the bare minimum to satisfy the law, NHTSA should put cars and trucks on a path to 42 mpg by 2020 and at least 50 mpg by 2030. This would cut global warming pollution from new cars and trucks in half by 2030 and would save about 50 billion barrels of oil through 2050.

A recent UCS report indicates that automakers can cost-effectively boost the fleet wide average fuel economy of cars and trucks to 42 mpg by 2020 and to more than 50 mpg by 2030, with a modest 25% penetration of hybrids by 2020. [Footnote: See original comment document] Yet the recent notice of proposed rulemaking just barely gets cars and trucks on the road to the 35 mpg minimum by 2020, and assumes that hybrids don't enter the market until 2014. [Footnote: See original comment document.] Let me just reiterate that – despite the fact that there are more than one million hybrids on the road today, in 2008, and that the Toyota Prius is the 9th best-selling car in America, the analysis NHTSA used assumes hybrids won't reach the market until 2014.

Comment Number: 0576-2
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA has obfuscated the relative benefits of the alternatives it considered by not putting the impacts in context.

NHTSA has unreasonably constrained its range of alternatives, omitting a number of reasonable options. For example, NHTSA considered but did not analyze in detail more aggressive or accelerated standards. Instead, the agency asserts that it requires standards be raised by 4.5 percent per year, a rate fast enough that extended to 2020 would exceed the 35 by 2020 mandate of Congress. The agency explains, "other alternatives that would establish higher CAFE standards would result in larger fuel savings and emission reductions than those resulting from the preferred alternative. However, they would also result in lower net benefits than the preferred alternative due to higher costs to society. As such, NHTSA is already considering accelerated fuel economy standards." [Footnote: See original comment document.]

Comment Number: 0588-1
Organization: New York State Department of Transportation
Commenter: Stanley Gee

The transportation sector currently contributes nearly a third of the national carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions, both byproducts of petroleum fuel combustion. There is a need to reduce these emissions to slow the rate of anthropogenic-induced climate change, which is having serious impacts on the global, and regional environment, Due to the global urgency associated with reducing the nation's reliance on imported petroleum and to reduce GHG emissions, the preferred alternative should increase the fuel economy standards beyond 35.7 mpg and 28.6 mpg for MY 2015 passenger cars and light trucks, respectively.

NYSDOT recommends that NHTSA establish a more aggressive standard and achievement timetable for the new CAFE standards. At a minimum, NHTSA should consider a hybrid alternative that is equivalent to the "Technology Exhaustion" alternative for light-duty trucks and "Total Costs Equal Total Benefits" alternative for passenger cars. NYSDOT believes that this approach would provide significantly greater GHG emissions reductions than the proposed preferred alternative, yet would consider the diminishing returns of technology exhaustion for passenger cars as indicated in Tables 3.2-2 and 3.2-3. It is important for environmental, energy and economic reasons to increase the national fuel economy from the proposed rate of increase to a much more rapid yet technologically achievable rate.

Comment Number: 0598-1
Organization: Sierra Club
Commenter: Caroline Keicher

NHTSA must set the right "optimized" standard and then recalibrate the other bounds. The 35 mpg target for 2020 is a floor, not a ceiling — the law directs that the standards should be the maximum that are technologically feasible.

Comment Number: 0598-3
Organization: Sierra Club
Commenter: Caroline Keicher

Because NHTSA' s proposed standards are based upon flawed assumptions, the range of options considered in the DEIS is incorrect. In the DEIS, NHTSA's basic approach to setting new fuel economy standards is to strictly adhere to hitting, but not exceeding, 35 mpg in 2020. At several points in the DEIS, NHTSA recognizes the two critical words "at least," which precede 35 mpg in the 2007 Energy Independence and Security Act. At other points, NHTSA says the standards must be set to merely hit 35 mpg in 2020. NHTSA should recognize that 35 mpg is the floor that Congress provided and set standards that are not improperly bound to meeting a minimum fleetwide average of 35 mpg in 2020. Because NHTSA's proposed standards are too low, the range of options NHTSA considers in the DEIS are also too low.

Comment Number: 0598-9
Organization: Sierra Club
Commenter: Caroline Keicher

If we implement the weak proposed standards that NHTSA has published, which put us on a path to 35 mpg by 2020, we will save around 1.4 million barrels of oil per day in 2020. This is equivalent to keeping almost 220 million metric tons of CO_2 out of the atmosphere. While this is significant, it isn't enough to get us to 423 MMT CO_2e. However, if NHTSA speeds up fuel economy standards to 35 mpg by 2015, using a more accurate price of gasoline and fully incorporating all of the current available technology advances, and puts us on a path to 42 mpg by 2020, we will save an additional 880,000 barrels of oil a day in 2020. This brings us to a grand total of 2.28 million barrels of oil saved every single day in 2020 – a number that will increase as the fleet turns over – and will keep at least 360 million metric tons of CO_2 out of the atmosphere. While still short of the target cuts from cars and light trucks, 35 mpg by 2015 gets us significantly closer to these goals.

To simplify this even further, to be on track for necessary carbon reductions, we need to reduce the emissions from cars and light trucks by 25%. NHTSA's proposed 35 mpg by 2020 standards only gets us halfway there. Not nearly enough in a global warming context.

Comment Number: 0599-4
Organization: Center for Biological Diversity
Commenter: Multiple Signatories

I call upon you to raise the proposed fuel—economy standards for model years 2011—2015 to at least 50 mpg, in order to challenge automakers to respond to the urgent need to conserve energy and reduce greenhouse pollution.

Comment Number: TRANS-06-4
Organization: Public Citizen
Commenter: Lena Pons

Other reasonable alternatives would include a situation wherein there was additional increases in fuel economy standards beyond the period of the Energy Independence and Security Act, which would require only that vehicles reach a standard of 35 miles per gallon for the combined fleet, cars and light trucks by 2020.

However, given the fact that there are significant market incentive and also environmental incentive to extend the standards beyond that level, then there is a likely, there's likely a reasonable alternative to consider what would happen if you had standards that extended beyond that level.

Comment Number: TRANS-07-2
Organization: Individual
Commenter: Eliza Berry

NHTSA is currently making a decision that will profoundly influence our emissions during the next 10 years and beyond. NHTSA should therefore contribute to the effort to peak emissions sooner rather than later. This means adopting the highest fuel economic standards economically and technologically possible.

In summary, I would like to ask NHTSA to reevaluate the conclusions drawn from their draft environmental impact statement, and encourage NHTSA to require a 35 mile per gallon fuel economy standard by 2015.

Comment Number: TRANS-08-1
Organization: Sierra Club
Commenter: Ann Mesnikoff

Raising fuel economy standards to at least 35 miles per gallon in 2015 is a key step to curing our oil addition and reducing global warming pollution.

Comment Number: TRANS-08-11
Organization: Sierra Club
Commenter: Ann Mesnikoff

The 35 mpg target in 2020 is a floor not a ceiling. The law directs that the standards be what is maximally feasible. How can the public have confidence in NHTSA, that NHTSA is setting the right standards when some of the key inputs in its analysis are flawed.

Second, can the public have confidence in the range of options considered in the DEIS. NHTSA strictly adheres to a 35 by 2020 standard. At several points NHTSA recognizes the two critical words which proceed 35 in the 2007 energy bill, the words at least.

Comment Number: TRANS-10-1
Organization: Individual
Commenter: Matt Dernoga

I find it perplexing that NHTSA would aspire to only a mere 35 miles per gallon by 2020, the bare minimum of what is required by the Energy Independence and Security Act.

Comment Number: TRANS-11-1
Organization: Individual
Commenter: Jazzlin Allen

NHTSA's current proposed standards for cars and light trucks put us on a path to increasing fuel economy to only the bare minimum, 35 miles per gallon by 2020 required by the Energy [Independence] and Security Act of 2007. NHTSA fails to take full advantage of available fuel saving technologies, and must reconsider the proposed standards and use its statutory authority to meet the urgent need of the United States to reduce carbon emissions, conserve oil, and meet the growing demand of American consumers for vehicles that go farther on a gallon of gas.

Comment Number: TRANS-12-1
Organization: Individual
Commenter: Sam Blodgett

I strongly believe that NHTSA must raise CAFE standards to 35 miles per gallon by the year 2015. Failure to do so would be a failure of the American people who are in desperate need of relief from rising gas prices.

Comment Number: TRANS-14-2
Organization: U.S. Public Interest Research Group
Commenter: Annie Chau

Set the 2011 to 2012 standards at a substantially higher level than previously proposed.

Comment Number: TRANS-15-3
Organization: Individual
Commenter: Marissa Knodel

Increasing CAFE standards to 35 miles per gallon by 2015, instead of waiting for 2020 as currently required save 300,000 gallons of oil per day by 2020, which is equivalent to keeping 280 million metric tons of carbon dioxide out of the atmosphere.

Comment Number: TRANS-19-7
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

The other list has been mentioned, but I just want to summarize and say your own analysis showed that if you use a more realistic gas price, or switch to an analysis based on total benefits, each of those would allow us to reach Congressionally mandated minimum five years earlier, so 35 miles per gallon by 2015, and would help us get a head start on solving our global warming problem.

Comment Number: TRANS-20-3
Organization: Sierra Club
Commenter: Caroline Keicher

In addition, the proportion of emissions saved is much less important than the total cumulative carbon savings. The front end reductions are more important and have more cumulative impact than later emission reductions.

Taking this into account, it seems even more obvious that NHTSA should set new fuel economy standards to reach 35 miles per gallon by 2015. Not only is this standard economically and technologically feasible when a more accurate gas price is used, but it gets our cars and light trucks traveling an average of 35 miles per gallon five years sooner, the cumulative carbon savings of which is anything but insignificant.

Comment Number: TRANS-21-3
Organization: Individual
Commenter: Christina Marie Yagjian

In order to ensure that we take the strongest measures available, NHTSA must do its part. They must begin now by evaluating fuel economy standards in the correct context and setting fuel economy standards at the maximum feasible level, at least 35 miles per gallon by 2015.

Comment Number: TRANS-21-5
Organization: Individual
Commenter: Christina Marie Yagjian

It has never been more important that we take the strongest measures available to us to curb global warming emissions, and to do our part to mitigate the effects of global climate change.

Comment Number: TRANS-23-1
Organization: Greater Washington Interfaith Power and Light
Commenter: Tara Morrow

As you set standards to meet the energy independence and security acts mandate to achieve a fleet wide fuel economy outreach of at least 35 miles per gallon by 2020, may you remember that 35 miles per gallon is a minimum, and future generations will applaud us for our boldness in implementing what is technologically feasible, or wonder how we lacked the creativity and will to respond to global warming and the challenges of energy security.

Comment Number: TRANS-24-1
Organization: Individual
Commenter: Heather Moyer

The technology exists today to safely and cost effectively make all passenger cars and light trucks reach a fleet wide fuel economy average of at least 35 miles per gallon by 2015. Taking this step will achieve the goals of the new fuel economy law, and is most pertinent to this hearing, will greatly reduce the global warming emissions from the transportation sector, which as you've heard others say, may currently make up 20 percent of our country's greenhouse gas emissions.

Comment Number: TRANS-25-3
Organization: Individual
Commenter: Emanuel Figueroa

I'm here to the matter of change because you, as NHTSA, have the power and responsibility to enforce fuel efficiency standards of at least 35 miles per gallon. And this is the biggest single step that you can do to create a better world, and this will save a lot of gasoline, and this will save us a lot of money.

Comment Number: TRANS-26-1
Organization: United Church of Christ
Commenter: Mari E. Castellanos

35 miles per gallon by 2015, an 80 percent reduction of greenhouse emissions by 2050, is the minimum that we must achieve, a commitment to their future.

Comment Number: TRANS-32-8
Organization: Environmental Defense Fund
Commenter: James Keck

NHTSA has not provided sufficient transparency to explain why it has departed from more stringent alternatives to better meet the energy conservation goal of EPCA.

Comment Number: TRANS-34-1
Organization: Individual
Commenter: Fred Teal, Jr.

I am here today because I'm very concerned about NHTSA's reluctance to upgrade corporate average fuel economy standards above minimum required levels.

Comment Number: TRANS-37-5
Organization: Individual
Commenter: Jaafar Rizvi

I urge you to increase the standards to 35 miles per gallon by 2015. And I would urge you to consider that this won't cause undue stress on American car manufacturers. In fact, I have tremendous faith in the ingenuity and the ability of the American people, specifically those in Detroit, not only to successfully meet the high standard, but to prosper and thrive and become leaders.

Comment Number: TRANS-39-7
Organization: American Jewish Committee
Commenter: Ami Greener

We cannot overestimate the importance of moving towards tougher fuel economy standards this time. Even if we – we shouldn't underestimate the challenges this and other actions addressing energy security will entail. But we see no alternative if we are to put the United States in a more sustainable energy path, essential to both our nation's security and environmental health.

Comment Number: TRANS-40-1
Organization: Individual
Commenter: Robert Dawes

I hope that NHTSA understands the dire necessity of putting existing fuel saving technology to work by increasing achievable standards for vehicles produced in future years. By doing this alone, these standards would save $54 billion dollars of gasoline over the five years addressed in rulemaking.

Furthermore, by setting standards to 35 miles per gallon in 2015, an additional $22 billion dollars in gasoline would be saved. This translates to 280 million metric tons of CO_2 out of the atmosphere.

Comment Number: TRANS-42-3
Organization: National Counsel of Churches and Christ
Commenter: Elizabeth McGurk

I urge you to strengthen the current proposed standards by setting a new standard of at least 35 miles per gallon by 2015.

Comment Number: TRANS-42-4
Organization: National Counsel of Churches and Christ
Commenter: Elizabeth McGurk

Achieving higher fuel economy standards for U.S. cars and trucks is one of the most important actions we can take to reduce our greenhouse gas emissions which are causing global warming and impacting both God's people and God's planet.

Comment Number: TRANS-44-4
Organization: Individual
Commenter: Emily Spear

The transportation sector has the ability to add their contribution by increasing fuel economy standards, if we know that currently America has the capacity to increase standards to 35 miles per gallon by 2015, what's stopping us?

Response

NHTSA received comments on the DEIS and the NPRM urging more "aggressive" fuel-economy standards. One commenter requested that NHTSA describe how more aggressive alternatives would contribute to reducing global warming. For a discussion of the environmental impacts associated with all of NHTSA's alternatives, including its most aggressive alternatives, <u>see</u> Sections 3.2.3, 3.3.2, 3.4.4, 4.2.2, 4.3.2, and 4.4.4 of this FEIS.

Most commenters emphasized that EISA's goal of at least 35 mpg by 2020 is a floor, or a minimum CAFE requirement by 2020, and argued that 35 mpg in the combined fleet can be reached as the maximum feasible fuel-economy level by 2015. NHTSA has considered the increasing need of the United States to become more energy independent, consistent with EPCA's overarching goal of energy conservation, and the threat of global climate change. NHTSA recognizes that this rulemaking is in a unique position to address both of these concerns. NHTSA takes this opportunity and responsibility very seriously. However, Congress has stated that when setting maximum feasible CAFE standards, NHTSA must consider and balance the four EPCA statutory factors. NHTSA notes that electing to impose more aggressive standards would impose substantial additional costs on the industry at a time when the industry and economy are both facing difficult conditions or induce more manufacturers to pay penalties rather than achieve higher levels of fuel economy. Overly aggressive standards would not achieve the result intended by EPCA, i.e., meeting EPCA's overarching goal of energy conservation while ensuring economic practicability and technological feasibility.

10.3 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

10.3.1 Introduction

Comments

Comment Number: 0595-11
Organization: Environmental Protection Agency
Commenter: Susan Bromm

In several places throughout the DEIS, the text implies that in addition to evaluating several alternatives for model year 2011-2015 CAFE standards, the DEIS also includes analysis of future model year 2016-2020 CAFE standards (for example, in the third paragraph of the June 24, 2008 DEIS cover letter from Deputy Administrator James F. Ports, Jr., and in the titles to Table 2.5-8 and 2.5-9, and the titles to Figures 2.5-3, and 2.5-4). The Environmental Protection Agency (EPA) was unable to determine from reading the DEIS if, in fact, new standards were analyzed for model years 2016-2020. NHTSA should clarify this issue in the final EIS, and to the extent potential CAFE standards were modeled for 2016-2020, such standard scenarios should be described in detail in the final EIS.

Response

NHTSA notes the need for clarification. Because EISA directs NHTSA to increase CAFE standards to reach a combined fleet average CAFE level of at least 35 mpg by model year 2020, MY 2016-2020 CAFE standards are reasonably foreseeable and must be accounted for when analyzing the cumulative impacts of the proposed action. For each alternative, NHTSA assumed that passenger-car and light-truck CAFE standards would continue to increase over model year 2016-2020 at their average annual rate of increase over MY 2011-2015. This assumption results in passenger-car and light-truck CAFE standards under each action alternative that meet or exceed the EISA requirement of a combined fleet average of 35 mpg by model year 2020. NHTSA assumed further that the fuel economy standards for model year 2020 would remain in effect through the end of the analysis period. Because the CAFE standards apply to new vehicles, this assumption results in emissions reductions and fuel savings that continue to grow as new vehicles meeting the CAFE standards for MY 2020 and beyond are added to the fleet in each subsequent year, reaching their maximum values when all passenger cars and light trucks in the U.S. fleet meet these standards. NHTSA included this effect in the analysis. NHTSA has expanded our explanation of these assumptions in the beginning of the FEIS cumulative impacts discussions. See FEIS Sections 4.3.2.1, 4.4 (introduction), 4.4.4.1, and 4.4.4.2.

10.3.1.1 Approach to Scientific Uncertainty and Incomplete Information

Comments

Comment Number: 0572-25
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The statement of "uncertainty" is overused and abused throughout the DEIS. To avoid further analysis and consideration of environmental impact, the DEIS frequently presents background on climate change, but qualifies the information as "uncertain." In most instances this is uncalled for. The argument could be made that every piece of information in any EIS is uncertain, yet an agency is expected to make a good faith effort to consider impacts that are reasonably certain. While the IPCC may label the intensity of some effects as "likely" as opposed to "very likely," the effects are still just as certain as effects such as smog due to criteria pollutant emissions. For instance, the IPCC states that "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." (Alley et al. 2007) By overusing the uncertainty qualification, the DEIS fails to consider important impacts of climate change and obfuscates the issue so that the decisionmakers and public will not be able to adequately evaluate the balance of harms that may occur as a result of different alternatives.

Comment Number: 0572-3
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Recent court decisions have shaped the context in which the NEPA analysis must be conducted with regard to global warming. The United States Supreme Court held in *Massachusetts v. EPA* that carbon dioxide and other greenhouse gases are "unquestionably 'agents' of air pollution" and unambiguously fall within the Clean Air Act's definition of an air pollutant. 127. S.Ct. 1438, 1460 n. 26(2007). Furthermore, the Court held that the EPA could not avoid its statutory obligation to regulate greenhouse gases merely due to "some residual uncertainty" about the "various features of climate change." 127. S.Ct. 1438, 1463 n. 26 (2007). This holding underscores that priority must be given to addressing climate change despite the lack of some details. The excessive use of "uncertainty" in the DEIS violates this mandate to act on what is already known.

Response

NHTSA appropriately refers to the "Incomplete or Unavailable Information" provision in the CEQ regulations (40 CFR § 1502.22) in its climate modeling discussion. NEPA requires federal agencies to assess the environmental impacts of proposed federal actions. See 42 U.S.C. § 4332(C). CEQ regulations provide a process for evaluating reasonably foreseeable significant adverse impacts when the necessary information is incomplete or unavailable. Under conditions of uncertainty, 40 CFR § 1502.22 requires evaluation of "existing credible scientific evidence" relevant to assessing significant adverse impacts, including catastrophic consequences that have a low probability of occurrence. See 40 CFR § 1502.22(b)(3)-(4). If the agency cannot obtain adequate information to evaluate the impacts, the EIS must explain the relevance of this information to evaluating reasonably foreseeable significant adverse impacts, and evaluate the impacts based on theoretical approaches or research methods generally accepted in the scientific community. See Mid States Coalition for Progress v. Surface Transportation Board, 345 F.3d 520, 549-50 (8th Cir. 2003) (quoting 40 CFR § 1502.22(b)). Where an agency reasonably determines that a risk is too remote or unquantifiable, a qualitative discussion of that risk and potential accompanying environmental impacts is appropriate. See 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures … which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ, Considering Cumulative Effects Under the National Environmental Policy Act (1984), available at http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

NHTSA's determination that distinctions between the alternatives in various areas of the impacts discussion cannot be quantifiably evaluated is also appropriate because the means to obtain the relevant information to accurately quantify these effects are not known. For example, climate modeling is not yet sensitive enough to model temperature, sea-level, or precipitation changes on regional levels or to such a precise order of magnitude as to allow the analysis to distinguish among the alternatives. CBD appears to be saying that NHTSA is labeling as uncertain changes or impacts that are clearly certain (i.e., *"increases in global average air and ocean temperatures"). NHTSA agrees that these are reasonably foreseeable future impacts. What are uncertain are their timing, degree, and ramifications within regional and global ecosystems. This uncertainty results because the current state of science does not provide a means to obtain this information to accurately quantify these aspects of the impacts. Accordingly, these foreseeable impacts of NHTSA's CAFE rulemaking fall within the meaning of "Incomplete or Unavailable Information," and NHTSA has included the appropriate qualitative analysis required by Section 1502.22 of the CEQ regulations. See Mayo Foundation v. Surface Transportation Board, 472 F.3d 545, 555-56 (8th Cir. 2006) (upholding the Surface Transportation Board's use of 40 CFR. § 1502.22(b) procedures after admitting that their model could not be used to model impacts at a local level, and the Board extensively discussed the potential impacts on air quality that could result from the implementation of the project in the EIS); Lee v. U.S. Air Force, 354 F.3d 1229, 1241-45 (10th Cir. 2004) (upholding EIS as adequately addressing, under NEPA, noise effects of increased overflights, impacts of increased low-level overflights on livestock, and environmental and economic impacts of aircraft accidents, against claims that the Air Force used flawed methodology to analyze noise impacts, used outdated studies to assess livestock impacts, and failed to consider the impact of aerial refueling or the potential secondary effects of aircraft accidents; deferring to Air Force's methodology where it was explained thoroughly in the EIS); Mid States Coalition for Progress v. Surface Transportation Board, 345 F.3d 520 (8th Cir. 2003) (holding that degradation of air quality was a "reasonably foreseeable" indirect effect of proposed rail lines, even if its extent was not; encouraging use of Section 1502.22 for evaluating reasonably foreseeable impacts of CO_2 emissions when necessary information is incomplete or unavailable – the EIS must explain the relevance of this information to evaluating reasonably foreseeable significant adverse impacts, and evaluate the impacts based on theoretical approaches or research methods generally accepted in the scientific community); Sierra Club v. Marita, 46 F.3d 606, 621 (7th Cir. 1995) (upholding U.S. Forest Service's EIS, including its refusal to apply conservation biology science suggested by petitioner, after considering the implications and "determin[ing] that science to be uncertain in application," holding that an agency is entitled to use its own methodology, unless it is irrational); Salmon River Concerned Citizens v. Robertson, 32 F.3d 1346, 1359 (9th Cir. 1994) (upholding U.S. Forest Service's EIS under NEPA, finding agency's accounting of "chemically sensitive persons by including a safety factor" resulted in a reasoned analysis and adequate disclosure of the evidence before it, where agency experts found that the scientific community cannot determine what causes a reaction in a chemically sensitive person, or define discreetly that reaction); cf San Luis Obispo Mothers for Peace v. Nuclear Regulatory Commission, 449 F.3d 1016 (9th Cir. 2006) (holding that the Nuclear Regulatory Commission's categorical refusal under NEPA to consider environmental effects of terrorist attack on proposed interim spent fuel storage installation, or the nuclear facility in general, was not reasonable).*

10.3.1.2 Modeling After 2020

Comments

Comment Number: 0550-4
Organization: Individual
Commenter: Sarah Larsen

NHTSA takes a presumed 35-mpg fleet in 2020, assumes that fuel economy stops increasing, and then measures the cumulative CO_2 savings through the year 2100. I believe NHTSA should only be measuring reductions at the 35-mpg fleet level for the life of these vehicles. Fuel economy should not be presumed to stop at 2020 levels. If NHTSA wants to evaluate carbon savings through the year 2100, then they should do so by assuming fuel economy standards continue to increase to the year 2100 at the same rate of increase as between 2011-2015. Furthermore, considering that relevant science is talking about reductions needed by 2050, it again seems out of context for NHTSA to have randomly picked the year

2100 as timeline for measuring success of today's carbon reductions from vehicles. I believe success and progress should be measured by how close these fuel economy improvements get us to reducing the transportation sector's carbon emissions by 80% in time for the 2050 deadline. To do otherwise fails to realistically evaluate vehicle emission reductions as a key part of the strategy to curb global climate change.

Comment Number: 0559-2
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

The DEIS, inconsistent with the regulations and policy guidance on cumulative effects, evaluates the effects of new CAFE standards without consideration of other important factors. For example, while NHTSA asserts the DEIS fully addresses foreseeable impacts through the year 2100, it errs by incorporating an assumption that technological improvements in fuel economy cease after model year 2020. [Footnote: NHTSA's apparent rationale is that the Energy Information and Security Act (EISA) mandates a fuel economy target that extends only through model year 2020.] In reality and in contrast with this approach, technology-forcing requirements historically have spurred technological innovation to meet and even exceed environmental benchmarks. This interrelationship between policy initiatives and technology advancement has been well documented by numerous researchers [Footnote: See original comment document.] for more than thirty years and has even been given a name: *induced technological change*. There is little question that policies and legislative initiatives aimed at reducing carbon emissions are in our future, and these programs will create economic disincentives to continued business as usual, relative to consumption of fossil fuels in the transportation sector. Consequently and according to the principles of induced technological change, business and government will respond by engaging in more extensive research and development, including in the fuel economy arena, with a goal of reducing reliance on conventional fuels. As these research and development efforts bear fruit, technological progress will follow.

Given this principle of induced technological change, coupled with the underlying legislative requirement (i.e., the Energy Policy and Conservation Act – EPCA) for NHTSA to take a technology-forcing approach to future fuel economy requirements, further improvements beyond model year 2020 are, in fact, *reasonably foreseeable*. Thus, the approach taken in the DEIS disregards both precedent and the law. It is also important to note that economics by itself will play a future role, inducing technological change to improve fuel economy. The U.S. Energy Information Administration in its *2008 Annual Energy Outlook* projects in its "high economic growth–high fuel price" scenario that between 2008 and 2030, energy use in the light duty vehicle sector will grow by 13 percent while at the same time, the price of gasoline will grow by 18 percent. As this scenario unfolds, there will be further incentives for investment into research and development for improving fuel economy. Therefore, NHTSA would do well to incorporate such economic factors into its cumulative effects analysis.

Comment Number: 0559-4
Organization: The Northeast States for Coordinated Air Use Management (NESCAUM)
Commenter: Arthur Marin

The DEIS, in its assessment of global benefits, also disregards the principle of technology transfer. If U.S. industries develop technology that markedly improves fuel economy, it's very unlikely that the technology will remain confined to the U.S. fleet. Ultimately, fleets worldwide will incorporate the same technologies. According to the World Resources Institute, energy consumption accounts for 61 percent of total GHG emissions and transport accounts for 22 percent of all energy consumption-related GHG emissions. U.S. transportation, according to the Energy Information Administration, accounts for 18 percent of global GHG emissions from petroleum consumption. Clearly, an aggressive program in the

U.S. to markedly improve fuel economy, coupled with technology transfer, can be a key strategy for reducing GHG emissions globally.

Comment Number: 0572-29
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

One of the ways NHTSA minimizes the apparent impact of its rulemaking is to limit its analysis to a world in which fuel economy levels become fixed beyond the last year of the current rulemaking. To limit the analysis to this assumption is inconsistent with the statutory scheme, which of course requires that (1) fuel standards for the combined fleet reach *a minimum* of 35 mpg by 2020 and (2) the NHTSA set fuel standards must be set at the "maximum feasible level" each year. 49 U.S.C. §32902(a); (b)(2)(C). This regulatory regime requires NHTSA to continue to raise standards each and every year through 2100. While the NHTSA may have been free to calculate and discuss the resulting environmental impact that would result from fixing the standard beyond the current rulemaking, disclosing only this piece of information was clearly not sufficient, especially given the statutory scheme that requires the NHTSA to continue increasing fuel economy to the maximum feasible level each year.

While the DEIS states that the standards for 2011-2015 will impact the 2016-2020 standards, the DEIS improperly limits its analysis to the environmental impacts from the emissions of just those vehicles in MY 2011-2015. Limiting the analysis in this manner allowed NHTSA to minimize the apparent impact of its action, because despite the fact that the lifetime emissions of these five model years of U.S. vehicles will be massive, even this large chunk of emissions can be made to incorrectly appear insignificant if it is compared to a large enough number. In order to give a complete picture of this aspect of the problem, NHTSA should have compared its alternatives for model years 2011-2015 not just to the emissions that would result if fuel economy standards thereafter remained fixed, but also to the emissions that would result if fuel economy standards continued to improve along the trajectories established by each of a reasonable range of alternatives. Had NHTSA done so, the impact of its action would have appeared in a very different light. This is particularly true since technology innovation today will both amplify the gains that can be made in the auto industry in the future, and will also have spillover effects into other sectors of the economy. The NHTSA was required to address these issues in the DEIS, but failed utterly to do so.

Because of the application of technologies developed in response to a valid, technology-forcing CAFE standard to other sectors of the economy and in other countries, there should be a non-linear increase in projected reductions with increased stringency of fuel standards. The DEIS should have included an analysis of continual increases in fuel economy through year 2100. EPCA requires that *each year* the maximal fuel economy standard be established. It is certain that technology will continue to improve and thus that the maximum feasible fuel standards will continue to increase through 2100. As shown in the figure below [See original comment document for figure.], one way to estimate the emissions savings due to a continual increase in fuel economy would be to iteratively sum the projected reduction in CO_2 from the MY 2011-2015 standards (obtained from the difference between the "no action" and "technology exhaustion" alternative emissions in Table 3.4-2 of the DEIS) out to year 2100.

Employing this strategy results in a substantially greater effect than the artificial assumption in the DEIS that fuel economy will not improve after MY 2015. The cumulative carbon savings would be 39 Gigatons of carbon by year 2100, and a 15 ppm difference between "no action" and "technology exhaustion" in CO_2 concentration in 2100.

Comment Number: 0576-3
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA does not consider impacts of extending fuel economy standards beyond the mandated 35 mpg by 2020, although there is clear need and a Congressional mandate to continue to improve efficiency to make the reductions that are needed, which serves to minimize the value of action when NHTSA extrapolates the benefits to 2100. However, EISA requires that NHTSA set fuel economy standards that are the maximum feasible for each model year from 2021-2030. Standards that exceed the 2020 level should be considered to increase at least until 2030, when the statutory mandate ends. It is also reasonably foreseeable that fuel economy standards or some combination of policies will be employed to continue to reduce oil consumption beyond 2020. [Footnote: See original comment document.]

Comment Number: 0585-5
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

NHTSA's cumulative impacts analysis fails to comply with this mandate and is flawed in several respects. On the one hand, in projecting the impact of the CAFE rule through 2100, NHTSA considers only the CAFE rules for 2011-2015 and 2016-2020, and assumes that miles per gallon will remain the same from 2020 through 2100. DEIS at 4-19, 4-27. On the other hand, it appears that NHTSA assumes that VMT will continue to increase through 2100. DEIS at 3-57. The combination of these assumptions understates NHTSA's ability to contribute cumulatively to GHG reduction efforts through more stringent CAFE standards. In the same way that it can be anticipated that VMT will continue to increase after 2020, it can also be anticipated that future CAFE rulemakings after 2020 will continue to increase the miles per gallon required for cars and light trucks, and that improved technology will enable car manufacturers to meet those increases. Thus, NHTSA must recalculate its cumulative projections to take into account the impact of future CAFE rulemakings after 2020 on the anticipated emissions through 2100.

Comment Number: 0596-2
Organization: Environmental Defense Fund
Commenter: Martha Roberts

The EIS fails to account for additional global ramifications of U.S. fuel efficiency standard setting; namely the influence of U.S. CAFE regulations on the global automobile market. Vehicle manufacturers tend to produce cars that comply with one of three dominant regulatory programs, the U.S., the European Union, or Japan, regardless of whether the vehicle is to be sold in that region. Thus U.S. CAFE standards impact the fuel efficiency of vehicles driven in other countries, and subsequently their greenhouse gas emissions. Although we do not have precise figures relating to the influence of the U.S. fuel economy standards on the global automobile market, figures for an analogous impact, that of U.S. vehicle emissions standards, are available. In addition to the approximately 17 million cars and light trucks sold in the U.S. in 2005, another 5.2 million vehicles were sold that year in other countries that met U.S. emissions regulatory standards. [Footnote: See original comment document.] The number of cars sold globally that follow U.S. fuel economy standards could be greater or less than those following emissions standards. The cumulative impacts assessment in this EIS must account for the additional non-U.S. vehicles that follow U.S. CAFE standards and the resulting cumulative effect that more stringent standards will exert on global greenhouse gas (GHG) emissions.

Comment Number: 0598-4
Organization: Sierra Club
Commenter: Caroline Keicher

NHTSA notes that only the 2016-2020 standards are foreseeable in the DEIS and therefore does not consider increases to the standards after 2020. The law clearly provides for maximum feasible standards in the years that follow. Increases beyond 2020 are foreseeable, perhaps just as foreseeable as the vehicle miles traveled (VMT) increases NHTSA presumes through 2100.

Comment Number: TRANS-08-12
Organization: Sierra Club
Commenter: Ann Mesnikoff

NHTSA says the standards must be set to 35 by 2020. NHTSA notes that the 2016 to 2020 standards are foreseeable in the draft environmental impact statement, but the law provides them for the maximum feasible thereafter. Increases beyond 2020 are foreseeable, perhaps just as foreseeable as the VMT increases NHTSA presumes through 2100.

Comment Number: TRANS-21-2
Organization: Individual
Commenter: Christina Marie Yagjian

An issue I would like to highlight is in this draft environmental impact statement is that NHTSA has arbitrarily picked 2100 as a time line for measuring the success of today's carbon reductions. A nearer term goal would help to ensure that the transportation sector does its part to achieve the goal set by the scientific community of 80 percent reductions by 2050.

In the EIS NHTSA presumes that fuel economy standards stop increasing after 35 miles per gallon in 2020. In order to properly evaluate carbon savings through 2100, NHTSA should extrapolate a curve of increasing fuel economy standards that continues to increase to 2100 at the same rate of increase as between 2011 and 2015.

Comment Number: TRANS-36-5
Organization: Individual
Commenter: Matt Kirby

And [NHTSA is] setting the 35 miles per gallon by 2020, but actually to extrapolate this through 2100, to not say that 35 miles per gallon is the be all, end all fuel efficient standard, because it shouldn't be.

Comment Number: TRANS-39-8
Organization: American Jewish Committee
Commenter: Ami Greener

NHTSA should not conclude in its analyses that fuel economy gains are presumed to stop at 2020 levels, but further grow by means of using existing technologies. We see the use of alternative and renewable fuels, new lightweight materials, and electric vehicles taking up a bigger percentage of miles driven in the U.S. in the near future.

Response

Because EISA directs NHTSA to increase CAFE standards to reach a combined fleet average CAFE level of at least 35 mpg by model year 2020, MY 2016-2020 CAFE standards are reasonably foreseeable and must be accounted for when analyzing the cumulative impacts of the proposed action. For each alternative, NHTSA assumed that passenger-car and light-truck CAFE standards would continue to increase over model year 2016-2020 at their average annual rate of increase over MY 2011-2015. This assumption results in passenger-car and light-truck CAFE standards under each action alternative that meet or exceed the EISA requirement of a combined fleet average of at least 35 mpg by model year 2020. NHTSA assumed further that the fuel economy standards for model year 2020 would remain in effect through the end of the analysis period. Because the CAFE standards apply to new vehicles, this assumption results in emissions reductions and fuel savings that continue to grow as new vehicles meeting the CAFE standards MY 2020 and beyond are added to the fleet in each subsequent year, reaching their maximum values when all passenger cars and light trucks in the U.S. fleet meet these standards. NHTSA included this effect in the analysis.

While NHTSA recognizes the possibility that technological advancement could continue absent future regulation, little empirical evidence supports this argument. In fact, from 1985 to 2005, when Congress prohibited NHTSA from promulgating new CAFE standards, in-use fuel economy decreased, despite gains in automobile fuel economy. See John German, Light Duty Vehicle Technologies: Opportunities and Challenges, available at http://www.its.ucdavis.edu/events/outreachevents/ asilomar2007/presentations%20list.php. Although vehicle engines became more efficient, manufacturers used this improved technology to make the vehicles more powerful and for other passenger amenities, rather than for additional gains in fuel economy.

Although it might be true that higher fuel prices will promote greater technical innovation and greater fuel savings, whether the current trend in higher fuel prices will persist remains to be seen. Most forecasts, including the EIA's, indicate only moderately high fuel prices in the future, which might not be sufficient to promote greater fuel efficiency without regulation. Recent literature suggests that a large increase in the real price of gasoline is necessary to substantially influence vehicle purchase decisions over the long term. See Small and Van Dender (2005).

Regarding increases in CAFE standards beyond 2020 as reasonably foreseeable, as previously explained, when setting "maximum feasible" average fuel economy levels under EPCA, NHTSA is required to consider economic practicability, technological feasibility, the effect of other motor vehicle standards of the government on fuel economy, and the need of the United States to conserve energy. See 49 U.S.C. § 32902(f). In the 1980s, NHTSA found it necessary to roll back fuel economy standards to lower levels because manufacturers could not meet them. Maximum feasible standards must be economically practicable under EPCA. The requirement to set economically practicable standards is especially important in times of economic uncertainty.

One commenter suggested that if VMT increases are reasonably foreseeable, then fuel economy increases also should be. According to the Federal Highway Administration, which tracks and reports VMT in its "Highway Statistics," the long-term trend of increasing VMT began in the 1950s when the Eisenhower Interstate System was established. Since then, VMT has shown a decline in only a few years. The trend is very clear. Fuel economy, on the other hand, exhibits no such long-term trend, and thus, is much more difficult to forecast.

Due to these complex and sometimes conflicting concerns, NHTSA had to ask: At what point would improving fuel economy no longer be technologically feasible, or should NHTSA assume that no *technological limits would be discovered? NHTSA selected the middle ground – maintaining fuel economy standards that would be constant at the 2020 level.*

Other commenters questioned the extension of the analysis through 2100 and expressed concern that extrapolating the impacts that far out minimized the impact of the proposed action. In this FEIS, NHTSA reports substantial reductions in GHGs under the action alternatives; demonstrates that such reductions compare favorably to other emissions-reduction initiatives; and has added a new analysis showing the effect of the alternatives on U.S. passenger vehicle emissions. See Section 3.4.4. NHTSA understands that the small climate effects exhibited for temperature, precipitation, and sea-level rise are functions of the magnitude of a problem that is global in nature. While NHTSA shows these impacts through 2100, we also present analyses for various periods between the present and 2100. While NHTSA might have chosen a shorter final time frame than 2100, we note that shortening the time frame would only serve to demonstrate even smaller climate effects.

Several commenters stated that NHTSA should compare these anticipated emissions reductions with a target reduction of 60 to 80 percent by 2050. See our response to these comments in Section 10.2.1.

10.3.2 Air Quality

Comment

Comment Number: 0595-12
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Chapter 1, pg. 1-6, Lines 26-29:

In order to address the limitations of the air quality modeling in the EIS, EPA recommends that these lines be revised as follows:

"EPA indicated that many of the factors that affect air quality, such as meteorology and atmospheric processes, will not be taken into account when evaluating human health and environmental impacts without a full-scale photochemical air quality modeling analysis. This limitation needs to be acknowledged. NHTSA agrees with EPA's suggestion, and this limitation is acknowledged in Chapters 3 and 4."

There is also no mention of this limitation in Chapter 4. Please repeat the limitation text in that chapter.

Response

NHTSA has revised Section 1.3.2.1 and Section 4.3.2.1 in response to this comment.

10.3.2.1 Affected Environment

Comment

Comment Number: 0588-11
Organization: New York State Department of Transportation
Commenter: Stanley Gee

NHTSA confuses the discussion of emissions impacts (particularly Figure 3.3-1) by including the effects of increased vehicle emission regulation stringency. NHTSA should revise its presentation to ensure that the effects of proposed CAFE standards are clearly differentiated from the effects of vehicle emissions standards and general VMT growth.

Response

NHTSA has revised the text of Section 3.3.1.4 to clarify the differences among effects of the CAFE standards, vehicle emissions standards, and VMT growth.

Comment

Comment Number: 0595-15
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Chapter 3, pg. 3-13, lines 36-40 and pg. 3-14, lines 1-3:

In order to accurately characterize ozone-related health impacts, EPA recommends adding the following sentence to the end of the ozone health effects description:

"There is also highly suggestive evidence that short-term ozone exposure directly or indirectly contributes to non-accidental and cardiopulmonary-related mortality."

Response

NTHSA has added this text to Section 3.3.1.2.

Comment

Comment Number: 0595-9
Organization: Environmental Protection Agency
Commenter: Susan Bromm

In several locations in Section 3.3.1, the description of hazardous air pollutants emitted by mobile sources (mobile source air toxics, or "MSATs") analyzed in the DEIS is mischaracterized and incorrectly cited. EPA recommends the following revisions and clarifications:

Page 3-1 1: As Section 112(b) of the Clean Air Act is not relevant to mobile sources and the analysis in the DEIS does not include all of the hazardous air pollutants, EPA recommends the following edit:

"The air quality analysis assesses the impacts of the alternatives with respect to criteria pollutants and some hazardous air pollutants from mobile sources (also known as mobile source air toxics.) ~~Hazardous~~

~~Air Pollutants (HAPs, also known as toxic air pollutants or air toxics) as defined under Section 112(b) of the CAA.”~~ [Strikethrough provided by commenter.]

Page 3-13: As EPA has not identified a specific list of priority MSATs, including in the MSAT final rule, we recommend the following edit to the fourth paragraph:

“~~The relevant air toxics for this analysis are referred to by EPA and Federal Highway Administration (FHWA) as the priority Mobile Source Air Toxics (MSAT). The priority MSATs~~ [Strikethrough provided by commenter.] The MSATs included in this analysis are acetaldehyde, acrolein, benzene, 1,3-butadiene, diesel particulate matter (DPM), and formaldehyde (~~EPA, 2008~~). [Strikethrough provided by commenter.] DPM is a component of exhaust from diesel-fueled vehicles and falls almost entirely within the $PM_{2.5}$ particle size class.”

In addition, page 3-13 states that the description of the health effects of the six Federal criteria pollutants is adapted from EPA 2008b. This does not appear to be properly referenced. There is no EPA 2008b listed in the references, and neither of the EPA 2008 references appear to be relevant here.

Page 3-15: Similarly, as EPA has not identified a list of priority MSATs, we request deletion of the word “priority” to describe the MSATS referenced. Furthermore, we believe that Claggett and Houk, 2006 is an inappropriate source for the information presented. A summary of health effects should be referenced to a more primary source (such as EPA’s Integrated Risk Information System), or EPA’s own synthesis of health effects (such as the 2007 MSAT rule preamble and/or RIA[Regulatory Impact Analysis]).

Page 3-16 cites EPA, 2008 as the reference for EPA’s MSAT rule. This is an incorrect reference. The MSAT rule was published in 2007, and the full details of that reference are in footnote 16. [See original comment document for footnote.]

Response

NTSHA has revised and clarified the text in Section 3.3.1 and has revised the references in response to this comment.

10.3.2.2 Methodology

Comment

Comment Number: 0572-39
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Black carbon is also detrimental to human health. It has been linked to a variety of circulatory diseases. One study found an increased mortality rate was correlated with exposure to black carbon (Maynard 2007). The same is true for heart attacks (Tonne 2007). Another study found that residential black carbon exposure was associated with increased rates of infant mortality due to pneumonia, increased chronic bronchitis, and increased blood pressure (Schwartz 2007).

In developed countries, diesel burning is the main source of black carbon. Diesel emissions include a number of compounds such as sulfur oxides, nitrogen oxides, hydrocarbons, carbon monoxide, and particulate matter. Diesel particulate matter is approximately 75% elemental carbon. (EPA Diesel Health Assessment 2002.) Furthermore, global inventories of emissions rates from a variety of sources exist to facilitate quantitative estimates. (See, e.g., Bond et al. 2004.) Thus, it is crucial that black carbon be addressed in the DEIS.

Analyzing particulate matter is insufficient to address black carbon.

Particulate matter (PM) refers to the particles that make up atmospheric aerosols. The primary constituents of PM are sulfates, nitrates, and carbon compounds. Sulfates and nitrates form in the atmosphere from the chemical reaction of sulfur and nitrogen dioxides. These may often be present as ammonium sulfate or nitrate salts. Carbon compounds may be directly emitted, e.g., black carbon emitted from combustion, or may form in the atmosphere from other organic vapors, e.g., oxidation of volatile organic compounds.

Because PM can be reduced through mitigation of other constituents of PM than black carbon, it is essential that black carbon emission reduction strategies be considered independently from PM reductions. The proportions of the constituents of PM vary over time and by location (see EPA Particle Pollution Report 2004). According to a recent series of surveys conducted at various U.S. cities under the EPA's "Supersite" program, black carbon was often only about 10% of total measured $PM_{2.5}$. [Footnote: See original comment document.]

In contrast to total $PM_{2.5}$, diesel PM is composed largely of black carbon. Nonetheless, some diesel PM reduction strategies do not affect black carbon. For instance, diesel oxidation catalysts can reduce diesel PM emissions as a whole by approximately 20 to 40%, yet they do not decrease black carbon emissions (Walker 2004). In addition, while low-sulfur fuel will reduce sulfate emissions, in and of itself low-sulfur fuel will not reduce black carbon. Low-sulfur fuel is important because it *allows* for better technology to reduce black carbon. See, e.g., 69 Fed. Reg. 38957, 38995 (June 29, 2004). Yet those reductions can only occur once the technology has been implemented.

Response

EPA is charged under the Clean Air Act with protecting human health from air pollution. EPA has established National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) for the PM_{10} and $PM_{2.5}$ size classes. EPA has identified diesel particulate matter (DPM) as a Mobile Source Air Toxic (MSAT) of concern that should be considered in air quality analyses (EPA 2001). EPA has not established NAAQS for DPM. DPM is composed of an elemental carbon core and adsorbed organic compounds (organic carbon), sulfates, nitrate, metals, and other trace elements (EPA 2004c). EPA provides no special status for elemental carbon, also called carbon black or black carbon. Rather, EPA considers elemental carbon to be a component of $PM_{2.5}$, produced from both gasoline- and diesel-powered vehicles.

The FEIS addresses PM in terms of $PM_{2.5}$ emissions, which are calculated using emissions factors from the EPA MOBILE6.2 model, EPA's required procedure for deriving highway vehicle emissions factors for an EIS. MOBILE6.2 estimates primary $PM_{2.5}$ (i.e., $PM_{2.5}$ that is emitted directly) from three sources: the vehicle tailpipe (the largest source); brake and tire wear; and reentrainment of road dust into the atmosphere. MOBILE6.2 calculates $PM_{2.5}$ and PM_{10} by vehicle type, and NHTSA uses the portion of PM_{10} emitted by light-duty diesel vehicles (cars and trucks) in the FEIS to represent DPM. EPA concluded in the 2002 Health Assessment for Diesel Exhaust Emissions (EPA 2002a) that DPM is "no more likely to be toxicologically potent than any other fine particle constituents that typically make up ambient $PM_{2.5}$" and that based on this "the annual $PM_{2.5}$ standard would also be expected to provide a measure of protection for DPM" (EPA 2002a, p. 6-30).

The FEIS addresses PM_{10} using $PM_{2.5}$ as a surrogate because almost all PM_{10} from light-duty vehicles consists of $PM_{2.5}$. Thus, PM_{10} emissions are very close to the reported $PM_{2.5}$ emissions. The $PM_{2.5}$ emissions analysis and the relationships noted above between $PM_{2.5}$ and black carbon suggest, first, that black carbon emissions associated with the alternatives should be less than $PM_{2.5}$ emissions. Second, black carbon emissions should vary among the alternatives in the same pattern as $PM_{2.5}$.

The elemental carbon component of DPM is only one factor in the human toxicological response, and the human health effects of elemental carbon cannot be considered independent of their PM constituents in relation to PM generated by motor vehicles. The EPA Air Quality Criteria Document for Particulate Matter described research findings about the health effects of elemental carbon independent of particulate matter, and ongoing research further assesses the health effects (EPA 2004c).

In research comparing elemental carbon and DPM, the organic components of DPM have been linked to the generation of reactive oxidative species; elemental carbon alone and diesel particles without organics did not induce apoptosis (cell death) (Hiura et al., as cited in EPA 2002). In addition, DPM has been shown to impair pulmonary defense, while elemental carbon particles alone did not have the same effect (Mundandhara et al. 2006). Elemental carbon particles have been shown to induce an inflammatory response, but this response is similar to the one induced by DPM (EPA 2002a). Elemental carbon particles are also important in the observed carcinogenic response in rats, but DPM containing the elemental carbon particles produced a similar carcinogenic response (EPA 2002a).

In air quality studies, black carbon (elemental carbon) is typically used as a surrogate for PM or DPM when better information is not available (Lewtas 2007). In epidemiological studies such as Maynard et al. (2007), elemental carbon is used as an identifier or an index for PM generated from motor vehicles. In toxicology research similar to that described in Mundandhara et al. (2006), elemental carbon is used as an experimental control to demonstrate the effects of other PM constituents.

Based on the above, NHTSA believes that considering the health effects of inhaled elemental carbon independently of PM or DPM is unnecessary because elemental carbon will not be emitted without the other accompanying components of PM. NHTSA has revised the FEIS to clarify the distinctions among PM as a criteria pollutant, DPM as an air toxic pollutant, and black carbon. See Section 3.3.1.2.

Comment

Comment Number: 0595-16
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Chapter 3, pg. 3-17, lines 40-43 & pg. 3-18, lines 1-2:

In order to better describe the limitations of the air quality analysis performed by NHTSA, EPA recommends the paragraph be revised as follows:

"Full-scale photochemical air quality modeling was not conducted for this analysis; therefore, the EIS is unable to characterize the ambient air quality impacts associated with each alternative. Instead, the action alternatives were analyzed by calculating the emissions from passenger car and light trucks that would occur under each alternative, and assessing the changes in emissions relative to the No Action Alternative. Lower emissions should result in lower ambient concentrations of pollutants on an overall average basis, which should lead to decreased health effects of those pollutants.

"Full-scale photochemical air quality modeling is necessary to accurately project levels of $PM_{2.5}$, ozone and air toxics. A national-scale air quality modeling analysis would analyze the combined impacts of each alternative on $PM_{2.5}$, ozone, and air toxics (i.e., benzene, formaldehyde, acetaldehyde, ethanol, acrolein and 1 ,3-butadiene). The atmospheric chemistry related to ambient concentrations of $PM_{2.5}$, ozone, and air toxics is very complex, and making predictions based solely on emissions changes is extremely difficult."

Response

NHTSA has made the suggested revision to the text in Section 3.3.2.3.

Comment

Comment Number: 0595-17
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Chapter 3, page 3-20, lines 7-16:

EPA recommends the paragraph be revised as follows in order to more clearly indicate that incomplete/unavailable information limitations affect the air quality and health impacts analysis done:

"As noted above, the estimates of emissions rely on models and forecasts that contain numerous assumptions and data that are uncertain. Examples of areas in which information is incomplete or unavailable include future emission rates, vehicle manufacturers' decisions on vehicle technology and design, the mix of vehicle types and model years, emissions from fuel refining and distribution, and economic factors. Furthermore, a full-scale photochemical air quality modeling analysis to estimate the ambient concentrations of PM, ozone, and air toxics was not conducted The lack of air quality modeling data limited the conclusions that could be made about health and environmental impacts associated with each alternative. Instead, a screening-level estimate of monetized health benefits, in the form of dollar-per-ton of criteria pollutant emissions reduced, was used to approximate the health benefits associated with each alternative. The use of such dollar-per-ton numbers, however, does not account for all potential health and environmental benefits, which leads to an underestimate of total criteria pollutant benefits. Where information in the analysis included in the DEIS is incomplete or unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable information. See 40 CFR § 1502.22(b). NHTSA has used the best available models and supporting data. The models used for the DEIS were subjected to scientific review and have received the approval of the agencies that sponsored their development. NHTSA believes that the assumptions that the DEIS makes regarding uncertain conditions reflect the best available information and are valid and sufficient for this analysis"

Response

NHTSA has made the suggested revision to the text of Section 3.3.2.3.

Comment

Comment Number: 0595-18
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Chapter 3, pages 3-26 and 3-28:

NHTSA's estimates of criteria pollutant reductions (e.g., 54,000 - 232,000 tons of NO_x in 2020) connected with the proposed CAFE standards appear to be larger than EPA would expect. EPA has not been able to replicate NHTSA's estimate, so we do not know for certain if there is an issue. The magnitude of the resulting inventory reductions suggests that NHTSA may be taking credit for criteria (and possibly toxic) emission benefits that occur internationally during crude oil transport to the U.S., rather than just counting the domestic benefits of reduced refinery and fuel distribution emissions. The lack of details in the DEIS does not allow EPA to comment for certain on how the NHTSA DEIS estimates were calculated, but the text in the Federal Register notice, page 24412, seems to support this suggestion:

"Reductions in domestic fuel refining using imported crude oil as a feedstock are tentatively assumed to reduce emissions during crude oil transportation and storage, as well as during gasoline refining, distribution, and storage, because less of each of these activities would be occurring."

An additional possible cause for the large emission reductions estimated by NHTSA is the use of the GREET model to generate those estimates. EPA has noticed that the heavy-duty truck, rail, and barge emission factors in GREET [Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation] do not reflect the latest round of EPA emission standards that substantially reduce VOC, NO_x, and PM emissions in future years (the heavy-duty highway 2007/2010 standards). Use of these more controlled emission factors would decrease the "No Action" emissions as well as emissions from the various CAFE alternatives, with the net result being smaller benefits from the program than estimated using an unmodified version of GREET. We suggest NHTSA verify what standards are assumed in the version of GREET used for the DEIS, and modify as appropriate for the final EIS.

Response

The commenter is correct that the DEIS counted emissions benefits that occur internationally during crude-oil transport to the United States, rather than just counting the domestic benefits of reduced refinery and fuel-distribution emissions. For the FEIS emissions estimates, NHTSA has revised the upstream emissions factors to reflect the assumption that 90 percent of the reduction in domestic fuel refining reduces imports of crude petroleum (and, thus, does not reduce domestic emissions from petroleum extraction or transportation), while only the remaining 10 percent reduces domestic production of crude petroleum (and, thus, reduces emissions during both petroleum extraction and transportation). NHTSA estimated these percentages by comparing U.S. fuel consumption and petroleum imports under several scenarios from EIA's Annual Energy Outlook (EIA 2008a).

The commenter is also correct that the emissions factors in GREET for heavy-duty truck, rail, and barge do not reflect the latest round of EPA emissions standards (the heavy-duty highway 2007/2010 standards). NHTSA coordinated with EPA to update the emissions factors for heavy-duty truck, rail, and barge processes. NHTSA updated these emissions factors in the modeling for the FEIS. The emissions reductions due to decreases in the amount of transportation and distribution of fuel now reflect the most current emissions factors.

Comment

Comment Number: 0595-10
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Page 3-20: For the section on treatment of incomplete or unavailable information, EPA recommends the following addition, indicating the limitations of the modeling done for upstream emissions of MSATs:

"Data used to estimate upstream emission impacts on air toxics are significantly older than data for criteria pollutants and use of more recent and complete data could affect results. In addition, all upstream toxic emissions were assigned to refinery processes, which could lead to over assignment of air toxic emissions to areas with refineries and an under assignment to areas without them."

Page 3-23 indicates that upstream MSAT emissions were estimated using the DOE [U.S. Department of Energy] GREET model. However, GREET does not include toxics, although in 2000, a version of GREET was developed which estimated air toxics using speciation factors. EPA assumes this was what was used. If that is the case, there are significant limitations which should be discussed. First, ethanol production is not included in the model. The model also used combustion emission factors for vehicles used in transport that are now significantly out of date, and assumed evaporative emissions of benzene were equivalent to levels of benzene in fuel. For refinery processes, the emission factors used are very old. As part of its analyses for last year's draft proposed greenhouse gas rule, and the upcoming rule implementing requirements under EISA, EPA developed air toxic emission factors for upstream processes using the most recent available information. We recommend that NHTSA coordinate with EPA on updating upstream toxic emission factors.

Also, all upstream toxic emissions were assigned to refinery processes. EPA does not believe this assumption is reasonable as it means that there will be an over assignment of emissions to areas with refineries and an under assignment to areas without them.

Page 3-25: In Section 3.3.2.2 "Results of the Emissions Analysis," the text states "As discussed in Section 3.31, pollutant emissions from vehicles have been declining since 1970 and EPA projects that they will continue to decline. This trend will continue regardless of the alternative that is chosen for future CAFE standards" (p. 3-25). A similar statement is in Section 3.3.2.3.2 (p. 3-28): "As with the criteria pollutants, current trends in the levels of air toxics emissions would continue, with emissions continuing to decline due to the EPA emission standards despite a growth in total VMT." In fact, Tables 3.3-3 and 3.3-5 show increases in VOC between 2025 and 2035 (and in the case of DPM, emissions increase in each analysis year in all scenarios, including No Action). The incorrect statements in the text should be deleted, and the trend of increasing emissions in the later analysis years should be acknowledged.

Response

NHTSA has clarified the discussion of upstream air toxic emissions in the FEIS. The following paragraphs respond to the commenter's individual points:

Page 3-20: The commenter is correct that NHTSA assigned all upstream toxic emissions to refinery processes, and that this results in an over-assignment of emissions to areas with refineries and an under-assignment to areas without refineries. As noted in the DEIS, this is a limitation of the GREET model, which does not provide a breakdown of fuel-refining emissions versus transportation, storage, and *distribution emissions. NHTSA has not been able to identify any data that would allow a further breakdown of upstream toxic emissions by source.*

Page 3-23: For the DEIS, NHTSA modeled upstream emissions of air toxics using emissions factors from Winebrake et al. (2000). This is the same source used for the 2000 air toxics version of GREET. NHTSA coordinated with EPA to update the air toxic upstream emissions factors for upstream processes. However, EPA stated that it would not be able to supply updated factors. EPA recommended that NHTSA continue to use the air toxic upstream emissions factors it used in the DEIS and that NHTSA revise the text in Sections 3.3.2.1.3 and 3.3.2.1.5 of the FEIS to explain the EPA recommendation. NHTSA has revised the FEIS accordingly. The statuses of some of the specific model limitations the commenter mentioned are as noted below and in the FEIS:

- *Ethanol production not included: This model limitation still exists.*
- *Transport vehicles: These emissions factors have been updated. See also the previous comment response in this section (10.3.2.2).*
- *Evaporative benzene emissions: This model limitation still exists.*
- *Refinery process emissions factors: These emissions factors have been updated. See also the previous comment response in this section (10.3.2.2).*
- *Updating of air toxic upstream emissions factors for upstream processes: As noted above, NHTSA coordinated with EPA to update the air toxic upstream emissions factors for upstream processes. However, EPA stated that it would not be able to supply updated factors. EPA recommended that the NHTSA continue to use the air toxic upstream emissions factors it used in the DEIS and that NHTSA revise the text in Sections 3.3.2.1.3 and 3.3.2.1.5 of the FEIS to explain the EPA recommendation. NHTSA has revised the FEIS accordingly.*

Page 3-25, page 3-28, Tables 3.3-3 and 3.3-5: NHTSA has updated the text and emissions tables in Section 3.3.

10.3.2.3 Consequences

Comment

Comment Number: 0588-12
Organization: New York State Department of Transportation
Commenter: Stanley Gee

Figures 3.3-3, 3.3-4, and 3.3-5 should show the effects of the proposed alternatives on light duty cars and light duty trucks separately. This would help to distinguish the differential effect that the various alternatives will have on the various components of the nation’s light duty fleet.

Response

NHTSA has added a table to Section 3.2.2 to show the effects of the alternatives on cars and light-duty trucks separately.

Comment

Comment Number: 0595-19
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Chapter 3, pg 3-27, Figure 3.3-2:

This figure, and others like it, suffers from a scale mismatch related to the tons associated with CO versus each of the other criteria pollutants. The different reductions between alternatives for PM, NO_x, SO_x, and VOCs are not minor. However, the scale of the table gives this misimpression. EPA recommends that CO be decoupled from this table, shown separately, and the scale of the existing table be revised to more accurately show differences in the alternatives for the other criteria pollutants.

Response

NHTSA has revised the relevant figures in Section 3.3.2.3 to more clearly show the differences among the pollutants.

10.3.2.4 Health

Comment

Comment Number: 0595-14
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Chapter 3, pg. 3-13, line 34:

EPA recommends the following sentence be added to the beginning of the paragraph, to clarify that a formal health impact analysis was not done:

"Though we did not conduct a formal analysis of health impacts, the alternatives considered in this EIS will contribute to reductions in criteria pollutants that will improve public health and welfare."

Response

NHTSA acknowledges the request and has added this sentence to Section 3.3.1.2.

Comment

Comment Number: 0595-25
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Chapter 1, pg. 1-7, Lines 20-28:

It does not appear that NHTSA undertook a complete health impacts analysis in its analysis of alternatives. Instead, the Volpe model substitutes $/ton values which reflect a measure of the monetized health related benefits associated with criteria pollutant emission reductions. The $/ton numbers omit a number of unquantified health and environmental effects, and are therefore an underestimate of total benefits. A complete health and environmental impacts analysis would begin with full-scale photochemical air quality modeling to demonstrate the changes in ambient air pollution exposure related to the emission changes associated with each alternative scenario. These ambient concentrations would then be fed through a health impacts model (EPA's Environmental Benefits and Mapping Analysis Program – BenMAP) to characterize population exposure and the change in health response associated with various health impact functions derived from the epidemiological literature.

Response

NHTSA has expanded the discussion of dollars-per-ton values to better explain how the emissions changes associated with the alternatives would produce these economic and health outcomes. NHTSA has added data to show, at a screening level, the health outcomes implied by the dollars-per-ton values. See Section 3.3.2.4.2.

Comment

Comment Number: 0596-10
Organization: Environmental Defense Fund
Commenter: Martha Roberts

NHTSA acted in an arbitrary and capricious manner by justifying attribute-based standards as a means to "eliminate the incentive for manufacturers to respond to CAFE standards in ways harmful to safety," while simultaneously ignoring the health consequences presented by the lower fuel efficiency permitted in larger vehicles. [Footnote: See original comment document.]

NHTSA purports to consider human health in developing CAFE standards through the use of attribute-based standards and rules in the VOLPE model that limit vehicle downweighting as a fuel efficiency technology. However this same health safety concern is not evident in the choice of fuel efficiency standards. Particularly egregious are the lower fuel efficiencies permitted to larger vehicles, which increase the harm to human health through increased emissions of air pollutants.

NHTSA refers to several reports on safety and vehicle weight reduction and quotes the National Academy of Science's finding that in 1993 between 1,300 and 2,600 traffic accident fatalities occurred as a result of earlier vehicle downsizing and weight reductions. [Footnote: See original comment document.] This is less than the estimated number of deaths attributable to air pollution from a less stringent CAFE standard, as compared to a more stringent one [see Table 1 in original comment document].

We request that NHTSA give the same attention to protecting human health from air pollution as it does to protecting human health in its analysis of crashworthiness. A more stringent CAFE standard will better balance the benefits of health protection with the other statutory considerations and better align with NHTSA's attribute-based safety justifications.

Response

The air quality analysis compares the health outcomes of the alternatives, as noted in the previous comment response in this section (10.3.2.4). These can be compared with the safety analysis in Section 3.5.4.

More specifically, it is important to note the context in which the action will occur, because the commenter appears to misconstrue the legal requirements under EPCA, as amended by EISA. NHTSA does not have the discretion to decide whether to adopt an attribute-based standard. Congress, in the *language of EPCA, required NHTSA to adopt an attribute-based standard. The National Academy of Sciences (NAS) also recommended an attribute-based standard. Different fuel economy targets for different sized vehicles are a necessary consequence of an attribute-based standard. In fact, different fuel economy targets by vehicle attributes are the reason why the NAS recommended, and Congress directed, NHTSA to address perceived disadvantages of the existing fuel-economy standards.*

One commenter stated that, as a policy choice, a more stringent CAFE standard represents a better balance between the health outcomes (mortality and illnesses) avoided by emissions reductions and the health outcomes (fatalities and injuries) avoided by improved crashworthiness. The preeminent goal of EPCA is energy conservation. While greater human health benefits from the more stringent alternatives would certainly be desirable (as would greater fuel savings or GHG reductions), NHTSA must act within the requirements of economic practicability and technological feasibility established under EPCA.

Comments

Comment Number: 0600-5
Organization: Centers for Disease Control and Prevention
Commenter: Sarah Heaton

Transportation-related emissions contribute to climate change. CAFE standards can promote the use of alternative technologies in the U.S. and abroad that reduce harmful emissions and, in turn, reduce contributors to climate change and improves human health outcomes. Although some health outcomes of climate change are difficult to predict, others are supported by considerable evidence. Health impacts affected by increasing or reducing contributors to climate change are appropriate for analysis of the human environment pursuant to NEPA.

Health outcomes from climate change, for which quantitative or qualitative impact analysis is possible, should be included in predictive modeling.

Automobile contributions to criteria air pollutants are affected by CAFE standards and such emissions directly affect human health outcomes. Asthma, bronchitis, chronic obstructive pulmonary disease, and cardiovascular disease are some of the most common health outcomes triggered or exacerbated by air pollutants from motor vehicles. Reducing ozone forming emissions, NOx, and hydrocarbons can improve human health outcomes and reduce medical care costs. The DEIS fails to discern among alternatives regarding the health impacts from emissions/air pollutants. For adequate analysis of impacts to the human environment pursuant of NEPA:

Analysis of the potential health effects from fleet emissions, both acute and chronic, is critical to include in the analysis of alternatives pursuant to NEPA.

Adequate cost/benefit analysis of alternatives should include health costs associated with the acute and chronic effects from auto emissions at each level in the range of alternatives to show both current associated costs and potential savings from reduced emissions.

Comment Number: 0596-6
Organization: Environmental Defense Fund
Commenter: Martha Roberts

NHTSA fails to comply with the NEPA regulations requiring agencies to “present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public" (CEQ 40 CFR 1502.14) in this EIS. In particular, the EIS fails to disclose the likely adverse health effects of conventional air pollutants associated with each alternative, fails to compare alternatives based on their impact on human health, and fails to identify how each alternative considered will eliminate or minimize these health effects. The EIS completely ignores the responsibility under NEPA to provide useful information to the decision maker regarding the degree to which each alternative will protect the public from the adverse health effects of air pollution from the transportation fuel cycle.

Council for Environmental Quality (CEQ) regulations require that an EIS assess both the direct and indirect effects of proposed actions and their significance (CEQ 40 CFR 1502.16 (a) and (b)), which include those effects related to human health (CEQ 40 CFR 1508.8) and requires that an EIS consider the "degree to which the proposed action affects public health or safety." (40 CFR 1508.27(b)(2)). Because the proposed alternatives will each significantly change human exposure to transportation fuel cycle emissions for the American public, and the adverse health effects resulting therefrom, a comparison of alternatives based on public health impacts is required. Under the CEQ regulations and settled case law, NHTSA cannot exclude these effects, which are obviously related to the proposed standards, from its EIS analysis.

The proposed CAFE alternatives result in varying levels of future air pollutant emissions that will differentially affect human health. NHTSA asserts that "assessing emissions is a valid approach to assessing air quality impacts because emissions, concentrations, and health effects are connected. Lower emissions should result in lower ambient concentrations of pollutants on an overall average basis, which should lead to decreased health effects of those pollutants." [Footnote: See original comment document.] However, the magnitude of this effect requires quantification, even if that quantification is subject to some uncertainty. The rote description of the various air pollutants and their related health impacts provided by the EIS does not satisfy NEPA. In the words of the Ninth Circuit court, "[g]eneral statements about "possible" effects and "some risk" do not constitute a "hard look" absent a justification regarding why more definitive information could not be provided." [Footnote: See original comment document.]

The EIS provides the relative future reduction of criteria air pollutants and hazardous air pollutants (HAPs) across the range of proposed CAFE alternatives. Unlike recent EPA regulatory impact analyses (RIAs) [Footnote: See original comment document.] however, this EIS fails to specify the relative human health impacts resulting from each emissions scenario.

To demonstrate that such a linkage is possible and to suggest the relative magnitude of the health effects of the various CAFE alternatives, we have used a simple methodology to estimate multiple health outcomes. This method quantifies the relationship between the amount of emitted pollutant and human health effects. Our approach, although slightly different methodologically from that used by the EPA, relies upon much of the same scientific literature and appears to provide similar results. We use the predicted future tonnage of conventional air pollutants in the EIS in association with the intake fraction, a unitless measure of the percent of an emitted pollutant that is inhaled or ingested by the population at large. [Footnote: See original comment document.] These two variables, in conjunction with empiric measures of exposure-response relationships, allow us to characterize the health effects related to different quantities of pollutant emissions. Basically the amount of emitted pollutant is multiplied by the intake fraction (calculated for the U.S. using spatial statistics to account for the locations and densities of emissions and people). We then multiply this number by a series of different exposure-response coefficients for different health outcomes, such as lung cancer, cardiovascular mortality, etc. The final product is the number of attributable health events for each pollutant over a year.

We found striking and troubling differences in the health impacts of the proposed CAFE alternatives, measured in thousands of avoided premature deaths. For example, in comparing the “optimized” (NHTSA’ s preferred standard) alternative with the more stringent “total costs equals total benefits” (“costs = benefits”) alternative, over 1,400 excess infant deaths per year result under the “optimized” alternative by 2020. In addition, the “optimized” alternative leads to more than 2,800 additional adult premature deaths, 8,800 children’s emergency room visits for asthma, and 640,000 lost work days yearly by 2020. See Table 1 [See original comment document for Table 1.] for more details on the health impacts of the various proposed CAFE alternatives.

Our analysis examined the health effects of only two pollutants, particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_x), of the more than ninety harmful air pollutants emitted by light vehicles. [Footnote: See original comment document.] Thus we significantly underestimate the true health protection of higher fuel efficiency.

The EIS, by omitting quantified health benefits, disregards one of its core purposes, namely, to “inform decisionmakers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment” (CEQ 40 CFR Sec. 1502.1). NHTSA must revise the EIS to include calculations of meaningful health outcomes, such that policy makers and the public more fully understand the implications of the proposed CAFE alternatives.

Response

The FEIS approach of relating relative reductions in emissions to relative reductions in health effects supports the primary NEPA purposes of informing the selection of an alternative, informing the decisionmaker of potential effects to human health and the environment, and ensuring public disclosure of information. Given these purposes, one objective of NEPA is generally to disclose adverse health outcomes. However, the outcomes of the CAFE rule will generally reduce emissions and be beneficial to human health, even though not all alternatives reduce emissions for all input scenarios and analysis years. The FEIS follows NEPA guidance by analyzing all impacts, even when the effects would be positive.

One commenter compares this EIS to EPA’s RIAs for its air quality rulemakings. A rulemaking in which the primary purpose is to reduce health risks, such as those promulgated by EPA, might need to be more explicit than this EIS about the health impacts that would be avoided through implementation of a proposed action. However, the CAFE rule is substantially different from EPA rules. Most significantly, EPA rules are designed for the express purpose of improving health through pollution reduction, as mandated by the Clean Air Act and other statutes. In contrast, the purpose of CAFE standards, as mandated by EPCA, is to reduce fuel use.

EPA, in the technical support documents to its "Advance Notice of Proposed Rulemaking: Regulating Greenhouse Gas Emissions under the Clean Air Act" of July 2008 (EPA 2008g), used a similar approach to NHTSA's that also examined the benefits, rather than the harm, of GHG reductions.

To provide more detailed information on the projected health benefits by alternative, NHTSA has expanded the discussion of air quality and health effects with more quantitative information on the relative impacts of the alternatives. Sections 3.3.2.4.2 and 4.3.3.2.3 of the FEIS provide estimates of the number of cases avoided for various health outcomes and the dollar value of avoided costs associated with the emissions reductions under each alternative.

NHTSA disagrees with the Environmental Defense Fund’s (EDF’s) characterization that the Optimized Alternative results in “over 1400 excess infant deaths” and “leads to more than 2800 *additional adult premature deaths." None of the alternatives would cause premature mortality. All of the alternatives are estimated to reduce adverse health outcomes to differing degrees; from this result it cannot be concluded that all alternatives except the most stringent would cause "excess," "additional," or "premature" outcomes. All of the action alternatives, including the Optimized Alternative, would reduce emissions of NO_x, $PM_{2.5}$, SO_x, VOC, DPM, benzene, and 1,3-butadiene and thus should lead to reduced mortality.*

Comment

Comment Number: TRANS-17-1
Organization: BG Automotive Group
Commenter: Barry Bernsten

What I did not read in the 414 pages of the environmental impact statement as it clearly relates to air quality, was the direct associated cost with the 1.5 million emergency room visits for asthma patients, or the $14 billion in health care costs related just to asthma related illnesses.

The report also did not include the direct costs associated with emphysema and/or chronic bronchitis due to CO_2 emissions or greenhouse cases. Why didn't the environmental impact statement consider the direct health costs associated with their study, and the quality of life costs associated with such an important report?

Response

NHTSA has expanded the discussion of air quality and health effects to provide more quantitative information on the relative impacts of the alternatives. See Sections 3.3.2.3.2 and 4.3.3.2.3.

Comment

Comment Number: TRANS-32-1
Organization: Environmental Defense Fund
Commenter: James Keck

EDF, while supporting the inclusion of climate change health impacts within the EIS is deeply concerned by the assertion that the agency and its consultants were unable to determine the magnitude of these impacts across the proposed CAFE alternatives, not only on the basis of climate change, but also regarding conventional pollutant health impacts.

Response

Two federal agencies, EPA and Centers for Disease Control and Prevention (CDC), commented on the human health discussions in the DEIS. EPA noted that NHTSA did not perform a complete health analysis. Rather than calling for additional analyses, EPA suggested that NHTSA insert text that would explain the level of analysis performed. EPA stated that a "complete health and environmental impacts analysis would begin with a full scale photochemical air quality modeling to demonstrate the changes in ambient air pollution exposure… These ambient concentrations would then be fed through a health impacts model… to characterize population exposure and the change in health response…." EPA provides text describing what NHTSA did and did not perform. By contrast, CDC called for more extensive modeling analysis, recommending that NHTSA include economic analysis of health costs and commenting that mitigation analysis is necessary. CDC draws on the wedge analysis described by Pacala and Socolow in Science magazine in 2004. CDC also had specific recommendations regarding *human health impacts associated with changes in fleet emissions, fuel consumption, and fleet design. Other parts of this chapter address these specific suggestions.*

Sections 3.5.4, 3.3.1.2, 3.3.1.3, and 4.5.8 discuss impacts to human health. NHTSA has provided a thorough description of how emissions can affect human health, specific assessments of the changes in emissions due to the standards, and discussions of impacts to human health from direct, indirect, and cumulative impacts perspectives based on information from the IPCC and the U.S. Climate Change Science Program (USCCSP). NHTSA has enhanced the information provided in the FEIS by including data on the potential health outcomes and costs reduced under each of the alternatives. NHTSA's reasoning is explained further below.

NHTSA appreciates and adopts the language EPA suggested to clarify the level of health analysis performed. NHTSA also notes EPA's description of the extensive photochemical, exposure, and health analysis that would be required to conduct a full-scale health-impacts analysis. NHTSA believes that adopting the text clarifications EPA suggested is a better approach than attempting to conduct more extensive health-impacts modeling, for two main reasons. First, the estimated health impacts resulting from the CAFE standards are beneficial. Because the alternatives would reduce GHGs and health costs (see Sections 3.4, 3.5, 4.4, and 4.5), the damage to human health is estimated to be similarly reduced. Although this does not relieve NHTSA from explaining the potential impacts to human health, it reduces the need for enhanced analytical rigor when compared to a case in which human health might be negatively affected.

Although one might argue that enhanced analysis might still be necessary even if the impacts were beneficial, NHTSA would note that improving human health is not the purpose of the proposed rulemaking. If it were, greater credence could be given to the need for enhanced analysis. The statutory purpose of the proposed rulemaking is to save energy, which according to the analysis in the DEIS and this FEIS, is expected to improve human health.

Second, the differences in emissions (GHGs, criteria pollutants, and air toxics) and in health costs avoided among the alternatives provide ample information for the decisionmaker, as required under NEPA. It is reasonable to anticipate that human health impacts will mirror these indicators. The information to be gained through the very extensive process of health modeling would not add substantial new information because the differences in estimated climate effects (temperature, precipitation, and sea-level rise) are small; therefore, changes in the health impacts related to these will also be small. Further, the differences among the alternatives will be smaller still, due to the global nature of the climate problem. Similarly, the screening-level analysis of avoided adverse human health outcomes and avoided health costs of criteria pollutants among the alternatives provides ample information for the decisinomaker, as required under NEPA.

To address CDC's request for additional economic/health-impacts analysis, NHTSA has provided more information in the FEIS regarding the relative health effects of criteria air pollutant emissions associated with the alternatives. Specifically, NHTSA has expanded the discussion in Sections 3.3.2.4.2 and 4.3.3.2.3 to include estimates of the number of cases avoided for various health outcomes and the dollar value of avoided costs associated with the emissions reductions with each alternative. This analysis is limited to the criteria air pollutants, because health damage estimates are not available for MSATs.

In suggesting further modeling, CDC cites the wedge analysis by Pacala and Socolow and might, therefore, misconstrue the action NHTSA is taking. NHTSA's action is limited to the CAFE rulemaking. The proposed rulemaking would result in substantial reductions in GHG emissions from passenger cars and light trucks in the United States, which when considered in a global context, would result in small *changes in temperature, precipitation, and sea-level rise. The proposed rulemaking also would result in substantial reductions in national emissions of NO_x, $PM_{2.5}$, SO_x, VOC, DPM, benzene, and 1,3-butadiene from passenger cars and light trucks in the United States, which would lead to incremental reductions in adverse health outcomes and costs. Under NEPA, the proposed rulemaking is the action that must be evaluated for environmental impacts. The FEIS does not, and should not in NHTSA's opinion, account for other emissions-reduction strategies beyond those reasonably foreseeable, as NEPA requires. Because the United States has not established in law or regulation other emissions-reduction strategies (except the MY 2016-2020 CAFE targets specified in EISA), including presumed improvements in energy efficiency, would be speculative. Accordingly, NHTSA continues to believe that the appropriate context for analysis of human health impacts is limited to the reduction in emissions resulting from the alternatives specified in the proposed rule. To provide more detailed information on the projected health benefits by alternative in the FEIS, NHTSA has expanded the discussion of air quality and health effects of criteria and toxic pollutants to provide more quantitative information on the relative impacts of the alternatives. Section 3.3.2.4.2 of the FEIS provides estimates of the number of cases avoided for various health outcomes and the dollar value of avoided costs associated with the emissions reductions with each alternative.*

Comment

Comment Number: TRANS-32-6
Organization: Environmental Defense Fund
Commenter: James Keck

The EIS notes that health costs are included within the Volpe model, used to select optimized alternative, but it fails to include estimates of adverse health events in its statement. And while the EIS provides the future relative reductions in tons of air pollutants across the different CAFE alternatives, it does not link these air pollutant reductions to health in a transparent and meaningful way.

To demonstrate that such a linkage is possible, we used a simple methodology to estimate the changes in meaningful health outcomes associated with a different CAFE alternatives. Although I do not have the time to relay all of the specific details of our findings, the health protection resulting from, for example, the pollutant reductions in the cost equals benefits alternative versus the optimized CAFE alternative is measured in thousands of avoided deaths, and thousands of avoided asthma visits to the emergency department per year by the year 2020.

Response

NHTSA has expanded the discussion of air quality and health effects to provide more quantitative information on the relative impacts of the alternatives. See Section 3.3.2.4.2.

10.3.3 Climate

Comment

Comment Number: 0530-2
Organization: Individual
Commenter: Dale Olson

Over 32,000 scientists have signed the "Oregon petition" stating they see no convincing scientific evidence that humans are causing catastrophic climate change. They have been joined by the American Physical Society, which recently announced that it was reassessing its prior position - that evidence for global warming was "incontrovertible" - because many of its 50,000 physicist members disagree strongly with climate chaos claims.

Response

The American Physical Society (APS) released a statement clarifying that the contrary viewpoint espoused by some of its members was not the official position of the APS. The APS states in a position adopted on November 18, 2007 that "The evidence is incontrovertible: Global warming is occurring." National Policy 07.1 Climate Change, available at http://www.aps.org/policy/statements/07_1.cfm. NHTSA uses the best available science from IPCC and CCSP in its analyses. Both of these groups, along with most scientists around the world, agree that human-induced climate change is occurring.

Comments

Comment Number: 0572-26
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

One prime example of inadequate context and information is the analysis of abrupt climate change, or tipping points. The CEQ regulations require that an agency "describe the consequences of a remote, but potentially severe impact" based on credible scientific information. 50 Fed. Reg. 32234, 32237 (August 9, 1985). The DEIS acknowledges that the possibility of abrupt climate change exists, yet by asserting uncertainty downplays the significance of tipping points. This approach is untenable. While no one may be able to predict with certainty on exactly which date a threshold for abrupt climate change may be reached, there is ample evidence that unchecked greenhouse emissions will result in abrupt climate change. In fact, various studies have attempted to quantify when such a threshold may be reached. The most recent estimate by Hansen and colleagues is that prolonged time spent over 350 ppm CO_2 will result in catastrophic impacts. (Although the climate literature often refers to "dangerous" levels of climate change to denote CO_2 concentrations above which climate impacts will be severe and irreversible, we use the term "catastrophic" here because current CO_2 levels have already surpassed the "dangerous" level of 350 ppm.) Previous estimates considered 450 ppm the threshold for catastrophic climate change.

Given the certainty that abrupt climate change will occur above some level of atmospheric concentration, the alternatives must be analyzed in the context of avoiding catastrophic climate change.

The DEIS does not adequately address climate tipping points.

Among the many consequences of climate change, "tipping points" carry the greatest threat to wildlife, human welfare, and economic security. As such, it is of paramount importance that any federal action be executed in a manner that reduces the possibility of abrupt climate change.

The Volpe model is the sole decision-making tool used to balance the factors set out in the EPCA. It does not capture the costs of abrupt climate change or tipping points. One of the factors that NHTSA considers under EPCA when setting the fuel standards is "the need of the United States to conserve energy." Environmental implications of the need for large quantities of petroleum are included in this factor. One of the environmental effects of continued heavy petroleum consumption is the possibility of passing over "tipping point" thresholds, or catastrophic climate change.

Because this is an acknowledged possibility, it must be included in the NEPA analysis and the balancing of the EPCA factors. The DEIS concludes that the science surrounding tipping points is too uncertain to be included in the analysis. This is simply not true. It is well-accepted that there will be tipping points.

(Meehl et al. at 775, 2007) A recent analysis of “tipping elements” indicates that contrary to the IPCC’s conservative projections, there is a strong chance that tipping points will be crossed within this century (Lenton et al. 2008). This study also indicates that it may be possible to identify thresholds for tipping points for the purposes of policy making.

Furthermore, a recent study by Weitzman, an economics professor at Harvard, indicates that while traditional cost-benefit analysis can not properly capture the costs of climate change, including tipping points, a different analysis is more likely to capture the costs (Weitzman 2007).

The economic impacts of climate change are astounding. The much-respected Stern Review, published in 2007, estimates that the costs of climate change will range from 5% to 20% of GDP. (Stern 2007). In contrast, the Stern Review estimated that rapid action to address climate change would only cost approximately 1% of GDP. [Footnote: See original comment document.] In 2007, this would have corresponded to approximately $138 billion. [Footnote: See original comment document.] In contrast, the cost of inaction—abrupt climate change—has been estimated at over $400 billion. [Footnote: See original comment document.] The message is clear: the U.S. can not afford to gamble with abrupt climate change.

Under all scenarios considered in the DEIS the atmospheric CO_2 concentrations would reach 550 ppm or greater—the “optimized” alternative would reach over 700 ppm. This is well above the threshold for abrupt and catastrophic climate change. As a result, no alternatives adequately address the need for deep reductions in CO_2 emissions.

The DEIS erroneously dismisses the potential for tipping points as an impact that will not occur this century and thus does not require consideration. The basis for this conclusory statement that abrupt climate change will not occur this century is a statement in the IPCC Fourth Assessment Report that ”[a]brupt climate changes … are not considered likely to occur in the 21st century, *based on currently available model results*.” See DEIS at 3-53 (emphasis added; citing Meehl et al. 2007). Yet, it is well accepted that climate models can not capture the dynamical processes that lead to climate instabilities and rapid shifts such as occur during abrupt climate change. See, e.g., DEIS at 3-52.

Model predictions consistently underestimate observed climate change, and thus very likely also underestimate when tipping points will occur. For a discussion and examples, see Hansen et al., *Target CO_2* at page 10 (2008). There are numerous examples of accelerated changes occurring well in advance of model predictions. One is the rapid rate of sea ice loss in the Arctic. The summer sea ice extent in 2007 shattered all records, dropping below the level that most models predicted would not occur until 2050. [See original comment document for figures.]

More recent models of Arctic sea ice predict that the Arctic could be sea-ice free by the summer of 2013. In a recent conference presentation, Professor Maslowski from the Naval Postgraduate School showed if current trends continue, the Arctic will be sea-ice free by 2013. (Maslowski et al. 2008) The summer sea ice predictions for 2008 suggest that the same precipitous decline may occur again [Footnote: See original comment document.], with some scientists suggesting a 50:50 chance that the North Pole will be ice-free this summer. [Footnote: See original comment document.] Arctic sea ice is important both because of the albedo feedback effect and because sea ice melt leads to a warmer Arctic Ocean, which in turn accelerates the melt rate of the Greenland ice sheets.

The best basis for determining tipping points may be the use of paleoclimate data. Based on such data, Hansen and colleagues have estimated that remaining at CO_2 concentrations above 350 for a prolonged period of time is likely to invoke tipping points (Hansen et al. 2008). Paleoclimate data also indicate that in the past, at temperatures expected to be reached by 2100, Greenland and Antarctica contributed several meters to sea level. (Overpeck et al. 2006) The rate of rise at this temperature was approximately 1.6 m/century. (Rohling et al. 2008) Thus, the current CO_2 level of 385 ppm is not only “dangerous,” but catastrophic and could lead to tipping points this century. No models, including those used by the IPCC, can capture the dynamic response of ice sheets or adequately predict current observations of sea level rise. (DEIS at 3-75; Rignot 2008)

Comment Number: 0572-53
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

In addition, the Ninth Circuit recently observed, in Center for *Biological Diversity v. National Highway Traffic Safety Administration*, that incremental increases in CO_2 can lead to abrupt, catastrophic, and irreversible changes, and that “even a small increase in greenhouse gases could cause abrupt and severe climate changes” (U.S.C. § 32902(a),(f)). [Footnote: See original comment document.] As such, NHTSA must consider not just the significant environmental, social, and economic benefit to achieving the maximum technologically feasible fuel economy and, therefore, greenhouse gas emissions reductions, but also the high premium associated with achieving dramatic reductions in the near-term.

Comment Number: 0585-8
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

The DEIS fails to present the data in a meaningful context. The DEIS fails to consider the scientific consensus that CO_2 concentrations must be kept below the level of “dangerous anthropogenic interference”

While the DEIS provides a significant amount of raw data, the data are meaningless unless they are put into context. For example, simply reporting that the new CAFE rule puts us on a trajectory to reaching CO_2 levels of over 700 ppm and an increase in temperature of over 2 degrees Celsius by 2100 (DEIS at 4-3 1), is meaningless to the uninitiated because it does not provide the context related to the “tipping point” beyond which devastating and irreversible climate change impacts may occur.

While the DEIS mentions the concept of a climate “tipping point” and the fact that some climate scientists believe that a CO_2 level exceeding about 450 ppm is dangerous (DEIS at 3-52 to 3-53), it then dismisses these concepts as “still a matter of scientific investigation” (DEIS at 1-10), and claims that “the state of the science does not allow for a characterization of how the CAFE alternatives influence these risks, other than to say that the greater the emission reductions, the lower the risk of abrupt climate change.” DEIS at 3-53 to 3-54, 4-26.

This perfunctory discussion is unacceptable. To put the raw data into a meaningful context, the DEIS should emphasize the scientific consensus that we must lower our GHG emissions significantly in order to keep CO_2 concentrations in the atmosphere below a threshold that represents “dangerous anthropogenic interference” (“DAT”). In the words of the Ninth Circuit, there is “compelling scientific evidence concerning ‘positive feedback mechanisms’ in the atmosphere” that could lead to abrupt and non-linear changes. Center for Biological Diversity, 508 F.3d at p. 554. While the precise level for DAT is not known, scientists generally agree that the threshold is below 550 ppm CO_2. [Footnote: See original comment document.] At higher levels it is likely we will have reached an irrevocable “tipping point” and the Greenland ice sheet and part of the west Antarctic ice sheet will ultimately melt, causing a 5 to 10 meter rise in global sea level, which will cause flooding of all major coastal cities, and ensure global cataclysm. Further, it is plausible that DAT will be reached even at CO_2 concentrations of 450 ppm or substantially lower. [Footnote: See original comment document.] The risk of environmental cataclysm, even if uncertain, is so enormous, that it cannot simply be ignored, as NHTSA does.

At the very least, the DEIS must inform the agency and the public that scientists agree that there is an area of dangerous anthropogenic interference in the range of 500 ± 50 ppm $C0_2$, or possibly lower, that must be avoided. This information must be incorporated into and direct the analysis. Without such information, it is clear that NHTSA has, in fact, not considered the issues in a meaningful way.

Comment Number: 0595-6
Organization: Environmental Protection Agency
Commenter: Susan Bromm

EPA recommends that the DEIS discussion of climate change tipping points be expanded somewhat in the FEIS to include a brief discussion of the impacts associated with a given tipping element, and to include a reference to additional tipping elements identified by the scientific community (see Lenton, T. M., Held, H., Kriegler, B., Hall, J. W., Lucht, W., Rahmstorf, S. and Schelinhuber, H. J. (2008). Tipping elements in the Earths climate system. Proceedings of the National Academy of Sciences, Online Early Edition. February 4, 2008), including:

- Increase in the El Nino Southern Oscillation
- Collapse of the Indian summer monsoon
- Greening of the Sahara/Sahel and disruption of the West African monsoon
- Dieback of the Amazon rainforest
- Dieback of the Boreal Forest

Response

Commenters asked NHTSA to consider the issue of tipping points in the climate system in more detail. NHTSA has expanded its consideration of the issue of tipping points to include new research, as suggested by commenters, and expanded the discussion from the IPCC and CCSP literature. See Section 3.4.3.2.4. NHTSA also has included paleoclimatic research, as suggested by commenters, which supports the hypothesis that abrupt and severe climate change has occurred in the past, and that these changes could occur in multiple climate systems or other climate-related systems on the planet that affect global climate patterns. While the expanded research NHTSA analyzed in response to comments appears to confirm that there is general agreement that there are thresholds in the climate system that might produce severe and abrupt climate changes and impacts, there is still substantial uncertainty surrounding the existence of a singular tipping point (whether that point is 450 ppm CO_2 concentration or a 2 ºC temperature increase). There is evidence of multiple tipping points within various global systems, supported in scientific observations, peer-reviewed scientific literature, and paleoclimatic data. These points might occur when CO_2 concentrations are lower than 450 ppm and would have varying direct and indirect impacts. However, there is also uncertainty about exactly what levels of CO_2 emissions or temperatures might trigger these thresholds.

Commenters also requested that NHTSA examine the alternatives in relation to reaching tipping points triggered by CO_2 emissions. While NHTSA considered the potential to explore this suggestion in greater detail, we believe that such an analysis is not meaningful. Indeed, due to the uncertainty about what the impacts of this action are in delaying or mitigating the triggering of tipping points in any quantitative manner, it is impossible for NHTSA to relate the reductions in CO_2 emissions, sea-level rise, precipitation changes, and temperatures to tipping-point thresholds or to what extent the different *alternatives would affect tipping points. This action alone, even as analyzed for the most stringent alternative, does not produce enough of a CO_2 emissions reduction to prevent abrupt and severe climate change. The issue of abrupt and severe climate change tipping points must be addressed with many more CO_2-reduction initiatives and will require a global effort to address. Under NEPA and applicable law, due to the incomplete and unavailable nature of the information surrounding this issue, the only non-speculative conclusion NHTSA can reach is that the reduction in CO_2 emissions expected under this rulemaking will lower the risk of abrupt climate change.*

10.3.3.1 Methodology

Comments

Comment Number: 0585-10
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

In making this determination, the DEIS could also make use of the concept of “stabilization wedges,” first advanced by Pacala and Socolow. [Footnote: See original comment document.] Pacala and Socolow envisioned the 50-year reductions scenario as a triangle, with the sides of the stabilization triangle delineated by a flat emissions trajectory of 7 gigatons carbon per year (“GtC/year”) by 2054, with a decline to zero emissions by sometime after 2100, and a “business as usual” scenario represented by a straight-line ramp rising to 14 GtC/year in 2054. (Footnote: See original comment document.] (We note, however, that the analysis was performed in 2004. Four years later, the amount of emissions reductions per wedge will have increased, so that the 7 GtC/year is likely too low an estimate. They then divided the stabilization triangle into seven equal wedges representing reductions in GHG emissions. Filling all seven wedges results in reducing GHG emissions sufficiently to stabilize CO_2 concentrations at 500 ppm. [Footnote: See original comment document.] In particular, they note that we will achieve one wedge of the stabilization triangle if cars in 2054 averaged 60 miles per gallon globally. [Footnote: See original comment document.]

The wedge analysis was applied by the EPA in discussing GHG emissions from the U.S. transportation sector. The EPA calculated that nine transportation wedges, each representing a reduction of 5,000 million metric tons of CO_2 equivalents (“MMTCO2e”) between now and 2050 would be enough to flatten emissions in the transportation sector. Of the nine wedges, about half (4.3) would be enough to flatten emissions from passenger vehicles. EPA Transportation Wedge Analysis at 2. The EPA analysis notes that the reductions in emissions from passenger vehicles will come from vehicle technology, alternative fuels, and travel demand reduction, acting in concert. The document then presents various vehicle technologies and the “reduction potential” for the technology in terms of wedges. [Footnote: See original comment document.]

NHTSA could, consistent with the EPA analysis, compare the GHG emissions from the proposed CAFE alternatives with the 4.3 wedges of reductions needed from the passenger car sector to reach emission stabilization by 2054 and begin the necessary decline in emissions. (Additional reductions may be created by other actions, such as those that reduce travel demand or VMT. However, these further reductions will be necessary to lower GHG emissions even further in order to reduce CO_2 concentrations below 500 ppm.) [Footnote: See original comment document.] This will enable the Agency to determine whether the proposed alternative will slow emissions growth sufficiently from the passenger car and light truck sector to flatten emissions as anticipated by the EPA analysis. If it will not, NHTSA must reassess the alternatives.

Comment Number: 0600-2
Organization: Centers for Disease Control and Prevention
Commenter: Sarah Heaton, Andrew Dannenberg

CAFE standards' impact on climate change deserves special attention. In the magazine *Science* (2004), S. Pacala and R. Socolow articulate the concept of an orchestrated approach to solving climate change with existing technologies, policy change, and behavioral changes. Each component in such an approach is referred to as a *Stabilization Wedge* (Pacala and Socolow, "Stabilization Wedges: Solving the Climate Problem for the next 50 Years with Current Technologies" *Science* 2004 Aug 13;305: 968-972). CAFE standards that increase fuel efficiency is a critical and necessary component in the wedge approach and ought to be assessed in this context.

Response

NHTSA recognizes that several approaches have been put forth for developing comprehensive, multi-sector strategies to reduce GHG emissions. The stabilization wedge concept is one that many analysts have found useful in illustrating that no individual policy or technology is likely to be sufficient to achieve stabilization of atmospheric GHG concentrations, and that investment in a portfolio of strategies across key emissions-emitting sectors will be necessary to limit GHG concentrations in the atmosphere compared to a business-as-usual approach. However, NHTSA's regulatory authority in the context of this rulemaking is limited to choosing an appropriate standard for CAFE, based on the four statutory factors mandated in EPCA. Thus, a comparison of various CAFE alternatives to other GHG mitigation approaches (e.g., those conceptualized as wedges) is beyond the scope of the EIS (as mandated by NEPA) and the rulemaking.

10.3.3.2 MAGICC Model

Comments

Comment Number: 0572-31
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

MAGICC [Model for Assessment of Greenhouse Gas-induced Climate Change] is used to estimate the increase in CO_2 concentration, global mean temperature, and sea level rise. The DEIS uses the SRES A1B-AIM scenario as a "baseline." The only comparisons in the DEIS are among the three SRES "business as usual" scenarios: B1, A1B, and B2. This analysis, however, is incomplete because it ignores the fact that in order to avoid catastrophic climate impacts greenhouse gas concentrations must be quickly reduced back to below 350 ppm. SRES A1B-AIM results in CO_2 concentrations of 715 ppm in year 2100—far above dangerous CO_2 levels. A more appropriate comparison would be one of the "WRE" stabilization scenarios that are included in the MAGICC software. These stabilization scenarios are provided for 350 to 750 ppm stabilization.

Regardless of the baseline that is selected, the numerical results do not accurately reflect the state of the science. The DEIS relies heavily on the IPCC's Fourth Assessment Report, published in 2007. The model version used for numerical analysis, however, is calibrated to the Third Assessment Report, which was published in 2001. The MAGICC software has been updated to reflect the values reported in the

Fourth Assessment report; the newest version is MAGICC 5.3. This update has important changes from version 4.1. These changes include:

- Values for climate forcings were updated and two new forcings for nitrates and land use were included
- The stabilization scenarios now include stabilization strategies for non-CO_2 gases as well as CO_2
- The method of sea level rise was improved to be more consistent with the IPCC Fourth Assessment Report
- Default climate sensitivity was changed from 2.6 °C to 3.0 °C, in conformance with the Fourth Assessment Report.

Most importantly, the modeling results should be presented with the disclaimer that non-linear responses are not included in the predictions. Emphasis should be placed on the fact that (1) the model does not capture actual sea level rise predictions because it does not include ice sheet dynamics and (2) the model does not include the impact of rapid increases in methane from widespread loss of permafrost.

Comment Number: 0572-33
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The "scaling approach" as applied to sea level is also misleading. First, MAGICC 5.3 reports increments of sea level rise of 0.1 mm – not 1 mm as reported in the DEIS. Thus, the MAGICC results can resolve sea level rise to the same precision as the "scaling approach."

Comment Number: 0595-23
Organization: Environmental Protection Agency
Commenter: Susan Bromm

While EPA believes that the overall methodology used by NHTSA to model climate effects for the different CAFE scenarios using MAGICC is sound, EPA does have some recommendations that would strengthen the analysis performed. EPA would recommend re-running the analysis using the revised version (5.3) of MAGICC, which incorporates climate models used in IPCC's Fourth Assessment Report. We would also suggest running MAGICC using a range of climate sensitivities to reflect the 2.0-4.5 °C range projected in the IPCC report.

Response

NHTSA has updated the analysis using MAGICC 5.3 (which was not available when analysis for the DEIS started) and has run other baseline scenarios and climate sensitivities (2.5 ºC, 3.0 ºC, and 4.5 ºC for doubled CO_2) to illustrate the uncertainty of the emissions reductions on key climate effects such as global temperature increase, CO_2 concentrations, and sea level. NHTSA recognizes that MAGICC 5.3 does not incorporate the latest information on sea-level rise, and has noted this in the FEIS.

NHTSA included the scaling approach in the DEIS because MAGICC 4.1 did not reflect the latest results in the IPCC Fourth Assessment Report. Because the FEIS uses MAGICC 5.3 (which is updated to *reflect Fourth Assessment science), it eliminates the scaling approach, but includes an expanded comparison of MAGICC 5.3 and the Fourth Assessment results.*

Given that MAGICC 5.3 generates sea-level rise estimates in increments of 0.1 mm, rather than 1 mm, the FEIS provides outputs at this level of resolution, as recommended by the commenter.

In terms of stabilization targets, the FEIS expands the discussion of tipping points to include a brief review of the European Union's recent proposed target of 450 ppm CO_2 equivalent and 2 ºC. The discussion notes that improvements in vehicle efficiency will be only one of many steps required to meet such a target. See Section 3.4.3.2.4.

Regarding non-linear climate responses and abrupt changes in climate, the FEIS includes an expanded discussion of tipping points that acknowledges the limitations in current simulations of sea-level rise (particularly in relation to ice-sheet dynamics), and the incomplete characterization of positive feedbacks (such as CH_4 [methane] emissions from permafrost). See Section 3.4.3.2.4.

10.3.3.3 IPCC Scenarios

Comments

Comment Number: 0572-32
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The "scaling approach" used in the DEIS is intended to test the effect of intermediate emissions scenarios. This is accomplished through linear interpolation between the relative outputs of three SRES scenarios: B1, A1B, and A2. This same estimate can be obtained by designating a "GAS" file in MAGICC that has intermediate CO_2 emissions.

From the skeletal description in the DEIS, it appears that (in a nutshell) the process involves taking the difference between the annual emissions (inputs) and the outputs (temperature, sea level, CO_2 concentration) associated with each of the SRES scenarios. The percentage change from "baseline" emissions for each alternative is then used to scale the outputs from the baseline scenario. See DEIS at 3-50. At a minimum, the calculation explanation must be improved, preferably with step-by-step examples to make the calculation accessible to the general public, as required by NEPA.

The underlying assumption to this process is that a linear transform will adequately describe the response to a change in emissions levels. Yet, as acknowledged in the DEIS at 3-52, climate interactions are non-linear. To test the linearity of the change between SRES scenarios, we ran an intermediate scenario in which the input annual carbon emissions were set at the midpoint between B1and A1B. We then plotted the output variables. Examples are shown below. [See original comment document for examples.] The numerical differences between each of the SRES scenarios and the intermediate scenario were not symmetrical. This indicates that climate outputs are not linearly related to emissions levels, violating the assumption of linearity upon which the scaling approach is based.

As acknowledged in the DEIS, the climate system is non-linear. DEIS at 3-52. Thus, it is not surprising that a linear transform between SRES scenarios is an inaccurate approximation of climate response.

Of course, comparing the scaling approach to MAGICC outputs assumes that MAGICC has accurately approximated the dynamics of the climate system. It seems likely, however, that MAGICC is the superior approximation. The MAGICC simulation routine has been extensively used by the IPCC and subjected to peer review. In contrast, no citations are provided in the DEIS that indicate the "scaling approach" has been subjected to similar scrutiny. Thus, the NHTSA should consider the MAGICC outputs more reliable. Furthermore, the DEIS provides no explanation why the "scaling approach" was deemed necessary.

Comment Number: 0572-35
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The scaling approach purports to correct for "overstatements" due to inertia in the climate system. Yet an apparent "bias" is *created* by applying the "scaling approach" from the DEIS. If an accepted model such as MAGICC is employed, the effects of climate inertia will be properly accounted for without being overly represented in the results. Thus, the solution to "overstatements" of climate inertia is to avoid using the scaling approach.

The scaling approach as applied to sea level change uses inaccurate values from Table 3.4-7, the temperature "scaling approach" results. When compared to the results from MAGICC at differing climate sensitivities, the scaling approach results in smaller differences in temperatures between alternatives. This in turn pollutes the results from the sea level scaling approach, making the sea level differences seem smaller.

Comment Number: 0585-9
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

The DEIS does not answer the ultimate question of whether the agency has adequately considered our need to reduce GHG emissions and to stabilize CO_2 concentrations.

In the end, neither the Agency nor the public can assess the impact of the CAFE rule on global warming unless the data are put into a meaningful context, which the DEIS has failed to do. One way to remedy this fundamental defect would be to refer to the various emissions scenarios modeled by the IPCC as a kind of a comparative baseline. These scenarios include the "business as usual" scenario, usually represented by the IPCC's A1B scenario, which assumes rapid economic growth, peak population by 2050, declining thereafter, rapid introduction of new, more efficient technologies, and a balanced use of both fossil and non-fossil fuels. [Footnote: See original comment document. The A1B scenario stabilizes CO_2 concentrations at 720 ppm by 2100 and is associated with additional warming of 2 to 4 degrees Celsius [Footnote: See original comment document.], which puts us well into the region of likely dangerous anthropogenic interference. [Footnote: See original comment document.]

The IPCC's "alternative" scenarios are those in which human inputs to global warming are constrained to varying degrees and the effects of global warming are mitigated to greater and lesser extent. In particular, the B1 scenario will reduce GHG emissions below 1990 levels well before 2100 and will maintain CO_2 concentrations below 550 ppm. [Footnote: See original comment document.] Under this alternative scenario, GHG emissions could continue to increase briefly, but would need to level out quickly, and decline before 2050, in order to allow for the possibility of adaptation that will avoid a catastrophic disruption of life on Earth. In order to stabilize CO_2 concentrations below 450 ppm, emissions would have to be lowered even sooner, with emission levels peaking by 2020 and then declining sharply. Even at this level, scientists predict warming of 2.0 degrees Celsius and sea level rise of half a meter or more by 2100. [Footnote: See original comment document.]

In the DEIS, NHTSA views the IPCC A1B scenario as representing the “no-action alternative.” DEIS at 3-51, 4-24. As noted above, NHTSA simply subtracts the changes in GHG emissions attributable to the various CAFE alternatives from the A1B emissions scenario to determine the effect on CO_2 concentration and temperature. See DEIS at 4-22, 4-51.

This analysis, however, is not meaningful, because it does not inform the reader whether the actions of the Agency, coupled with anticipated actions of other agencies, will be sufficient to change our trajectory from the A1B “no-action” scenario, to the B1 scenario of stabilized CO_2 concentration and temperature. Thus, neither the agency nor the public can determine whether NHTSA has considered and given sufficient weight to the dangers of global warming in setting the CAFE standard at the “optimized” level, rather than at a higher level.

In order to answer the latter question, NHTSA must consider its actions within the context of the steps that are being taken or are reasonably foreseeable to be taken by all agencies, organizations, nations, and localities to prevent CO_2 concentrations in the atmosphere from reaching a level of dangerous anthropogenic interference. As noted above, it is generally agreed that, in order to maintain CO_2 concentrations at the 500 ± 50 ppm level, emissions must stabilize and begin to decline either by 2020 or 2050. Given this consensus, the DEIS should calculate what CAFE mileage standard would have to be reached by those dates, taking into account anticipated increases in VMT, in order to stabilize and reduce GHG emissions from passenger cars and light trucks. The DEIS must then determine whether the new CAFE rule moves us forward sufficiently so that we will be poised to reach the required future goals. If the proposed CAFE rule will not enable us to stabilize and begin to reduce emissions by 2020 or 2050, then what CAFE standard is necessary now to enable us to achieve the future reductions?

Comment Number: 0595-24
Organization: Environmental Protection Agency
Commenter: Susan Bromm

For the emissions scenarios analyzed, EPA would suggest using A2, A1B, A1FI, and B2. We would suggest adding some text indicating that recent socioeconomic and emissions trends are higher than those captured by SRES and even more recent scenarios.

Additionally, EPA has the following questions and comments regarding the climate projections used by NHTSA:

1. Why was the SRES MB chosen as the baseline scenario? How does it compare to current trends? Other potential futures should be considered.
2. What climate sensitivity was used? If only a climate sensitivity of 3 was considered, then NHTSA has ignored the implications for the distribution of potential climate outcomes in 2030, 2060, and 2100.
3. There are inconsistencies in the treatment of climate and other analyses:
    a. NHTSA is using an SRES A1B emissions scenario for climate projections, yet using a mean SCC estimate based on a variety of climate projections;
    b. NHTSA is combining a domestic estimate of the SCC with global climate variables; and

c. NHTSA is using SRES A1B emissions for global climate, yet is using U.S. EPA emissions for transportation which are not consistent with A1B.

Response

For the FEIS analysis, NHTSA used MAGICC Version 5.3. NHTSA also has responded to the suggestions to use multiple scenarios from the Special Report on Emission Scenarios (SRES) to simulate the base case (the No Action Alternative) emissions corresponding to a variety of socioeconomic and emissions trends, and comments suggesting running other baseline scenarios and climate sensitivities (2.5 ºC, 3.0 ºC, and 4.5 ºC) to illustrate the uncertainty of the emissions reductions on key climate effects such as global temperature increase, CO_2 concentrations, and sea-level rise.[23] Section 3.4 of the FEIS incorporates all of these results to show the sensitivity of results to different assumptions on base-case emissions and climate sensitivity. In addition, by definition, the IPCC SRES scenarios exclude any global policy to reduce emissions and avoid climate change but might include other policies that could impact GHG emissions. Even the B1 family of scenarios is defined as follows in the IPCC SRES report: "[t]he emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives." (Nakicenovic et al. 2000).

Regarding attaining stabilization of atmospheric CO_2 concentrations below 500 ppm (or any other target suggested by commenters), GHG reductions in any one sector and any one nation will not be sufficient to stabilize at these levels, and it is clear that none of the alternatives evaluated in the FEIS would meet such an objective. NHTSA recognizes that several approaches have been put forth for developing comprehensive, multi-sector strategies to reduce GHG emissions. However, NHTSA's regulatory authority in the context of this rulemaking is limited to choosing an appropriate CAFE standard, based on the four statutory factors mandated in EPCA. Thus, a comparison of various CAFE alternatives to other GHG mitigation approaches (e.g., those conceptualized as wedges) is beyond the scope of the EIS and the rulemaking.

NHTSA included the scaling approach in the DEIS because MAGICC Version 4.1 did not reflect Fourth Assessment Report science. Because the FEIS uses MAGICC Version 5.3, it eliminates the scaling approach and includes an expanded comparison of MAGICC Version 5.3 and Fourth Assessment Report results.

10.3.3.4 Non-CO_2 GHGs

Comments

Comment Number: 0572-38
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Although the DEIS quantifies CO_2 emissions, it utterly fails to address black carbon, an important short-lived pollutant that contributes to global and regional warming. Black carbon is produced by incomplete combustion and is the black component of soot. Although combustion produces a mixture of black carbon and organic carbon, the proportion of black carbon produced by burning fossil fuels, such as diesel, is much greater than that produced by burning biomass. The CAFE standards will affect both gas and diesel engines, and may result in a higher percentage of diesel-fueled vehicles. Thus, it is essential to consider the impact of the new standards on black carbon emissions.

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[23] *The SRES scenarios are long-term emissions scenarios representing different assumptions about key drivers of GHG emissions. Section 3.4 of the FEIS describes the SRES scenarios in more detail.*

Black carbon heats the atmosphere through a variety of mechanisms. First, it is highly efficient at absorbing solar radiation and in turn heating the surrounding atmosphere. Second, atmospheric black carbon absorbs reflected radiation from the surface. Third, when black carbon lands on snow and ice, it reduces the reflectivity of the white surface which causes increased atmospheric warming as well as accelerates the rate of snow and ice melt. Fourth, it evaporates low clouds. Notably, black carbon is often complexed with other aerosols such as sulfates, which greatly increases its heating potential. (Ramanathan & Carmichael 2008; Jacobson 2001)

Due to black carbon's short atmospheric life span and high global warming potential, decreasing black carbon emissions offers an opportunity to mitigate the effects of global warming trends in the short term (Ramanathan & Carmichael 2008). Black carbon is considered a 'short-lived pollutant'(SLP) because it remains in the atmosphere for only about a week in contrast to carbon dioxide, which remains in the atmosphere for over 100 years. Furthermore, the global warming potential of black carbon is approximately 760 times greater than that of carbon dioxide over 100 years (Reddy & Boucher2007) and approximately 2200 times greater over 20 years (Bond & Sun 2005). It is estimated that black carbon is the second greatest contributor to global warming behind carbon dioxide (Ramanathan & Carmichael 2008).

Unlike traditional greenhouse gases, which become relatively uniformly distributed and mixed throughout the Earth's atmosphere, black carbon exerts a regional influence. The impacts of black carbon on a regional level include both atmospheric heating, as discussed above, and hydrological changes. Hydrological changes occur due to alterations in cloud formation and heat gradients (Ramanathan & Carmichael 2008). For instance, aerosol pollution has been linked to decreases in the summer monsoon season in tropical areas as well as the drought in the Sahel region of Africa (Ramanathan & Carmichael 2008). Black carbon also impacts the drought-fire cycle. The more drought conditions prevail, the more forest fires burn, and the forest fires in turn emit massive quantities of black and organic carbon. The release of these aerosols intensifies the drought effect.

Another impact of black carbon is accelerated snowmelt; for instance, black carbon is likely contributing to the retreat of Himalayan glaciers and the resulting water shortage in areas of Asia (Ramanathan & Carmichael 2008). When black carbon settles on snow, it makes the snow darker so that it absorbs more solar radiation. This directly leads to snow melt. In addition, local atmospheric heating due to black carbon increases the melting rate. These same effects may well be operating on mountain ranges in the U.S. such as the Sierra Nevada, which would reduce water availability throughout California, a highly populated region, at crucial times of the year.

Comment Number: 0572-60
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

NHTSA states, on page 24413 of the NPRM, that "[for] purposes of this rulemaking, NHTSA estimated emissions of vehicular CO_2 emissions, but did not estimate vehicular emissions of methane, nitrous oxide, and hydroflourocarbons. Methane and nitrous oxide account for less than 3 percent of the tailpipe GHG emissions from passenger cars and light trucks, and CO_2 emissions accounted for the remaining 97 percent. Of the total (including non- tailpipe) GHG emissions from passenger cars and light trucks, tailpipe CO_2 represents about 93.1 percent, tailpipe methane and nitrous oxide represent about 2.4 percent, and hydroflourocarbons (i.e., air conditioner leaks) represent about 4.5 percent." Although these emissions make up a relatively small portion of the total greenhouse gas emissions from automobiles, they nonetheless represent large amounts of greenhouse gases and must be included in both the economic and environmental analyses. For example, nitrous oxide emissions with greenhouse gas impacts equivalent to 29 million metric tons of CO_2 are far from insignificant.

Comment Number: 0595-21
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Finally, EPA is concerned that NHTSA has not accounted for non-$C0_2$ GHG emissions changes that would be expected with the policy, e.g., changes in fuel use will bring changes in non-$C0_2$ GHG emissions associated with fossil fuel extraction, production, transportation, refining, and combustion.

Response

NHTSA has added a discussion of black carbon to the FEIS. See Section 3.4.4.4.2. This discussion notes that while MAGICC 5.3 estimates radiative forcing from black carbon, emissions trends for black carbon are assumed to bear a fixed relationship to emissions of SO_2 and cannot be specified separately in the model. The tailpipe emissions factors derived by Volpe using MOBILE6.2 include both "elemental carbon" and "organic carbon" as components of both $PM_{2.5}$ and DPM emissions, although emissions of individual PM components were not estimated or reported separately.

The FEIS includes estimates of methane and nitrous oxide emissions, and the emissions reductions (related to the No Action Alternative) were included in the climate modeling analysis. NHTSA did not estimate emissions from HFCs, which are not expected to change substantially as a result of the CAFE rule. NHTSA has revised Section 3.4.3.1 of the FEIS to make clear that emissions estimates include non-CO_2 gases (CH_4 and N_2O) and include upstream sources of emissions of CO_2 and these non-CO_2 gases. In addition, NHTSA has clarified that the following non-GHGs were also estimated by the Volpe model and accounted for in the climate modeling: SO_2, NO_x, CO, and VOCs.

10.3.3.5 Consequences

Comment

Comment Number: 0585-4
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

The DEIS improperly compares the decrease in growth of emissions from the CAFE rule with the absolute decrease in emissions from the U.S. regional programs, creating a false impression of the benefits of the rule.

The DEIS further misleads the public by setting up a false comparison between the reduction in growth of GHG emissions from the CAFE alternatives, and the absolute decrease in emissions from the climate programs created by groups of states such as the Western Climate Initiative ("WCI") and the Regional Greenhouse Gas Initiative ("RGGI"). DEIS at 3-57, 4-28 to 4-29. For example, in the cumulative impacts section, the DEIS states that the WCI has a goal of reducing CO_2 equivalent emissions by 350 million metric tons ("MMT") from 2009 to 2020, and the CAFE rule will reduce CO_2 emissions by 455-830 MMT over the same time period. The DEIS further states that the RGGI will reduce CO_2 emissions by 268 MMT from 2006 to 2024 and the CAFE rule will reduce CO_2 emissions by 1,100-1,834 MMT over the same time frame. The DEIS therefore concludes that "the alternatives analyzed here deliver GHG emission reductions that are on the same scale as many of the most progressive and ambitious GHG emission reduction programs underway in the United States." DEIS at 4-29.

The above analysis, and in particular, the latter statement, are affirmatively misleading. The regional goals represent absolute reductions from prior levels. In reducing CO_2 equivalents by 350 MMT, the WCI is actually committed by 2020 to bringing its level of emissions 15% below the levels that existed in 2005. See Western Climate Initiative, Statement of Regional Goal, 2007 at 1. [Footnote: See original comment document.] Similarly, the RGGI will result in a 2018 emissions budget that is 10% smaller than the 2009 emissions budget. See Overview of RGGI CO2 Budget Training Program, October 2007 at 2. [Footnote: See original comment document.] In contrast, the emission figures cited by NHTSA as attributable to the CAFE rule actually represent a significant increase above previous levels. In order to be "on the same scale as many of the most progressive and ambitious GHG emission reduction programs underway in the United States," the CAFE rule would have to reduce the level of GHG emissions below existing levels. Clearly, no such reduction is envisioned. In fact, a more accurate statement would be to say that the increase in GHG emissions from previous levels allowed by the CAFE rule would wipe out reductions in emissions achieved by the various regional climate coalitions.

Response

NHTSA has added more analysis to Section 3.4.4.1 of the FEIS to illustrate the change in GHG emissions due to each measure (RGGI and WCI) in terms of percent change from the baseline and percent change from the beginning of each measure. The additional text clarifies that while the RGGI and WCI measures are designed to reduce emissions in relation to both expected future emissions and levels in a base year, the CAFE alternatives reduce emissions from the expected future emissions from cars and light trucks in the United States, and result in continued increases in relation to any given base year that might be chosen. That is, CAFE standards do not reduce GHG emissions from cars and light trucks from base-year emissions levels.

Emissions from cars and light trucks are a function of both fuel economy and vehicle miles traveled. NHTSA's assumptions on growth in future VMT are based on historical trends. Despite the improvement in fuel economy resulting from this rulemaking, the growth in VMT traveled is anticipated to outweigh the improvement in fuel economy, and thus emissions from cars and light trucks are expected to continue increasing.

Nevertheless, it cannot be argued that the alternatives would result in an absolute increase in emissions. Emissions under the alternatives would surely be lower than under the No Action Alternative, and thus, represent a verifiable improvement to the environment.

Comments

Comment Number: 0585-12
Organization: Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, and Oregon, Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, and New York City Corporation Counsel
Commenter: Edmund Brown Jr., Joseph Powers, Martha Coakley, Michael Cardozo, Anne Milgram, Gary King, Andrew Cuomo, Hardy Myers

The DEIS fails to make clear the connection between anticipated CO_2 concentrations and extreme environmental impacts.

The DEIS contains a qualitative discussion in chapter 4 of the potential impacts of global warming, but avoids linking the CAFE rule with particular impacts, noting that the impacts from the rule in isolation are too small to quantify. DEIS at 2-13. While technically correct that the GHG emissions from the CAFE rule in isolation cannot be linked to particular environmental impacts, the DEIS should make clear that the levels of CO_2 concentrations and temperature increase that it anticipates, more than 700 ppm CO_2 and 2.7 degrees Celsius (Table 4.43 at DEIS 4-31), are directly associated with some of the more extreme environmental effects.

One way to explain the connection between the atmospheric concentrations of CO_2 and the increased temperatures anticipated by the DEIS on the one hand, and the real environmental effects on the other, would be to rely on the materials presented by the IPCC. For example, Figure SPM.2 [Footnote: See original comment document.] illustrates graphically how various extreme environmental effects become increasingly likely as temperature rises. Notably, the figure demonstrates that the increase in temperature of 2.7 degrees Celsius anticipated by the DEIS may result in the extinction of more than 20 to 30% of the species on earth, coastal flooding affecting millions of people, increasing burdens from malnutrition and disease, and increased mortality from heat waves, floods, and droughts. This type of graphic representation will, consistent with the purposes of NEPA, enable the reader to understand that, in setting the CAFE standard, NHTSA anticipates that we are potentially on the path to dangerous anthropogenic interference and cataclysmic climate change.

Comment Number: 0596-4
Organization: Environmental Defense Fund
Commenter: Martha Roberts

In this EIS GHG emissions for the CAFE alternatives are presented primarily in terms of the small relative differences among them, instead of the total GHG from the vehicle categories projected for each alternative. This is misleading because it gives the impression that each alternative will progressively decrease the nation's GHG emissions, when in fact, under each alternative total GHG emissions increase considerably compared to the present. Merely demonstrating the relative reductions of stricter alternatives versus "no action" paints a mirage of future benefits that do not exist.

We have conducted a simple analysis that provides this more appropriate contextual information. It demonstrates, for example, that under the "optimized" alternative, atmospheric CO_2 concentrations will increase by approximately 12 ppm by 2100. (This estimation relies upon the cumulative greenhouse gas (GHG) emissions presented in section 4 of the EIS and the assumption that oceans and forests will sequester half of the total GHG emissions. Then each 8,000 MMT CO_2e contributes 1 ppm of atmospheric CO_2e. See the EPA's paper, A Wedge Analysis of the U.S. Transportation Sector (EPA 420-R-07-007, U.S., 2007) for more details.) This is a more appropriate depiction of its impact than showing, as the current EIS does, the tenths of a ppm variation between the different alternatives by 2100. NEPA requires that each proposal, including the "no action" alternative, be considered against the baseline condition so that cumulative impacts, which are defined as both adverse impacts and the enhancement of the environment, can be compared with existing environmental impacts. This comparative analysis is unlawfully omitted from the EIS.

Response

NHTSA included the suggested discussion of impacts from extreme temperature increases from the IPCC Fourth Assessment Report to put the baseline emissions and emissions reductions into context. See Section 3.4.1.4. NHTSA also expanded the discussion of tipping points to address this point. See Section 3.4.3.2.4.

NHTSA disagrees with the interpretation that the Optimized Alternative increases CO_2 concentrations from the baseline. The baseline represents continued increases in emissions from cars and light trucks, consistent with increases in population and income. The CAFE alternatives reduce the CO_2 emissions and concentrations from these levels. The emissions are greater than current emissions, but it is not reasonable to view current conditions as the baseline.

NHTSA added a discussion in this FEIS to better show the emissions reductions from the CAFE standards alternatives as emissions reductions from cars and light trucks in the United States, which shows that it does represent substantial emissions reductions from the transportation emission sector. See Section 3.4.4.1.

10.3.3.6 Sea-level Rise

Comments

Comment Number: 0572-27
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The DEIS cannot rely solely on model results to predict sea level rise. Instead, the prediction should be based on the sea level measurements from paleoclimate data, which indicate that in the past sea level was approximately 25 meters higher at temperatures only 2-3° C of warmer and atmospheric CO_2 concentrations of 350 – 450 ppm. (Hansen 2007). For comparison, the DEIS predicts that temperature in 2100 under the A1B "business as usual" scenario will be approximately 2.7° C warmer. DEIS at 3-63, Table 3.4-5. Although the DEIS acknowledges that Rahmstorf (2007) has predicted a sea level rise of over 1 m by 2100, even his prediction does not capture the non-linearity of ice-sheet loss (Hansen 2007). If this non-linearity is taken into account, "business as usual" sea level rise this century is more likely to be on other order of 5 m (Hansen 2007; Overpeck et al. 2006).

Given the strong scientific evidence that sea level will rise by substantially more than predicted in the IPCC Fourth Assessment report, the EIS's analysis, both qualitative and quantitative, must be adjusted to account for the economic impacts of severe and abrupt climate change. It is certain that sea level will rise significantly this century, and assuredly at a rate much greater than that reported in the DEIS. Regardless of the actual numerical value, the amount of increase will be enough to constitute a major environmental and economic impact. Economic analyses exist to estimate the economic impact of such an event. (Stern 2007) [Footnote: See original comment document.] As a result, the DEIS must include the substantial economic cost in the cost-benefit analysis.

Comment Number: 0572-34
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The example of the scaling approach as applied to sea level and as illustrated in Table 3.4-14 is obscure and impossible to follow. Data appears to be missing from Table 3.4-14 (column 1) and the values do not appear to correspond to the steps outlined on page 3-77. This needs to be clarified so that readers can assess the validity of the numerical results. The value for sea level rise for "no action" corresponds to the midpoint for the B1 scenario (28.0 cm [centimeter]), not the A1B scenario (34.5 cm) that is purportedly represented in Table 3.4-14. If the steps provided on page 3-77 are carried out, it appears that the difference between alternatives for sea level rise is approximately double the range of values reported in Table 3.4-14.

Regardless, the approach itself is deeply flawed. First, using the IPCC estimates of potential sea level rise does not correct the shortcomings in MAGICC. The IPCC did not account for ice sheet dynamics in any of their estimates. As a result, any modeling or scaling attempt will not capture the most important components of sea level rise, as acknowledged in the DEIS at 3-76. As a result any attempt to estimate sea level rise from IPCC data will be deeply flawed. If a scaling approach is to be used, it should be based on paleoclimate data predicting the sea level rise associated with various temperature and CO_2 concentrations.

Response

In Section 3.4.3.2.4 of the FEIS, NHTSA expands its research and consideration of the issue of tipping points to include new research, as suggested by commenters, and expands the discussion from the IPCC and USCCSP literature. NHTSA expands the discussion within the FEIS to include the consideration of paleoclimatic research, which shows that abrupt and severe climate change has occurred in the past, that greater increases in sea-level rise occurred in the past and at temperatures consistent with those being simulated for 2100, and that these climate changes can occur in multiple climate systems or related systems affected by climate. While there is still substantial uncertainty surrounding the exact thresholds where tipping points occur, and the interrelationships among tipping points, scientists are improving their understanding of the processes that determine the potential for abrupt or irreversible change. As noted by commenters, the triggering of abrupt and severe climate-change events could increase the costs to society in an equally abrupt fashion.

Given the current state of science on tipping points, it is not possible for NHTSA to quantitatively relate the reductions in CO_2 emissions, temperatures, precipitation changes, and sea-level rise to tipping-point thresholds. Like all other individual GHG mitigation actions being considered by governments around the world, this action alone, even as analyzed under the most stringent alternative, does not produce enough of a CO_2 emissions reduction to avert levels of abrupt and severe climate change. Abrupt or severe climate change can only be avoided through implementation of many more GHG-reduction initiatives, and will require a global effort. To the degree that the action in this rulemaking reduces the rate of CO_2 emissions, the rule contributes to the general reduction or delay in reaching these tipping-point thresholds. Alternatives that reduce greater amounts of CO_2 contribute a greater degree to the avoidance of any tipping points within global climate systems.

NHTSA included the scaling approach in the DEIS because MAGICC 4.1 did not reflect Fourth Assessment Report science. In the FEIS, NHTSA used MAGICC 5.3 and eliminated the scaling approach, but included an expanded comparison of MAGICC 5.3 and Fourth Assessment Report results.

10.3.4 Resource Impacts of Climate Change

10.3.4.1 Introduction

Comment

Comment Number: TRANS-33-5
Organization: Individual
Commenter: Fred Dobb

Spiritually and ethically, we cannot reduce endangered species, flood and famine refugees, or the integrity of recreation to pennies in an equation, not that the draft EIS even accounts for them at all.

Response

The FEIS discusses the impacts of floods and droughts on the population, both nationally and globally. See Section 4.5.7.1; Section 4.5.7.2; Section 4.5.7.2.1; Section 4.5.8.2.3; and Section 4.5.8.3. While these can certainly be devastating events, the science of directly linking floods and droughts to anticipated changes in climate on the local and regional scale is still developing. A number of endangered species are likewise considered in the DEIS. See DEIS 4.5.4; DEIS p. 4-81, Section 4.5.4.2.3. NHTSA has chosen not to monetize such relationships as the impact upon health and environment because the DEIS and this FEIS focus on changes in, and impacts to, the environment - not on the monetized values of those changes.

10.3.4.2 Industries, Settlements, and Society

Comment

Comment Number: TRANS-37-7
Organization: Individual
Commenter: Jaafar Rizvi

Now, of course, these disasters aren't entirely preventable, but it's within our power to lessen the severity of them.

The DEIS report states that 4 percent of the world's global warming emissions come from American transportation. And if we can lower these emissions by 25 percent, we're lowering the global emissions by 1 percent.

If a decrease in 1 percent could decrease, you know, the severity of the next Katrina by 1 percent, you're talking about saving thousands of lives, and you're talking about saving a billion dollars.

Moreover, we can expect to have more than one large disaster every year. We have been having tons all over the world. Katrina was the last huge one in the U.S. But the International Federation of the Red Cross showed in its 2007 world disaster report that there has been an increase in natural disasters of over 115 percent since 2004, totaling 541 individual disasters. It states that this increase has been due entirely to weather related disasters.

Response

The commenter attempts to establish a causal relationship between global warming and a particular weather event, in this case, Hurricane Katrina. No single weather event can be attributed to global warming, even though global warming can increase the likelihood of some extreme weather events. Because of this and the non-linear nature of global warming, it is not possible to make the connection the commenter tries to make by attributing a reduction in the strength of a storm to an equal reduction in CO_2 emissions. Further, the relationship between emissions levels and weather-related natural disasters is not clear. The state of scientific knowledge is not sufficient at this time to determine how weather-related disasters would be affected by the action alternatives, other than to state that the reduction in CO_2 emissions estimated by this rulemaking would contribute to the reduction of impacts of global warming, including severe weather events.

10.3.4.3 Human Health

Comments

Comment Number: 0596-3
Organization: Environmental Defense Fund
Commenter: Martha Roberts

The cumulative impacts section in this EIS fails to provide the proper context to evaluate the climate change potential or consequent health impacts of the proposed fuel efficiency standards. In omitting this context NHTSA directly contradicts the Court's instructions in *Center for Biological Diversity v. NHTSA* regarding the agency's obligation to address cumulative impacts under NEPA, explaining that the environmental review must:

"provide the necessary contextual information about the cumulative and incremental environmental impacts of the Final Rule in light of other CAFE rulemakings and other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions." [Footnote: See original comment document.]

The EIS draws heavily upon the most recent Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report in describing the causes of climate change and its impacts on the environment and human welfare. However, the EIS ignores the strong language in the IPCC report that describes appropriate, science-based targets to avoid the most drastic of these impacts. For example, the IPCC states that "avoidance of many key vulnerabilities requires temperature change in 2100 to be below 2.6 °C above pre-industrial levels." [Footnote: See original comment document.] Key health-related vulnerabilities include the risk of floods, droughts, and deteriorating water quality and supply for hundreds of millions of people. [Footnote: See original comment document.] Rising global temperatures increase the likelihood of severe weather events, net declines in world food production, and widespread deglaciation with the resultant loss of reliable summer melt stream flows, all detrimental to human health. In order to avoid passing this dangerous temperature threshold, the IPCC indicates that GHG emissions must peak within 10 years (of 2007) and atmospheric carbon dioxide (CO_2) levels stabilize at less than 440 parts per million (ppm). This corresponds to a 30-60% reduction in global GHG emissions by the year 2050 from the year 2000. [Footnote: See original comment document.]

The type of risk management approach, which seeks a reasonable target to avoid severe health, environmental, and other impacts of dangerous climate change, has been proposed by the EPA in its recent "Technical Support Document on the Benefits of Reducing GHG Emissions" and summarized by Environmental Defense Fund in its supplemental comments on the NPRM for the CAFE standards. These comments are attached here and we hereby incorporate them as part of EDF's [Environmental Defense Fund's] comments on the draft EIS.

Comment Number: 0600-5
Organization: Centers for Disease Control and Prevention
Commenter: Sarah Heaton, Andrew Dannenberg

The anticipated effects of increased CAFE standards on the human environment in the United States will occur primarily through the following mechanisms: 1) Fleet emission changes 2) Fuel consumption changes 3) Fleet design changes. To adequately assess the potential impact of CAFE standards on the human environment:

Health impact analysis and modeling of each mechanism is necessary for each of the proposed alternatives.

Fleet Emission Changes and Human Health:

Transportation-related emissions contribute to climate change. CAFE standards can promote the use of alternative technologies in the U.S. and abroad that reduce harmful emissions and, in turn, reduce contributors to climate change and improves human health outcomes. Although some health outcomes of climate change are difficult to predict, others are supported by considerable evidence. Health impacts affected by increasing or reducing contributors to climate change are appropriate for analysis of the human environment pursuant to NEPA.

Health outcomes from climate change, for which quantitative or qualitative impact analysis is possible, should be included in predictive modeling.

Automobile contributions to criteria air pollutants are affected by CAFE standards and such emissions directly affect human health outcomes. Asthma, bronchitis, chronic obstructive pulmonary disease, and cardiovascular disease are some of the most common health outcomes triggered or exacerbated by air pollutants from motor vehicles. Reducing ozone forming emissions, NO_x, and hydrocarbons can improve human health outcomes and reduce medical care costs. The DEIS fails to discern among alternatives regarding the health impacts from emissions/air pollutants. For adequate analysis of impacts to the human environment pursuant of NEPA:

Analysis of the potential health effects from fleet emissions, both acute and chronic, is critical to include in the analysis of alternatives pursuant to NEPA.

Adequate cost/benefit analysis of alternatives should include health costs associated with the acute and chronic effects from auto emissions at each level in the range of alternatives to show both current associated costs and potential savings from reduced emissions.

Comment Number: 0600-10
Organization: Centers for Disease Control and Prevention
Commenter: Sarah Heaton, Andrew Dannenberg

The anticipated effects of increased CAFE standards on the human environment in the United States will occur primarily through the following mechanisms: 1) Fleet emission changes 2) Fuel consumption changes 3) Fleet design changes. To adequately assess the potential impact of CAFE standards on the human environment health impact analysis and modeling of each mechanism is necessary for each of the proposed alternatives.

Fuel Consumption Changes and Human Health:

Decreased demand and consumption of fossil fuel in an environment of increasing costs likely affects economic stability which affects human health outcomes (e.g. “drive or eat”). These health determinants and potential health outcomes should be considered as factors affected by CAFE standards and discussed.

Comment Number: TRANS-32-1
Organization: Environmental Defense Fund
Commenter: James Keck

EDF, while supporting the inclusion of climate change health impacts within the EIS is deeply concerned by the assertion that the agency and its consultants were unable to determine the magnitude of these impacts across the proposed CAFE alternatives, not only on the basis of climate change, but also regarding conventional pollutant health impacts.

Response

Quantifying the impacts of climate change on human health is a complex analysis requiring a thorough understanding of not only the direct impacts of varying each climate stressor on human health, but the indirect impacts associated with multiple climate stressors. The complex ecosystem response further amplifies the potential feedbacks of climate change on human health, making it very difficult to adequately quantify this relationship. This would require significant health and environmental modeling, which could provide results with a large amount of uncertainty and which might rely on science still under development. EPA notes in its comments on the DEIS that a "complete health and environmental impacts analysis would begin with a full scale photochemical air quality modeling to demonstrate the changes in ambient air pollution exposure…. These ambient concentrations would then be fed through a health impacts model…to characterize population exposure and the change in health response…." Furthermore, the CCSP 2008 report entitled "Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems" notes that, "the body of literature [on health impacts of climate change] remains small, limiting quantitative projections of future impacts." It also notes that there is still a need to "[d]evelop quantitative models of possible health impacts of climate change that can be used to explore a range of socioeconomic and climate scenarios." Instead, NHTSA describes the impacts by providing a thorough qualitative description of the current "state-of-the-art" science linking climate change impacts to human health. NHTSA also discusses peer-reviewed studies based on modeling and other rigorous tools that link climate change impacts to human health.

Sections 3.3.1.2, 3.3.1.3, 3.5.4, and 4.5.8 of the FEIS describe impacts to human health. In addition, Section 3.4.3.2.4 of the FEIS includes a discussion of tipping points to describe the most drastic impacts of climate change.

10.3.5 Non-Climate Cumulative Impacts of CO_2 Emissions

10.3.5.1 Consequences

Comment

Comment Number: 0572-36
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The DEIS ignores one of the major, direct impacts of increased atmospheric CO_2: ocean acidification. Carbon dioxide is readily exchanged between the atmosphere and the sea surface. The increase in CO_2 is a direct result of human activity—fossil fuel burning. Due to the fact that the ocean has a carbonate buffer system, an increase in aqueous CO_2 reduces the concentration of carbonate while increasing the concentration of bicarbonate. The direct result is a decrease in ocean pH.

The reduction in free carbonate ions harms organisms that form calcium carbonate shells. There is a profound impact on the *entire* marine ecosystem due to the fact that many calcifying plankton, the basis of the food web, are severely affected by ocean acidification. Furthermore, organisms such as fish also experience direct effects from increased ocean CO_2, which include metabolic, immune, and reproductive dysfunction.

There is an extremely high level of scientific consensus regarding the destructive effects of ocean acidification. A recent comment letter signed by the top 25 marine scientists who study ocean acidification emphasized that the decrease in pH due to un-checked CO_2 emissions will be devastating and irreversible on human time scales (Caldiera and 25 others, 2007).

Ocean acidification has also been recognized by advisory bodies. For instance, the USCOP characterizes climate change as "among the most pressing scientific questions facing our nation and the planet." (USCOP Ocean Blueprint 2004). Furthermore, the USCOP report states that ocean acidification is impairing some organisms and has "potentially profound impacts on marine production and biodiversity" (USCOP Ocean Blueprint 2004). The resulting recommendation is that scientific information be used to modify management strategies. Likewise, the Pew Commission discussed the myriad effects of climate change on marine life, including changes in ocean chemistry. The report stated that the Commission "feels strongly" that the U.S. must reduce its emission of greenhouse gases to limit injury to the marine environment (Pew Oceans Commission Living Oceans 2003).

The oceans have already taken up about 40% of the CO_2 that humans have produced since the industrial revolution, and this has lowered the average ocean pH by 0.11 units (Sabine et al. 2004). Although this number may sound small, it represents a significant change in acidity. The ocean takes up about 30 million metric tons of CO_2 each day (Feely et al., 2008). While pre-industrial levels of atmospheric CO_2 hovered around 280 ppm (Orr et al. 2005)), they have now increased to 380 ppm; if current trends continue they will increase another 50% by 2030 (Turley et al., 2006). Over time, the ocean will absorb up to 90% of anthropogenic CO_2 released into the atmosphere (Kleypas et al. 2006).

Unlike future climate change, the pH change in response to increased atmospheric CO_2 is relatively easy to predict because it involves basic chemical reactions and is unlikely to be affected by global temperature change (McNeil & Matear 2006). Thus, there is a strong consensus in the field that the oceans will undergo extensive acidification as the atmospheric CO_2 concentration rises.

Studies have established that anthropogenic CO_2 is the direct cause of the decrease in ocean pH. For instance, a tracer technique can be used to separate naturally occurring and dissolved carbon from that due to human activity (Gruber et al. 1996). Oceans absorb CO_2 more slowly than humans are currently releasing it. Current levels of anthropogenic CO_2 have virtually guaranteed that ocean pH will continue to decrease in the foreseeable future. Anthropogenic CO_2 emissions will result in a decrease in oceanic pH of 0.4 units by 2100 according to a model based on "business as usual" IPCC scenarios (Caldeira & Wickett 2003). This would constitute a catastrophic pH level (Zeebe et al. 2008). Disastrous impacts to marine ecosystems can only be avoided with rapid reductions in CO_2 emissions (Zeebe et al. 2008).

Despite the strong scientific consensus and direct connection between CO_2 emissions and oceanic pH, the DEIS treats ocean acidification as an indirect, cumulative impact. This is unacceptable. The ecological impacts of the proposed CAFE standards on ocean acidification must be fully analyzed. Ocean acidification is even more predictable than changes in temperature or sea level rise, for instance. Yet, the DEIS makes no effort to quantify the influence of the alternatives on ocean pH.

Response

Section 4.7.2.1 of the FEIS includes a discussion of ocean acidification. In addition, Section 4.7.1 describes a projected decrease in ocean pH.

10.3.6 Other Potentially Affected Resources Areas

10.3.6.1 Biological Resources

Comment

Comment Number: 0572-44
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The rulemaking will impact listed species in ways beyond global warming and ocean acidification. For example, vehicles are a primary source of excess nitrogen in the environment. Excess nitrogen contributes to major environmental problems including reduced water quality, eutrophication of estuaries, nitrate-induced toxic effects on freshwater biota, changes in plant community composition, disruptions in nutrient cycling, and increased emissions from soil of nitrogenous greenhouse gases (Fenn et al. 2003). Nitrogen deposition therefore impacts species listed under the Endangered Species Act in a number of ways.

Nitrogen deposition has contributed to the severe decline of the threatened bay checkerspot butterfly, endemic to the San Francisco Bay Area. (Fenn et al. 2003) The bay checkerspot butterfly is restricted to outcrops of serpentine rock which are low in nitrogen and support a diverse native grassland with more than 100 species of forbs and grasses, including the butterfly's host plants. (Fenn et al. 2003) Nitrogen deposition in the soil creates a more hospitable environment for non-native grasses which crowd out the butterfly's host primary host plant, *Plantago erecta*. (Fenn et al. 2003)

Response

Sections 3.5.1 and 3.5.2 of the FEIS acknowledge the influence of petroleum combustion in the introduction of nitrogen to waterbodies and terrestrial ecosystems, and the negative effects of this introduction on aquatic and terrestrial habitats. Additionally, NHTSA has expanded the text in Section 3.5.2.1.4 to mention the potential influence of nitrogen and other air pollutants on sensitive species and habitats. As stated in Section 3.5.2, NHTSA continues to believe that the proposed rule will minimally affect the deposition of nitrogen and resulting impacts to water and biological resources. See *Section 3.3 and Appendix B-1 for more discussion of changes in air-pollutant levels.*

Comments

Comment Number: 0572-43
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

On May 15, 2008, the U.S. Fish and Wildlife Service listed the polar bear as a threatened species throughout is range due to global warming. Endangered and Threatened Wildlife and Plants, Determination of Threatened Status for the Polar Bear (*Ursus maritimus*) Throughout its Range, 73 Fed. Reg. 28212-28303 (May 15, 2008). The NHTSA must consult on the impact of its rulemaking, and its proposal to set fuel economy standards far below what is technologically achievable, on the polar bear. (At the same time that the Secretary published the Final Listing Rule he also issued separate regulations, pursuant to Section 4(d) of the ESA, 16 U.S.C. § 1533(d), which authorize the widespread incidental take of polar bears and purport to exempt greenhouse gas pollutants from Section 7's consultation requirements. Endangered and Threatened Wildlife and Plants, Special Rule for the Polar Bear, 73 Fed. Reg. 28306-28318 (May 15, 2008) ("4(d) Rule"). In a section of the 4(d) Rule entitled "Consultation under Section 7 of the ESA," the Secretary alleges that "the best scientific data currently available does not draw a causal connection between GHG emissions resulting from a specific Federal action and effects on listed species or critical habitat by climate change, nor are there sufficient data to establish the required causal connection to the level of reasonable certainty between an action's resulting emissions and effect on species or critical habitat." 73 Fed. Reg. 28306, 28313. NHTSA must not rely on this rule as an excuse to forgo consultation because it is contrary to the best available science and the legal standards for Section 7 consultation. Moreover, exempting greenhouse gas emitting actions from Section 7 cannot be legally accomplished through section 4(d) of ESA. The Center and co-plaintiffs are currently challenging the 4(d) rule in court. See, e.g. Second Amended Complaint in *Center for Biological Diversity v. Kempthorne*, Civ. No. 08-1339 (CW) (N. Dist. Cal.).)

On May 9, 2006, the National Marine Fisheries Service listed the staghorn and elkhorn corals as threatened due in part to increasing ocean temperature and ocean acidification due to anthropogenic greenhouse emissions. 71 Fed. Reg. 26852. The NHTSA must consult on the impact of its rulemaking on these coral species. The NHTSA must also consult on the impact of its rulemaking on the polar bear's and the corals' critical habitat, once such habitat is designated.

Global warming was cited by the U.S. Fish and Wildlife Service in its critical habitat rulemakings for the Quino Checkerspot and Bay Checkerspot butterflies. See 73 Fed. Reg. 3328-3373 and 72 Fed. Reg. 48178-48218. The NHTSA must consult on the impact of its rulemaking on these species and their critical habitat.

The NHTSA must not limit its consultation, however, to species like the polar bear, corals, and checkerspot butterflies for which anthropogenic greenhouse emissions were cited as a reason for listing or as an impact in the listing or critical habitat rules. The Center has identified 143 listed species for which a recovery plan has been adopted that specifically identifies climate change or a projected impact of climate change as a direct or indirect threat to the species, as a critical impact to be mitigated, as a critical issue to be monitored, and/or as a component of the recovery criteria. [See Exhibit A in original comment document.] This is clear evidence that the NHTSA's rulemaking "may affect" these species. The NHTSA must consult on the impact of its action all listed species which may be affected.

While we are cognizant that federal agencies, for the most part, have not to date been complying with their obligation to consult on the impact of their greenhouse gas emissions on listed species, and therefore there may be some capacity building required for this consultation, this can in no way be used an excuse for continued non-compliance with the law. The direct, indirect, and cumulative impacts of setting fuel economy standards for all cars and light trucks nationally are extraordinarily significant, and therefore a large number of species may be implicated. Where, as here, the NHTSA's rulemaking is national in scope, the NHTSA should conduct a nationally focused consultation. Again, the NHTSA must not attempt to use the large scale of its action as an excuse for ignoring its environmental review duties, since the highly significant nature of the action only makes it more important to thoroughly review its impacts under all applicable laws. Nor can the mere fact that a large geographical area or large number of species be used as an excuse for inaction. See, e.g., *Wash. Toxics Coalition v. EPA*, 413F.3d 1024 (9th Cir.

Wash. 2005) (upholding order requiring the EPA to consult on the impact of 54 pesticide ingredients on 25 species of fish.). If anything, a nationally focused consultation will provide the opportunity to most efficiently analyze the impact of the rulemaking on species and groups of species.

Comment Number: 0572-42
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The NHTSA's rulemaking will impact species listed as threatened and endangered in several ways, yet the NHTSA has failed to initiate the required Section 7 consultations with the Services [U.S. Fish and Wildlife and National Marine Fisheries Services] on its impact. The NHTSA must initiate and complete the required Section 7 consultations on the rulemaking, or it may be held liable for take of listed species from the impacts of its action, including increased greenhouse gas emissions and other emissions such as NO_x.

Comment Number: 0572-48
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Setting fuel economy standards for U.S. automobiles is one of the single greatest actions impacting overall greenhouse gas emissions in this country. NHTSA's regulations authorize billions of metric tons of CO_2 and other greenhouse gas emissions over the lifetime of the vehicles. As such, NHTSA must initiate consultation with the FWS and NMFS on the impact of the greenhouse gas and other air pollutants on listed species. Without a non-jeopardy biological opinion and incidental take statement, NHTSA may be liable for take of listed species from increased greenhouse gas emissions and global warming that result from the NHTSA's action. Additional information on the requirement for NHTSA to conduct an ESA Section 7 consultation is contained in Attachment 2 [See original comment document for attachment.], consistent with NHTSA's request to limit primary comments to 15 pages or less. 73 Fed. Reg. 24476.

Response

The CBD submitted comments asking NHTSA to complete a Section 7 consultation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service because, according to CBD, NHTSA's action will impact endangered species. Specifically, CBD argues that NHTSA's action is responsible for "…increased greenhouse gas emissions and other emissions such as NO_x." NHTSA's action actually reduces the rate of emissions by increasing fuel economy, evidenced by overall (tailpipe and upstream) decreases in emissions of NO_x, $PM_{2.5}$, SO_x, VOC, DPM, benzene, and 1,3-butadiene. However, in the FEIS, NHTSA estimates that VMT will increase over time as the per-mile costs decrease (called the rebound effect). Consequently, the Nation's total car and truck emissions are expected to increase. To be accurate in calculating future scenarios, NHTSA must account for this factor, even if the amount of automobile use is beyond NHTSA's control.

Federal agencies are responsible for determining whether consultation on their proposed actions is required. To make this determination, an agency examines the direct and indirect effects of its proposed action to see if the action "may affect" a listed species. For indirect effects, the impact to the species must be later in time, must be caused by the proposed action, and must be reasonably certain to occur.[24]

[24] *Letter from the Director of the Fish and Wildlife Service to the Regional Directors regarding "Expectations for Consultations on Actions that Would Emit Greenhouse Gases" dated May 14, 2008.*

All of the action alternatives analyzed in this FEIS show a reduction in emissions of CO_2, NO_x, $PM_{2.5}$, SO_x, VOC, DPM, benzene, and 1,3-butadiene compared to the No Action Alternative. The FEIS also quantifies the resulting decreases in sea-level rise, changes in precipitation, and temperature decreases for each of the alternatives from decreasing CO_2 emissions. NHTSA then qualitatively discusses the impacts to ecosystems, ocean acidification, natural resources, wildlife, and many other factors. Because it is beyond the ability of current modeling and the level of uncertainty is very high, it is not possible to quantitatively calculate the effects of this CO_2 reduction on specific localized ecosystems. NHTSA discussed the issue with the U.S. Fish and Wildlife Service to ensure proper compliance. Without sufficient data to establish the required causal connection (to the level of reasonable certainty) between the proposed rulemaking, GHG emissions, and the subsequent impacts to listed species or critical habitat, Section 7 consultation is not required.

10.3.6.2 Land Use and Development

Comment

Comment Number: 0595-8
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Finally, the DEIS states that impacts to land use and development "could include increased agricultural land use" due to increasing use of biofuels. Increased mining is also a potential impact as the search grows for raw materials to create new lightweight materials and hybrid structures. Mining and related land disturbance activities could also have an impact on water resources and aquatic health, particularly where increasing sediment runoff in rivers and streams is an issue.

Response

NHTSA has revised Sections 3.5.1 through 3.5.3 and Section 3.5.5 to include a discussion of mining and related land disturbances.

10.3.6.3 Need for Additional Health Impacts Analysis

Comments

Comment Number: 0595-26
Organization: Environmental Protection Agency
Commenter: Susan Bromm

Also, the $/ton source needs to be cited throughout the document and characterized appropriately. EPA used these $/ton estimates in its ozone NAAQS analysis to *supplement* the formal health impacts analysis — they were not used as a substitute for that analysis.

In light of these observations, EPA recommends the text be revised as follows:

> "NHTSA's analysis of alternative CAFE standards incorporates the economic value of reduced damages to human health that would result from the reductions in emissions of criteria air pollutants and GHGs estimated to result from each alternative. These reductions in damages to human health are valued using estimates of damage costs per unit of emissions of each pollutant that approximate the chemical composition

> and geographic distribution of emissions generated by motor vehicle use arid by production and distribution of transportation fuels.
>
> "The dollar-per-ton estimates only provide a screening-level approximation of the potential value of health improvements associated with each alternative. They are not meant to replace a formal health impacts analysis that quantifies and monetizes health incidence such as premature mortality, chronic bronchitis, and respiratory and cardiovascular illnesses, but instead provide an estimate of health-related benefits in the absence of a formal analysis. It should also be noted that the monetized benefits associated with criteria pollutant reductions underestimate total benefits because the dollar-per-ton values used in this analysis omit a number of unquantified human health and environmental impacts.
>
> "The dollar-per-ton estimates used in this analysis were developed by EPA for use in a supplemental analysis of the benefits associated with the final ozone NAAQS RIA [NHTSA should insert the following footnote: U.S. Environmental Protection Agency. August 2007. Benefit Per Ton Technical Support Document, Docket No. EPA-HQ-OAR-2006-0834, Proposed Regulatory Impact Analysis (RIA) for the Proposed National Ambient Air Quality Standards for Ozone Prepared by: Office of Air and Radiation, Office of Air Quality Planning and Standards.]. Human health is further discussed in Chapters 3 and 4."

Comment Number: 0600-1
Organization: Centers for Disease Control and Prevention
Commenter: Sarah Heaton, Andrew Dannenberg

So that comprehensive impact analysis of the human environment for CAFE standards might be carried out and adequately considered in the assessment:

- Collaboration with public health professionals is suggested for assessment and analysis of the CAFE standards' human health impacts.
- Economic analysis should include health costs associated with the environmental impacts of alternatives. This should be described in the EIS.
- Mitigation analysis for projected public health outcomes is necessary. Current mitigation analysis in the DEIS is insufficient.

Response

Two federal agencies commented on the human health discussions in the DEIS. EPA stated that NHTSA did not perform a complete health analysis. Rather than calling for additional analyses, however, EPA suggested clarifying language be inserted in the text that would explain the level of analysis performed. In particular, EPA notes that a "complete health and environmental impacts analysis would begin with a full scale photochemical air quality modeling to demonstrate the changes in ambient air pollution exposure…. These ambient concentrations would then be fed through a health impacts model…to characterize population exposure and the change in health response…." EPA provided text that explains what analysis NHTSA did and did not perform. By contrast, CDC called for more extensive modeling analysis, recommending that economic analysis of health costs be included and commenting that mitigation analysis is necessary. The CDC draws on the wedge analysis described by

Pacala and Socolow in Science magazine in 2004. CDC also provided specific recommendations regarding human health impacts associated with changes in fleet emissions, fuel consumption, and fleet design. See Sections 10.3.2.4, 10.3.4.3, and 10.3.6.4, which address these specific suggestions.

Sections 3.5.4, 3.3.1.2, 3.3.1.3, and 4.5.8 of the FEIS discuss impacts to human health. NHTSA has provided a thorough description of how emissions can affect human health, specific assessments of the changes in emissions due to the new CAFE standards, and discussions of the impacts to human health from direct, indirect, and cumulative impacts perspectives based on information from IPCC and USCCSP. NHTSA has enhanced the information by including data on the potential health costs reduced under each of the alternatives. See Sections 3.3.2.4.2 and 4.3.3.2.3.

NHTSA appreciates and adopts the language EPA suggested to clarify the level of health analysis performed in Section 3.3.2. NHTSA also notes EPA's description of the extensive photochemical exposure and health analysis that would be required to conduct a full-scale health-impacts analysis.

NHTSA believes that this is a better approach than attempting to conduct more extensive health impacts analysis. The differences in emissions reductions (GHGs and air pollution) and in health costs avoided among the alternatives provide ample information for the decisionmaker, as required under NEPA. It is reasonable to anticipate that human health impacts will mirror these indicators. The information to be gained through the very extensive process of health modeling would not add substantial new information, because the differences in estimated climate effects (temperature, precipitation, and sea-level rise) are small; therefore, changes in the health impacts related to these effects would also be small. Further, the differences between the alternatives will be smaller still, due to the global nature of the problem. Similarly, the screening-level analysis of avoided health outcomes and avoided health costs of criteria pollutants among the alternatives provide ample information for the decisionmaker. Additional levels of analysis would on the other hand introduce substantial new uncertainties as each new level of analysis depends on the previous analysis. Thus existing uncertainties are magnified by multiple levels of analysis.

Section 3.4 describes the climate effects and shows that temperature differences between the alternatives are within 0.02 ºC; differences in precipitation are within 0.02 percent; and sea-level rise is within 0.02 to 0.11 centimeter across the alternatives. In fact, NHTSA does not believe that it is possible to credibly estimate the differences between the alternatives, as discussed in Section 4.4 (Cumulative Impacts). This is supported by the USCCSP 2008 report entitled "Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems." This report, which is one of just 21 "priority" Synthesis and Assessment Products issued by the U.S. Government, notes that, "the body of literature [on health impacts of climate change] remains small, limiting quantitative projections of future impacts." The report also notes that there is still a need to "[d]evelop quantitative models of possible health impacts of climate change that can be used to explore a range of socioeconomic and climate scenarios."

To address CDC's request for additional economic/health impacts analysis, NHTSA has provided more information regarding the health effects due to emission of criteria air pollutants. Specifically, NHTSA has expanded the discussion in Sections 3.3.2.4.2 and 4.3.3.2.3 to include estimates of the economic costs and benefits due to asthma, bronchitis, pulmonary disease, and cardiovascular disease. This analysis is limited to the criteria air pollutants because per-unit health damage estimates are not available for MSATs.

In suggesting further modeling, CDC cites the wedge analysis by Pacala and Socolow (2004) and might, therefore, misconstrue the action NHTSA is taking. NHTSA's action is limited to the CAFE rulemaking. The proposed rulemaking would result in substantial reductions in GHG emissions from *passenger cars and light trucks in the United States, which, when considered in a global context, would result in small changes in temperature, precipitation, and sea-level rise. Under NEPA, this is the action that must be evaluated for environmental impacts. The FEIS does not, and should not, in NHTSA's opinion, account for other emissions-reduction strategies beyond what is reasonably foreseeable, as required under NEPA. Because the United States has not established in law or regulation other emissions-reduction strategies (except the MY 2016-2020 CAFE targets specified in EISA), including presumed improvements in energy efficiency would be speculative. Therefore, NHTSA continues to believe that the appropriate context for analysis of human health impacts is limited to the reduction in emissions resulting from the alternatives specified in the proposed rule.*

Finally, CDC suggested inclusion of health expertise in development of the FEIS. An expert in the area of health research and analysis has been added to the consultant team assisting NHTSA on this effort.

10.3.6.4 Vehicle Downweighting

Comments

Comment Number: 0530-1
Organization: Individual
Commenter: Dale Olson

I find it truly amazing that in the past when environmental rules were promulgated EPA justifies them with health risks and estimates of deaths. In the case of fuel economy you are disregarding this very concern. To achieve high fuel economy standards vehicles will be made of lighter less strong materials which will make the vehicles less safe and significantly increase highway fatalities. I find it disingenuous that in this case human health can be discounted.

Comment Number: 0554-5
Organization: Individual
Commenter: James Adcock

NHTSA continues to misinterpret the results of Kahane exactly backwards. Kahane's studies illuminate nothing about how manufacturers might actually design new vehicles to achieve higher furl economy. For hypothetical example a vehicle redesigned to have a carbon fiber body with the same stiffness but lower weight might have higher fuel economy AND greater safety. We don't know. Nothing in the Kahane studies comes close to addressing these kinds of engineering design tradeoffs. But on the contrary, Kahane does well-model the scenario where in the face of high gas prices consumers are on average forced within an existing market mix of vehicles to purchase slightly smaller vehicles in order to achieve affordable fuel economy when facing a market where NHTSA and Manufacturers have failed to provide vehicles with fuel economy matching market gas prices. NHTSA then, should be looking to Kahane to illuminate the excess deaths caused to consumers when NHTSA sets fuel economy standards too weak in the face of high gas prices. Such a failure to regulate, and the excess deaths that result, represent a direct failure of NHTSA to meet its primary mandate of Highway Safety. Weak fuel economy standards equals excess traffic deaths. Not the other way around. Consumers need to be able to buy the fuel economy they need in the vehicle size they want without being forced to downsize due to NHTSA setting fuel economy standards that are too weak. Continuing to read Kahane "backwards" results in setting GHG emissions standards too high.

Comment Number: 0572-63
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The NPRM, on page 24359, states that a 2002 report by a committee of the National Academy of Sciences "cautioned that the safety effects of downsizing and downweighting are likely to be hidden by the generally increasing safety of the light-duty vehicle fleet. It said that some might argue that this improving safety picture means that there is room to improve fuel economy without adverse safety consequences; however, such an approach would not achieve the goal of avoiding the adverse safety consequences of fuel economy increases." However, this misrepresents the findings of the report by omitting the findings that weight reduction for vehicles greater than 4,000 lbs. curb weight would result in a safety benefit, as was discussed in detail in the recent Ninth Circuit opinion. [Footnote: See original comment document.] Omitting the benefits of weight reduction skewed the development of the CAFE standards toward lower efficiency vehicles.

Comment Number: 0576-32
Organization: Public Citizen
Commenter: Joan Claybrook

NHTSA's unfounded position on weight reduction reinforces the common myth that fuel economy standards reduce vehicle safety by promoting downweighting. The agency says directly in its notice "[b]ecause downweighting is a common compliance strategy, and because the agency believes that downweighting of lighter vehicles makes them less safe, our model does not rely on weight reductions to achieve the standards for vehicles under 5,000 pounds GVWR and then only up to 5 percent." Downweighting of lighter vehicles has actually never been a common compliance strategy. When NHTSA implemented its first fuel economy standards in the 1980s, 85 percent of fuel economy gains were made by adding fuel saving technologies, and only 15 percent came from weight reductions, and then weight was only removed from the heaviest vehicles. [Footnote: See original comment document.]

NHTSA relies on a 2003 study by Charles Kahane to justify not considering weight reduction as a compliance strategy for vehicles under 5,000 pounds GVWR (73 FR 24456.) Kahane's study oversimplifies the relationship between weight and safety, obfuscates findings which show that reducing weight from only the *heaviest* vehicles actually improves safety, and overlooks the relationship between the *difference* in vehicle weight, rather than simply the weight of the vehicle. [Footnote: See original comment document.] NHTSA has taken the position that improving fuel economy by reducing vehicle weight poses an unconscionable threat to highway safety, largely based on the Kahane study and Crandall-Graham analysis cited above. [Footnote: See original comment document.] The auto industry opposes a focus on extensive weight reduction because pickup trucks and SUVs have been their cash cows.

One way of thinking about the impact of fuel economy and safety is in terms of compatibility and aggressivity of a given vehicle in a two-vehicle crash. "Compatibility" refers to how well one vehicle matches with another in a crash, and "aggressivity" roughly describes how harmful a vehicle is to occupants of a struck vehicle in a two-vehicle crash. [Footnote: See original comment document] There are several vehicle attributes which describe vehicle compatibility and aggressivity, such as weight, bumper overlap, vehicle geometry, including bumper height and average height of force, and front-end stiffness. (S. 357 of the 110th Congress, the "Ten in Ten Fuel Economy Act," introduced by Sen. Dianne Feinstein on January 22, 2007 included a provision which would have required NHTSA to establish a compatibility and aggressivity reduction safety standard to promote improved vehicle compatibility. While this language was not included in the Energy Independence and Security Act, Public Citizen recommends that NHTSA develop a compatibility and aggressivity standard.] NHTSA's position on fuel economy and safety is inconsistent with its own research on incompatibility.

The agency claims that the restructured CAFE scheme will improve safety by "eliminating the regulatory incentive to downsize vehicles." (71 FR 17568) But NHTSA ignores the impact that the light truck loophole has already had on safety through increased incompatibility, and fails to address the problem by providing no regulatory incentive for automakers to build more compatible light trucks, or by amending the regulatory definitions of cars and light trucks to close this dangerous and wasteful loophole. NHTSA says "by raising the light truck standards . . . there is no regulatory incentive from the CAFE program to design small vehicles as light trucks instead of passenger cars." This overlooks the fact that the new standards do not close the light truck loophole. It sets lower standards for larger vehicles, and eliminates the leveling effect of the corporate average (that is, balancing lighter vehicles against heavier ones). [Footnote: See original comment document]

Comment Number: 0600-11
Organization: Centers for Disease Control and Prevention
Commenter: Sarah Heaton, Andrew Dannenberg

The anticipated effects of increased CAFE standards on the human environment in the United States will occur primarily through the following mechanisms: 1) Fleet emission changes 2) Fuel consumption changes 3) Fleet design changes. To adequately assess the potential impact of CAFE standards on the human environment:

Health impact analysis and modeling of each mechanism is necessary for each of the proposed alternatives.

…Vehicle safety is a public health concern. Appropriate vehicle design as well as decreasing vehicle fleet disparities in size and weight can act to decrease crash-related injury to those driving lighter-weight automobiles and trucks as well as other modes of transportation such as bicycles, motorcycles, and scooters. Changing CAFE standards will affect fleet design and therefore have the potential to increase or decrease crash-related injury. Potential fleet design and composition by which vehicle manufacturers will comply with new CAFE standards warrants comprehensive analysis. Modeling these projections is critical to an adequate analysis of the impact that new CAFE standards will have on the human environment. To adequately promote and protect human health assuming shifts in the U.S. automobile fleet make-up:

Analysis of current vehicle fleet composition, prospective fleet composition, and optimal fleet composition with respect to transportation user needs, CAFE standards, and decreasing crash-related injury to transportation system users is also warranted for adequate assessment.

Response

NHTSA considered the potential safety concerns of making vehicles lighter (i.e., downweighting) in both the rulemaking and the FEIS. See DEIS Section 3.5.4, Safety and Other Human Health Impacts, for NHTSA's approach to these safety concerns. In that section, NHTSA describes the importance of the new form of the CAFE standard ("Reformed CAFE") to alleviate the potential for downweighting. By using an attribute-based standard, which the NAS recommended in 2002 and the EISA requires, NHTSA believes that the incentive to downweight vehicles should be reduced or eliminated.

Contrary to Public Citizen's concerns that NHTSA relies too heavily on the Kahane study, NHTSA routinely reviews the full spectrum of relevant studies because safety is a major NHTSA concern. Several of these studies are noted in the FEIS. See Section 3.5.4.

It is because of this complexity that NHTSA believes that all relevant literature should be examined. Public Citizen cites the dissent to the NAS study, but fails to note that the majority report, agreed to by 11 of 13 panel members, concluded that downsizing and weight reduction that occurred in the late 1970s and early 1980s likely resulted in between 1,300 and 2,600 crash fatalities under the previous form of the CAFE standard. This led to the NAS recommendation that the form of the CAFE standards be changed to an attribute-based approach. As for misinterpreting the results of the Kahane study, as Mr. Adcock alleges, Dr. Kahane is on the NHTSA staff and is a recognized expert in the field of vehicle safety. His interpretation of the results of his own study is definitive.

While the study of safety and fuel economy is multi-faceted, Public Citizen's recommendation for compatability and agressivity standards is misplaced. NHTSA can use its authority under the Safety Act to address unreasonable risks to safety. NHTSA's rulemaking and its EIS are focused directly on new CAFE standards. The FEIS addresses safety concerns because they are potential health impacts.

NHTSA agrees with CDC's statement that changing fleet design can have important impacts on human health, but disagrees with CDC's contention that prospective vehicle fleets, or an "optimal" vehicle fleet, can be assessed for impacts on human health. One of NHTSA's primary responsibilities is to assess the crashworthiness of current model vehicles, a responsibility we faithfully fulfill. CDC's proposed analysis, on the other hand, would go far beyond this, and demonstrates a lack of understanding regarding the structure of the rulemaking. NHTSA has no authority to require a specific composition of the vehicle fleet. This proposed rulemaking does not require vehicle manufacturers to implement specific technologies or specific approaches to meet the new standards. Manufacturers might or might not meet their requirements by downweighting (against NHTSA's advice for most vehicles). There is a wide variety of technologies available to assist manufacturers to comply with the new standards. The extent to which they will do so in reaction to the new standards cannot be accurately estimated. Therefore, NHTSA concludes that the analysis CDC proposes would be impossible to do in any sort of a meaningful way.

10.3.6.5 Hazardous Materials and Regulated Wastes

Comment

Comment Number: 0595-7
Organization: Environmental Protection Agency
Commenter: Susan Bromm

EPA believes the DEIS could be strengthened (page 3-88) by adding supporting information on the topic of hazardous materials. We recommend the DEIS document in more detail that future efforts at downweighting of vehicles by substitution of aluminum, plastics, composites, and synthetic materials for steel and ductile iron parts, will not result in a net (overall) increase in the hazardous waste stream, and that if there are any increases, these will be manageable under current technologies.

Some published studies have also suggested that the trend toward substitution of lighter weight aluminum for steel in autos increases energy demands and may result in increased pollution from bauxite mining, alumina refining, and aluminum smelting operations. The DEIS should cite current research on how the substitution of lighter weight materials can avoid significant effects on water or biological resources, and reduce CO_2. The DEIS simply states that the "projected reduction in fuel production and consumption as a result of the proposed action and alternatives may lead to a reduction in the amount of hazardous materials and wastes created by the oil extraction and refining industries." No mention is made of the consequences/impacts of the increasing substitution to lighter weight materials.

Response

NHTSA has revised Section 3.5.5 to include a discussion of the hazardous-waste stream and lighter materials.

10.3.6.6 Environmental Justice

Comment

Comment Number: TRANS-15-1
Organization: Individual
Commenter: Marissa Knodel

This is an issue of environmental justice, since these countries have contributed the least to global warming, and yet given their size, location, geography and lack of political power, will suffer the most from global warming.

The highest point on many of these islands is only a few years high. Now, with global warming causing sea levels to rise, and increasing the magnitude and severity of tropical storms, many of these nations already have agreements with the governments of New Zealand and Australia to evacuate their entire populations with the expectation that their homes will be under water within the next 50 years.

Response

Sections 4.5 and 4.6 of the FEIS include discussions of the effects of climate change on environmental justice populations; these sections describe the particular vulnerability of low-lying atolls to sea-level rise. NHTSA recognizes that populations on low-lying atolls are likely to be disproportionately affected by sea-level rise as a result of increased CO_2 emissions. However, these impacts are from global emissions releases, not just from U.S. emissions releases. To the extent that the reductions estimated from the alternatives considered in this rulemaking reduce or delay sea-level rise, this rule could offset these impacts. However, to avert sea-level rise that would displace these populations, many more CO_2-reduction initiatives will be required.

10.3.7 Cumulative Impacts - General

Comment

Comment Number: TRANS-32-2
Organization: Environmental Defense Fund
Commenter: James Keck

We believe that NHTSA has failed to comply with the Ninth Circuit's previous mandate to quote, provide the necessary contextual information about the cumulative and incremental environmental impacts of the final rule in light of other CAFE rulemakings and other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions.

Response

NHTSA acknowledges that under NEPA we are required to take a "hard look" at the effects of our actions on global warming within the context of other actions that also affect global warming. Thus, consistent with CEQ regulations, guidance, and applicable case law, the DEIS and this FEIS provide appropriate contextual information about the cumulative impacts of increased CAFE standards "on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions." 40 CFR § 1508.7.

Agencies retain substantial discretion as to the extent of the inquiry and the appropriate level of explanation. Marsh v. Oregon Natural Resources Council, 490 U.S. 360, 376-77 (1989). Indeed, CEQ recognizes the impracticality of requiring an agency to "analyze how the cumulative effects of an action interact with the universe; the analysis of environmental effects must focus on the aggregate effects of past, present, and reasonably foreseeable future actions that are truly meaningful" (CEQ 2005). An EIS must discuss "reasonably" foreseeable cumulative effects. Blue Mountain Biodiversity Project v. Blackwood, 161 F.3d 1208, 1214-15 (9th Cir. 1998). When an agency's determination of "reasonably foreseeable future actions" and "component parts" is "'fully informed and well-considered,'" the courts will defer to the agency's determination. Id. at 1208 (quoting Save the Yaak Comm. v. Block, 840 F.2d 714, 717 (9th Cir. 1988)). Some level of detail is required in describing the cumulative effects of a proposed action. "To consider cumulative effects, some quantified or detailed information is required." Neighbors of Cuddy Mountain v. U.S. Forest Service, 137 F.3d 1372, 1376 (9th Cir. 1998).

The past and present actions related to the CAFE rulemakings are addressed in the emissions time series, as described in Section 4.4 of the FEIS. Although literally hundreds of future actions are contemplated to address climate change – both in the United States and elsewhere – the set of reasonably foreseeable actions is quite limited. In fact, existing regulatory commitments in the United States and elsewhere generally expire within the next 5 years (during the time the MY 2011-2015 CAFE standards would be in effect).

Although it is not possible to reasonably foresee the profile of global GHG mitigation policies over the remainder of the 21st Century, the SRES emissions scenarios NHTSA used in the climate modeling bracket a wide range of potential combinations of population, economic development, technology evolution, and energy intensity. While they are not designed to portray various GHG mitigation policy outcomes, they indicate the effect of a diverse set of conditions. NHTSA has expanded the FEIS analysis to use multiple emissions scenarios and multiple climate sensitivities, which provide insight on how the regulatory options affect climate under a variety of background conditions. See Section 3.4.4.4.

10.4 OTHER COMMENTS ON THE DEIS

10.4.1 Mitigation

Comments

Comment Number: 0572-28
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

After summarizing an environmental problem, the next required task of an EIS is to discuss ways to reduce the project's impact and solve the problem. This rulemaking is particularly well suited for such an analysis since EPCA requires the fuel economy standard to be set at the "maximum feasible" level and higher fuel economy standards result in lower greenhouse gas emissions. Yet the failure to discuss solutions is one of the DEIS's most glaring failures.

In the bizarre and constrained world presented in the DEIS, there is no solution to global warming. The full range of alternatives considered by NHTSA, combined with NHTSA's assumptions, discussed below, result in atmospheric CO_2 concentrations of between 705.4 and 708.6 ppm. DEIS at 2-16. While global warming is indeed a daunting problem, presenting the analysis in this truncated form leaves the false impression that nothing can be done about it, violating both the letter and the spirit of NEPA. Leading scientists are able to tell us with a high degree of certainty that allowing CO_2 concentrations to rise to more than 700 ppm by the end of this century will result in catastrophic climate impacts. NHTSA has a mandatory duty to disclose in the DEIS what NHTSA can do to contribute to the solution.

Comment Number: 0600-1
Organization: Centers for Disease Control and Prevention
Commenter: Sarah Heaton

Mitigation analysis for projected public health outcomes is necessary. Current mitigation analysis in the DEIS is insufficient.

Response

The commenters appear to misconstrue NEPA requirements and NHTSA's role in setting CAFE standards within the context of climate change. Climate change is global in nature and stems from GHG emissions that trap heat and cause global temperatures to rise. According to the IPCC and USCCSP, the final impacts of climate change are anticipated to include a wide variety of detrimental effects. The sources for these GHGs, however, are numerous. In addition to transportation sources, GHG emissions are generated by the industrial, commercial, agriculture, and residential sectors, and electricity generation. In fact, many human activities that require power generate GHGs because a great deal of our power is generated through the use of carbon-based fuels, including home heating and cooling, and driving. According to EPA's "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005" (2007d), Table 2-14, transportation sources (including air travel and freight) accounted for 28 percent of GHGs (expressed in carbon dioxide equivalents), and electricity generation accounted for 34 percent. Other sectors contribute to GHG emissions as follows: industry (19 percent), agriculture (8 percent), commerce (6 percent), and residential (5 percent).

To slow or reverse the anticipated impacts of climate change, it is likely that all sectors would have to reduce emissions. Some scientists have called for as much as an 80 percent reduction in GHGs *by 2050 to moderate (but not eliminate) the detrimental impacts of climate change. This will require substantial reductions from all sectors. Further, it will require such sectoral reductions in all nations.*

By contrast, NEPA only requires that NHTSA disclose the environmental impacts of its proposed action. NHTSA's action is limited to the CAFE rulemaking. EPCA, as amended by EISA, is not designed, and NHTSA has no authority, to dictate the U.S. Government's GHG emissions reduction policy. Addressing climate change in a meaningful way would likely require new legislation from Congress in conjunction with that from other nations.

The agency's action would result in substantial reductions in GHG emissions from passenger cars and light trucks in the United States, which, when considered in a global context, would result in small changes in temperature, precipitation, and sea-level rise. Under NEPA, this is the action NHTSA must evaluate for environmental impacts. Because the alternatives will reduce GHGs, the agency's action is expected to reduce the effects of climate change.

In addition, most of the air pollution emissions are anticipated to decrease, even as some increase slightly under some alternatives and in some years. The additional health analyses shown in Sections 3.3 and 4.3 indicate that net health impacts should be beneficial to human health. For these reasons, NHTSA continues to believe that mitigation, when considered within the NEPA definition of reducing the harmful effects of an agency's action, is unnecessary.

10.4.2 List of Preparers

Comments

Comment Number: 0596-1
Organization: Environmental Defense Fund
Commenter: Martha Roberts

Although the team that created this EIS is well-credentialed in many areas of environmental assessment, we do not believe they had the proper expertise to adequately evaluate the health impacts of the proposed CAFE alternatives. We note that among the team of 47 technical experts, the reviewers, and the project managers not one had obtained a graduate degree in public health. The National Highway Traffic Safety Administration (NHTSA) asserts in its response to comments from the Centers for Disease Control and Prevention (CDC) also calling for inclusion of public health professionals,

"NHTSA feels confident that the consultants retained to assist in the analysis and development of the DEIS, along with its own staff, have the requisite knowledge and skills to effectively incorporate health issues into the document." [Footnote: See original comment document.]

EDF supports the CDC's recommendation for inclusion of public health professionals in the process of developing the EIS. Given the length and complexity of this EIS, it is unlikely that a teleconference with the CDC was sufficient to obtain the "high degree of understanding" NHTSA asserts, and therefore unlikely that the appropriate disciplinary expertise in public health was applied to this EIS. [Footnote: See original comment document.]

Comment Number: 0600-12
Organization: Centers for Disease Control and Prevention
Commenter: Sarah Heaton

Collaboration with public health economists is warranted.

Response

NHTSA is confident that the consultants retained to assist in the analysis and development of this NEPA analysis, along with its own staff, have the requisite knowledge and skills to effectively incorporate health issues into the document. In addition, staff with degrees in public health have contributed to the analysis presented in the FEIS. See Chapter 7, Preparers.

10.4.3 Appendix C Cost-Benefit Analysis Excerpt from the Preliminary Regulatory Impact Analysis

Comments

Comment Number: 0574-15
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

The technology penetration tables in the PRIA are not sufficient to show the technology combinations that NHTSA actually assumed. The information contained in the "decision tree" figures isn't sufficient either. Answers to the following questions would help us determine what combinations were actually modeled:

1. Why does the MY 2015 penetration rate of VVT [variable valve timing] technology in Table V-11b and similar tables exceed 100%?

2. On which transmissions is ASL [aggressive shift logic] assumed to be used in MY2015?

3. What other engine technologies are used in combination with Turbo/Downsize? Specifically, is VVLTD [variable valve lift and timing (discrete VVL)], VVLTC [variable valve lift and timing (continuous VVL)], or cylinder deactivation (DISP) assumed?

4. In the "decision tree" on page V-64, is DISP retained when VVLT is added?

5. In the "decision tree" on page V-64, is VVLT retained when GDI [gasoline direct injection] is added?

6. In the "decision tree" on page V-65, is ASL retained when the transmission is changed to AMT [Automated Shift Manual Transmission]?

Answers to the following questions would help clarify the benefit estimates that NHTSA is assuming for specific technologies:

1. Shift Logic — Does NHTSA have a specific definition of baseline non-aggressive shift logic and aggressive shift logic in terms of the upshift and downshift points as a function of engine load in each gear? How did NHTSA determine the percent of vehicles using aggressive shift logic in the baseline?

2. Understanding Hybrid Benefits — Based on Table V-2, the benefits of 2-mode hybrids and Power Split hybrids over the non-hybrid baseline are 15.2% (1-(1.075*1.035*1.035)) and 22.6% (1-(1.075*1.035*1.035*1.065)), respectively. However, the text says "NHTSA estimates that Power Split hybrids can achieve incremental fuel consumption reductions of 25 to 35% over conventionally powered vehicles." Is the difference due to the fact that the hybrid estimates in

Table V-2 are incremental to the use of something other than "conventionally powered vehicles?" If so, at what point in the "decision trees" are hybrids applied and do the engine technologies already applied at that point carry forward? For example, is hybrid technology used in combination with Turbo/Downsize or VVLTC? Is it correct to assume the transmission technologies do NOT carry forward, but the hybrid benefits are incremental to something other than a baseline transmission? If so, what is the transmission that the hybrid system benefits are incremental to?

3. Cam Phasers — The decision tree on page V-64 indicates that dual cam phasers are applied subsequent to the use of intake cam phasers. Does that mean that the benefit of dual cam phasers shown in Table V-2 is incremental to intake cam phasing?

4. In Table V-2, is the benefit for cylinder deactivation incremental to the use of dual cam phasers and are dual cam phasers assumed to still be used?

5. In Table V-2, are the benefits for VVLT incremental to cylinder deactivation and is cylinder deactivation assumed to still be used when VVLT is added?

6. On the overhead valve branch of Table V-2, does the incremental benefit for continuous VVLT assume that coupled cam phasing was in the baseline?

7. If cylinder deactivation is ever assumed to be used in combination with VVT or VVLT, what "synergy" was assumed?

8. If cylinder deactivation or VVLT are ever assumed to be used in combination with Turbo/Downsize, what "synergies" are assumed?

Comment Number: 0595-27
Organization: Environmental Protection Agency
Commenter: Susan Bromm

The excerpted Cost and Benefit RIA chapters appear to have been pulled from an outdated version of the RIA. EPA recommends that the text be replaced with that found in the April, 2008 version of the RIA.

Response

To the extent that the AAM and EPA have identified aspects of NHTSA's analysis that need updating, clarifying, or correcting, NHTSA has revised its analysis. Other comments from AAM address very specific issues concerning the application of technologies to improve fuel economy in the Volpe model. NHTSA has taken all of the AAM's questions and suggestions regarding technology costs and transparency of analysis into consideration in revising and updating the technology inputs to the Volpe model. For further discussion of this issue, see the agency response in 10.2.2 above.

10.4.4 Additional Comments

Comments

Comment Number: 0554-11
Organization: Individual
Commenter: James Adcock

Manufacturers are widely misrepresenting EPA Fuel Economy values on TV by quoting highway mileage values as if they are combined mileage values. NHTSA needs to act to correct these deliberately distorting practices. These advertisements are in turn representative of the fact that NHTSA has been setting fuel economy standards too low, forcing manufacturers to misrepresent to the public how they have chosen to implement those standards. Allowing these advertising deceptions results in higher GHG.

Comment Number: 0575-10
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

Based on Tables la and lb from the Preliminary Regulatory Impact Analysis, it appears that NHTSA expects a significant number of manufacturers will opt for civil penalties instead of compliance. Under NHTSA's proposed "Optimized (7%)" scenario, the projected harmonic average for the passenger car fleet falls 0.2-1.0 mpg (between 2011 and 2015) short of the required fleet average, while the projected harmonic average for the light truck fleet falls 0.2-0.6 mpg short of the required fleet average. [Footnote: See original comment document.] Under other scenarios (i.e., Optimized (3%), TC=TB, etc.) projected harmonic averages fall short of required fleet averages by even greater amounts.

The $5 penalty has remained in effect since 1975. Since that time, inflation has devalued the impact of that penalty. A fine of equivalent value today would need to be more than $20 per 0.1 mpg. [Footnote: See original comment document.] Increasing the noncompliance civil penalty would boost its effectiveness in achieving its original policy intent. Given the escalating economic and environmental importance of energy conservation, UCS [Union of Concerned Scientists] recommends that the Secretary of Transportation invoke a CAFE noncompliance civil penalty of $10 per 0.1 mpg.

Comment Number: 0575-30
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

NHTSA's analysis indicates that a significant number of manufacturers will opt for civil penalties over compliance with fuel economy requirements. Increasing the civil penalty would ensure the benefits are actually realized. The Secretary of Transportation should use existing authority to increase the CAFE noncompliance civil penalty from $5 to $10 per 0.1 mpg.

Comment: Number: 0572-49
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

The NRPM on page 24461 further argues that "since EISA now permits manufacturers to transfer credits earned for their passenger car fleet to their light truck fleet and vice versa, it makes even less difference how a vehicle is classified, because the benefit a manufacturer gets for exceeding a standard may be applied anywhere." However, the NPRM on page 24393 states explicitly that NHTSA "does not attempt to account for either CAFE credits or over-compliance … EPCA and EISA do not allow NHTSA to consider those credits toward compliance in future or prior model years. Therefore, the Volpe model does not attempt to account for these flexibilities." Thus, NHTSA specifically constrained the Volpe model from including precisely those considerations that NHTSA points to as justification for not revising the definition of light trucks, indicating that the revision of the definitions to classify pickup trucks and SUVs as passenger vehicles would indeed result in higher standards for many vehicles.

Response

Fuel economy advertisements: The issue of whether any advertisements misrepresent EPA fuel economy estimates is beyond the purview of this action and, in any event, within the jurisdiction of the Federal Trade Commission.

Civil penalties: As discussed in the NPRM, EPCA authorizes NHTSA to increase the civil penalty up to $10.00 for each tenth of a mpg that a manufacturer's average fuel economy falls short of the standard for a given model year, exclusive of inflationary adjustments, if NHTSA decides that the increase in the penalty (1) will result in, or substantially further, substantial energy conservation in model years in which the increased penalty may be imposed, and (2) will not have a substantial deleterious impact on the economy of the United States, a State, or a region of a state. See 49 U.S.C. § 32912(c). In the NPRM, NHTSA asked for comments on whether it should initiate a proceeding to consider raising the civil penalty. A number of commenters indicated that they would favor raising the civil penalty to $10. NHTSA will consider the comments in deciding whether to initiate rulemaking to raise the civil penalty.

Credits: CBD's comment suggests that NHTSA might not have been completely clear in its explanation of how the use of credits interacts with the classification of vehicles. NHTSA does not believe that the statutory prohibition on considering credits in determining CAFE standards has the effect of producing standards that would be higher if NHTSA reclassified certain light trucks as passenger cars.

10.4.5 Rulemaking

10.4.5.1 State Preemption

Comments

Comment Number: 0554-4
Organization: Individual
Commenter: James Adcock

The NHTSA assertion of CAA [Clean Air Act] preemption is not rational for several reasons. First, NHTSA's proposed standards do not actually regulate GHG tailpipe emissions. Rather NHTSA sets relationships between tailpipe emissions and footprint. NHTSA does not know how much GHG will be emitted because it will depend on the actual mix of car, trucks, and their footprints. States might set rules that tend to affect this mix or limit GHG which would not stop NHTSA from setting whatever GHG/footprint, car versus truck relationships NHTSA wants. Secondly, Congress specifically prevents NHTSA from consideration of alternative fuels, which states might use in their regulations to limit overall GHG net emissions. For example California might set regulations designed to make 10% of their autos electric powered by green electricity, thereby reducing GHG emissions by 10% compared to federal regulations.

Comment Number: 0572-66
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

Following a rulemaking in which NHTSA repeatedly and systematically manipulates the analysis in order to select an absurdly low fuel economy level, NHTSA then asserts that its rulemaking preempts state regulation of greenhouse gas emissions from automobiles. NHTSA's statements in this regard are incorrect, inappropriate, and either legally irrelevant or contrary to existing law. We request that all statements regarding preemption be removed prior to publication of the final rule.

Comment Number: 0575-18
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

UCS is disappointed in NHTSA's attempt to use this CAFE NPRM to address California's vehicle global warming pollution regulations. The previously discredited legal arguments made by the agency were rejected in decisions by the Supreme Court and two separate district courts. It is clear that EPA's authority to regulate greenhouse gases under the Clean Air Act is separate and distinct from NHTSA's authority to set fuel economy standards. It is inappropriate for NHTSA to go beyond its authority, challenge the court decisions, and parrot the auto industry's flawed legal claims. The administration should grant the waiver to California and allow the states to move forward.

Interestingly, as shown in Table 2 below [see comment document], NHTSA's own analysis demonstrates that with proper assumptions—such as employing a Total Cost-Total Benefit (TC=TB) economic practicability assessment, or using realistic gasoline prices—fuel economies higher than the approximate California Pavley regulation MPG equivalent are both technically achievable and economically practicable.

Response

NHTSA does not believe that the EIS is the appropriate forum in which to address the merits of NHTSA's position on preemption, and refers readers to Section XIII.D of the NPRM. While NHTSA has explained its considered view that state GHG emission regulations for motor vehicles are largely preempted by EPCA insofar as those regulations address tailpipe emissions of CO_2*, EPCA does not have any effect on state regulation of matters beyond NHTSA's authority (for example, GHGs from motor vehicles other than tailpipe emissions of carbon dioxide), or from motor vehicles (for example, motorcycles) or other machinery not subject to CAFE. NHTSA also has no authority over state regulation of alternative fuels, although it does have authority over state regulation of alternative-fuel vehicles, as such regulations would be "related to fuel economy" and preempted under 49 U.S.C. § 32919. In terms of the environmental impacts of such state regulations, however, NHTSA cannot analyze the effects of inchoate potential future regulations with any reasonable degree of certainty. NHTSA notes further that EPA denied California's Clean Air Act waiver request, as noted in the NPRM, and that California's (and other states' based on California's) light-duty motor vehicle GHG regulations are therefore currently unenforceable. NHTSA will address comments regarding the preemption issue in the final rule.*

10.4.5.2 Vehicle Footprint

Comments

Comment Number: 0554-3
Organization: Individual
Commenter: James Adcock

Truck CAFE curves cross Car CAFE curves. [See graph attached to original comment document.] For several years at medium values of footprint NHTSA compliance curves set lower values for cars than for trucks. Since the mpg values for trucks have historically been set lower than for cars because of the unique challenges and abilities trucks have, including greater hauling capacity and greater towing capacity, inverting this relationship never makes sense. This problem is part of a larger problem: that NHTSA has largely designed the curves for cars and trucks independently when instead NHTSA needs to recognize that both consumers and manufacturers have the choice of car versus truck. Thus the curves for cars and trucks need to be designed in a consistent and rational manner to work together. For example, the great disparity between car and truck curves for small footprints should encourage manufacturers to design “AMC Eagle” style small “trucks” which have car-like characteristics except for being high and needlessly unstable, leading to unnecessary rollover fatalities. NHTSA's choice of design curves for cars versus trucks works directly against NHTSA's charter of highway safety while resulting in greater GHG.

Comment Number: 0554-6
Organization: Individual
Commenter: James Adcock

Bias in the High Threshold transition point of the truck curves. NHTSA has lowered the high point threshold in the truck curves without a rational basis for doing so. Having incomplete information on the subject means choosing a best estimate, not biasing that estimate. Biasing this threshold results in greater GHG, and reduces most consumers’ ability to choose a rationally sized vehicle to meet their family’s needs without fear of death in collisions with those large trucks that the biased high threshold encourages, which again increases GHG.

Comment Number: 0575-17
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

A size-based system has a built-in risk of vehicle upsizing whereby manufacturers upsize vehicles in order to achieve lower fuel economy targets. This issue is a less of a concern when the logistic curve is not as “steep.” As noted in the NPRM, however, the proposed curves, particularly those for passenger cars are quite steep, opening the door for manufacturer “gaming.” Under the proposed curves, for example, a Honda Civic could lower its target by almost 2 mpg (38.4 to 36.6) by simply increasing its footprint 1 square foot. Similarly, a 1 square foot change in size would lower the Saturn Aura’s target fuel economy by nearly 1 mpg. Vehicles have, indeed, been getting larger; the archetypal Honda Accord sedan’s footprint, for example, increased by 0.6 ft^2 between 2001 and 2004, and an additional 1.9 ft^2 by 2008. [Footnote: See original comment document.] Certainly, with such steep curves, ample opportunities exist for all manufacturers to game the system to their favor, eroding warranted energy savings.

UCS strongly opposes the adoption of a “dual attribute” approach, as it is unclear that a reasonable second attribute exists that will deliver the benefits of a size-based system. One unfortunate consequence of an attribute-based system is that the attribute is removed from the “toolkit” of resources automakers can employ to make their vehicles more fuel efficient. The incorporation of a second attribute, such as horsepower, would remove automakers' abilities to use the attribute to improve vehicle fuel economy. Worse yet, the attribute becomes a mechanism for the industry to "game" their fuel economy obligations; automakers could boost engine power to help a vehicle meet a lower fuel economy target. For the past 20+ years, automakers have steadily increased vehicle weight and power while keeping fuel economy constant. Today's average vehicle is 900 pounds heaver and has 90 percent more horsepower than its 20 year-old counterpart. [Footnote: See original comment document.] NHTSA should not employ regulations that further encourage this attribute trend.

Response

NHTSA uses the same methodology for setting both the passenger-car and light-truck curves, as discussed in the NPRM, but applies that methodology to the passenger-car and light-truck fleets separately, because EPCA (as amended by EISA) requires NHTSA to set separate standards for passenger cars and light trucks.

NHTSA explained at length in the NPRM that it is aware of steepness issues with the proposed passenger-car curve and has considered the issue very carefully in developing the FEIS and the final rule. The curves representing the analysis contained in this FEIS are much less steep than the curves in the NPRM. Regarding the concerns expressed by UCS about attribute-based CAFE standards, NHTSA notes that an attribute-based standard is required under EISA and was recommended by the National Academy of Sciences (NAS). NAS' expressed concern was the potential for downsizing and its negative impacts on safety. NHTSA notes the UCS concern, but it runs counter to the law and the NAS recommendation.

10.4.5.3 Ratably

Comments

Comment Number: TRANS-01-6
Organization: Alliance of Automobile Manufacturers
Commenter: Julie Becker

In our scoping comments, we asked NHTSA to consider how to construe the term ratably, a term that the Energy Dependence and Security Act of 2007 makes central. And so we would ask you to reconsider that issue as well.

Response

NHTSA disagrees that the EIS alternatives were not properly established because the agency did not conduct a full "textual" analysis in interpreting the term "ratably." NHTSA analyzed a range of alternatives that would capture a full spectrum of potential environmental impacts, ranging from vehicles continuing to maintain their MY 2010 fuel economy, to standards based on the maximum technology expected to be available over the period. The various alternatives analyzed create standards that present several points on a continuum of alternatives. A different construction of the term "ratably" than NHTSA used in the NPRM might affect the levels of increase in the standards from one year to the next, but we are satisfied that any "ratable" analysis would still fall within the spectrum covered by the existing alternatives and would have impacts that fall within the range identified in this FEIS. Therefore the decisionmakers and the public will be fully informed of the potential environmental impacts of all the reasonable alternatives.

10.4.5.4 Vehicle Classification

Comments

Comment Number: 0572-62
Organization: Center for Biological Diversity
Commenter: Brian Nowicki, Mickey Moritz, Kassie Siegel

In the development of the proposed CAFE standards, NHTSA relies on an outdated and inadequate definition of light trucks. This defies the recent Ninth Circuit opinion that found the use of these definitions to be arbitrary and capricious and required NHTSA to revise the definition of light trucks and, by extension, SUVs. [Footnote: See original comment document.] NHTSA's attempt to justify its failure to revise the definitions of light trucks and SUVs to reflect the fact that light trucks and SUVs are overwhelmingly used as passenger vehicles is unavailing. 73 Fed. Reg. 24459.

The NPRM on page 24460 argues that "The EISA adds a significant requirement to EPCA—the combined car and light-truck fleet must achieve at least 35 mpg in the 2020 model year. Thus, regardless of whether the entire fleet is classified as cars or light trucks, or any proportion of each, the result must still be a fleet performance of at least 35 mpg in 2020. This suggests that Congress did not want to spend additional time on the subject of whether vehicles are cars or light trucks." However, this interpretation entirely fails to address the primary reason for revising the definition of light truck—the fact that SUVs and pickup trucks are overwhelmingly used as passenger vehicles.

Comment Number: 0575-16
Organization: Union of Concerned Scientists
Commenter: Eli Hopson

The Energy Independence and Security Act of 2007 sets separate attribute-based target mpg levels for passenger and non-passenger vehicles, accommodating an industry interest in having non-passenger vehicles held to less stringent fuel economy standards than passenger vehicles of the same attribute (i.e., footprint size). These separate standards, which have been in effect in one form or another since the 1970s to accommodate performance-oriented, non-passenger work vehicles, are the source of a long-standing loophole created when NHTSA began equating SUVs, minivans, crossovers and even some station wagons with non-passenger vehicles. The association of these categories has allowed automakers to tweak passenger vehicle characteristics in order to have them classified as light trucks that are held to lower fuel economy standards.

This "gaming" of the system is contrary to the original intent of the law and robs the nation of energy savings. In a 2007 ruling on NHTSA's fuel economy standards for model year 2008-2011 light trucks, the Ninth Circuit Court of Appeals deemed that NHTSA's decision not to close the SUV loophole (by revising the definition of passenger and non-passenger automobiles) was arbitrary and capricious. The court ruled that, among other factors, NHTSA's decision "runs counter to the evidence showing that SUVs, vans, and pickup trucks are manufactured primarily for the purpose of transporting passengers and are generally not used for off-highway operation." [Footnote: See original comment document.]

In NPRM documentation, NHTSA argues that Congress had the opportunity to change the definitions and did not, which "strongly suggests Congressional approval of the agency's 30-year approach to vehicle classification." [Footnote: See original comment document.]

As the saying goes, absence of evidence is not evidence of absence. In not addressing the definitions legislatively, Congress merely preserved the same definitions upon which the Ninth Circuit decision was made. The notion that Congressional inaction "strongly suggests" approval is flawed. It could equally be interpreted that the inaction of Congress was a result of a belief that the Ninth Circuit decision (which came out a month before passage of the Energy bill) sufficiently spoke to the issue and negated a need for clarification. Indeed, in an extension of remarks on the Senate amendments to H.R. 6, bill author Congressman Edward I. Markey (D-MA) specifically noted,

"Section 1061 is not intended to codify, or otherwise support or reject, any standards applying before model year 2011, and is not intended to reverse, supersede, overrule, or in any way limit the November 15, 2007 decision of the U.S. Court of Appeals for the Ninth Circuit in *Center for Biological Diversity v. National Highway Traffic Safety Administration* (No. 06-71891)." [Footnote: See original comment document.]

Given these findings, UCS recommends that NHTSA revise its definition of passenger and non-passenger vehicles in accordance with the ruling of the Ninth Circuit Court of Appeals.

Comment Number: 0576-42
Organization: Public Citizen
Commenter: Joan Claybrook

Now that the market is shifting towards vehicles that more closely resemble large cars and station wagons, NHTSA should restore their classification as cars, primarily designed for the purpose of transporting passengers.

Response

Comments on the issue of classification may be grouped into several categories of arguments that the regulatory definitions relating to whether some vehicles are passenger cars or light trucks were incorrect: first, that they did not comport with the Ninth Circuit's opinion in CBD and do not reflect the fact that many light trucks are used as passenger vehicles; second, that they were not ratified by Congress in EISA; third, (which is related to the first) that they do not ensure that some vehicles which they believe should be classified as passenger cars are in fact classified as such; and fourth, they allow manufacturers to "game" the definitions by making minor changes to vehicles to obtain a light truck classification and thus, a lower fuel economy targets. NHTSA responds to these comments below.

In light of the Ninth Circuit remand, NHTSA intends to include certain vehicles in the passenger automobile category that had been in the light truck category. *As proposed in the NPRM, in this FEIS, NHTSA has tightened the coverage of its regulatory definition of "light truck" to ensure that two-wheel drive versions of an SUV are not classified as light trucks under 49 CFR § 523.5(b) simply because the SUV also comes in a four-wheel drive version. In order to be properly classifiable as a light truck under Part 523, a two-wheel drive SUV must either be over 6,000 lbs GVWR and meet 4 out of 5 ground clearance characteristics to make it off-highway capable under § 523.5(b), or it must meet one of the functional characteristics under § 523.5(a) (e.g., greater cargo carrying capacity than passenger carrying capacity). This clarification, which the vehicle manufacturers largely supported, would result in the re-classification of an average of 1,400,000 two-wheel drive SUVs from light trucks to passenger cars in each of the five model years covered by the standards. The result of this re-classification would be an average increase of 0.8 mpg in the combined passenger car and light truck standards over MY 2011-2015, producing a corresponding additional 4.5 billion gallons of fuel savings and 54 million metric tons of avoided carbon dioxide emissions during the useful life of vehicles sold during these model years. All of the alternatives and scenarios analyzed in this FEIS reflect this re-classification.*

As to other vehicles, NHTSA has considered in this FEIS whether recategorization would result in improved fuel economy and therefore lower emissions of carbon dioxide and other pollutants. This is discussed below.

NHTSA disagrees that consumers' use of vehicles is determinative of their CAFE classification. *With regard to the commenters' argument that the standards do not reflect the fact that many light trucks are used as passenger vehicles, NHTSA discussed at length in the NPRM that the fact that vehicles are used for personal transportation does not make them passenger cars for purposes of CAFE. The commenters' argument overlooks the statutory definition of passenger automobile. This term is defined to mean an automobile that the Secretary decides by regulation is "manufactured" primarily for transporting not more than . . ." The statute does not employ the word "used". If Congress had wanted all vehicles that transport passengers to be classified as passenger automobiles, it would have said "used primarily" in EPCA, instead of "manufactured primarily." The commenters also overlook the key role played by vehicle design and functional capabilities in vehicle classification for CAFE purposes. Instead, Congress specifically identified particular characteristics in the definition of passenger automobile, and gave NHTSA discretion to determine the contours of the regulatory definitions for purposes of the CAFE standards. NHTSA refers readers to the discussion in the NPRM at 73 FR 24458-24461 (May 2, 2008) for additional information on this issue. See further the discussion of EPCA's legislative history in the proposal and final rule establishing NHTSA's vehicle definition regulation. 41 FR 55368, 55369-55371, December 20, 1976, and 42FR 38362, 38365-38367, July 28, 1977. That discussion, and not the incorrect and anomalous description of it in a preliminary notice published by the agency in late 2003 (68 FR 74908, 74926, December 29, 2003), represents the agency's historical position.*

NHTSA disagrees that Congress intended to codify the Ninth Circuit opinion. *With regard to the commenters' argument that Congress did not approve of NHTSA's vehicle classification system in EISA and their suggestion that Congress codified the Ninth Circuit's opinion with respect to classification, NHTSA has carefully considered the discussion of this issue in the extension of remarks by Congressman Edward Markey. The agency notes that Congress did not amend the definition of "passenger automobile" or direct the agency to amend the definition of that term in the agency's classification regulation. NHTSA notes further that the remarks of Congressman Markey were not spoken on the floor during the House's consideration of EISA. 153 CONG. REC. H14253 (editor's note) and H14444 (daily ed. Dec. 6, 2007) (statement of Cong. Markey). Accordingly, we do not believe that the views in those remarks can be ascribed to Congress as a whole.*

In developing the EIS, NHTSA has considered whether changes in the regulatory vehicle categorization definitions in 49 CFR Part 523 would result in improved fuel economy and therefore lower emissions. *One of the concerns underlying the Ninth Circuit's decision was the potential impact of vehicle categorization on the ultimate fuel economy for light trucks. The commenters, too, were concerned about this in general. NHTSA has taken a hard look at this.*

In 2006, when NHTSA issued its MY 2008-2011 light truck fuel economy rule, and in 2007, when the Ninth Circuit issued its initial opinion in CBD, EISA had not been enacted. Under EPCA as it then existed, the passenger car standard was a flat 27.5 mpg average requirement. 49 U.S.C. 32902(b) Re-classifying light trucks as passenger cars, in the flat pre-EISA world, intuitively would have resulted in their having to meet a higher standard, or in the manufacturers' having to build more small, lightweight vehicles in order to balance out those new arrivals, and could have resulted in more fuel savings. This assumption may no longer be correct, because such a recategorization could now result in lower standards for passenger automobiles.

In EISA, Congress made both the passenger car and light truck standards attribute-based, which means that the fuel economy target curves for each standard are a function of the fleet subject to that standard. In developing the curves that determine fuel economy targets for each vehicle footprint, NHTSA fits the curve based in part on the sizes (footprint) and fuel economy levels (given the estimated effects of adding fuel-saving technologies) of the vehicles in each regulatory class. Consider, for example, a small SUV typically classified as a light truck, and assume that the small SUV gets relatively good fuel economy for a truck. Moving the small SUV out of the truck fleet may reduce the overall average fuel economy level required of light trucks, because the vehicles remaining that regulatory class will be the larger ones that have relatively lower fuel economy. Averaging their capabilities will result in a lower target than if the small SUV in question was remained in place. Moving the SUV into the passenger car fleet may either boost or lower the average fuel economy level required of passenger cars, depending on how the size and potential fuel economy of the given SUV compares to those of the vehicles that were already classified as passenger cars.

NHTSA's analysis indicates that the direction and magnitude of the net effects of vehicle re-classification depend on the composition of the fleet and the specific nature of the change in classification. As shown in Figure 10-1, assigning two-wheel drive SUVs and those vehicles that do not meet the third row requirement to the passenger car fleet would add to the passenger car fleet a set of vehicles (labeled "PC Formerly Classified as LT") with fuel economy levels that are generally (though not universally) in the same range as those of passenger cars of similar footprint. However, further reassigning to the passenger car fleet minivans and vehicles that <u>do</u> meet the third row requirement, as commenters appear to suggest, would add to the passenger car fleet a set of vehicles (labeled "LT Reassigned to PC under Alternative Definition") with fuel economy levels that are generally (though not universally) lower than those of passenger cars of similar footprint. Figure 10-2 shows how the composition of the light truck fleet is affected by such shifts. Reassigning either the smaller or larger group of vehicles to the passenger car fleet removes from the light truck fleet vehicles that are generally (though not universally) smaller and more efficient than the vehicles that remain in the light truck fleet.

As discussed above, in the context of the MY 2011-2015 passenger car and light truck standards, moving 1,400,000 two-wheel drive SUVs from the light truck to the passenger car fleet, as reflected in this FEIS, increases the fuel economy standards for both light trucks and passenger cars. However, going further and reclassifying other light trucks as passenger cars, as the commenters would have NHTSA do, would change the form and stringency of the curves for the maximum feasible standards. Substantially, it would reduce overall average required CAFE levels by an average of 0.4 mpg during MY 2011-2015, reducing fuel savings by 2.7 billion gallons over the useful life of vehicles sold in these model years, and increasing carbon dioxide emissions by 28 million metric tons.

Accordingly, EPCA and EISA's overarching purpose of energy conservation would not be better fulfilled by further changing the vehicle classifications.

The current definitions are tighter and more difficult to game than commenters suggest. *With regard to the commenters' argument that the standards allow manufacturers to "game" the definitions by making minor changes to vehicles to obtain a light truck classification and thus, a lower fuel economy target, NHTSA notes that minor changes are not sufficient, and that fairly major changes would be necessary in order to reclassify a passenger car as a light truck. To make a two-wheel drive SUV a light truck, for example, manufacturers would need either to add a third row of seats to it, convert it to four-wheel drive, or raise its GVWR over 6,000 lbs and ensure that it met 4 out of the 5 ground clearance characteristics. These changes are not minor, and likely can be made only every several years at the time of one of the periodic vehicle redesigns. Additionally, the minor benefit to be gained in terms of a lower target must be balanced against consumer demand. In a time of high gas prices and increasing*

Figure 10-1. Passenger Car Fleet

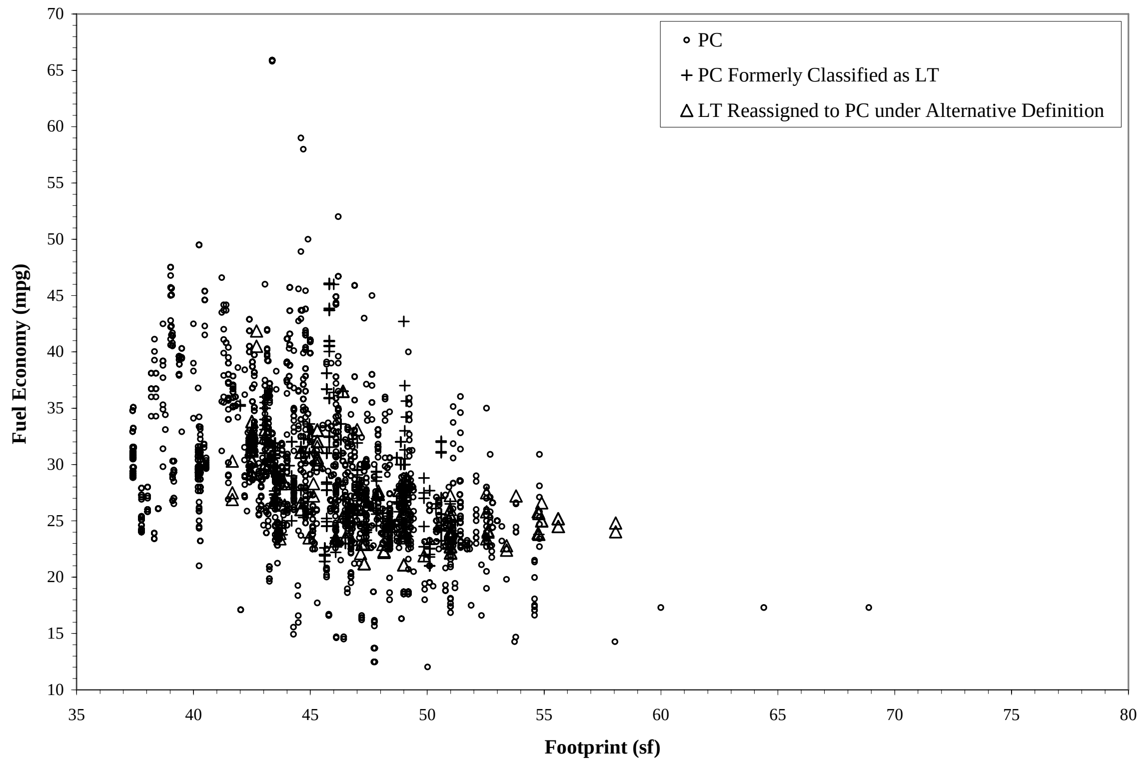
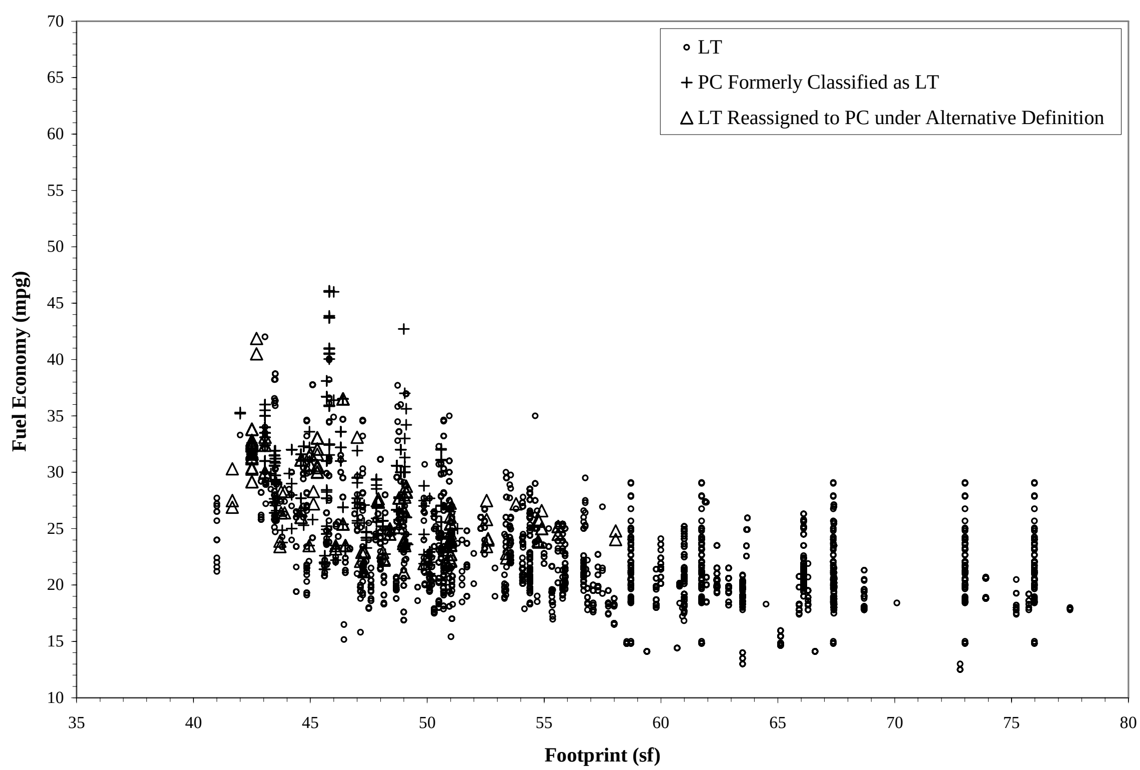


Figure 10-2. Light Truck Fleet



consumer interest in high fuel economy vehicles, it seems unlikely to NHTSA that manufacturers would take the risk of turning passenger cars into light trucks solely to obtain the slightly lower light truck target.

Further, to the extent that commenters and the Ninth Circuit believe that EPA's regulatory definitions for emissions purposes are "tighter" than NHTSA's, we note that this is not an apt comparison for several reasons. First, the NAS Report and the 9th Circuit are referring to EPA's Tier 2 criteria pollutant emissions requirements for mobile sources. These requirements are different from the CAFE requirements—light trucks produce more criteria pollutants than passenger cars not just because they tend to consume more fuel, but because their engines tend to be tuned differently to produce more torque for cargo-carrying and towing, which creates more pollution. Thus, the effect of having more light trucks on the roads (and thus wanting to limit their classification as light trucks) is greater for criteria pollutant emissions purposes than for CAFE purposes.

Second, EPA continues to use the same definitions as NHTSA does for CAFE purposes.[25] Even though EPA has changed its definitions for Tier 2 purposes, the effect of those changes was to move only four vehicle models—the Chrysler PT Cruiser, the Chevrolet HHR, the Honda Element, and the Dodge Magnum—whose combined production is currently less than 250,000 per year. NHTSA believes that manufacturers currently classify these four vehicles as light trucks either because they come in four-wheel drive, or because their rear seats may be easily removed to create a flat, floor level surface that increases cargo-carrying capacity. After MY 2011, vehicles may only be classified as light trucks on the basis of permitting expanded use of the vehicle for cargo-carrying purposes if they have three rows that fold flat. As currently designed, none of these four models would meet this requirement, so NHTSA would likely classify these vehicles as passenger cars as well. And third, after MY 2009, EPA will have no distinction between passenger cars and light trucks for Tier 2 purposes—all vehicles will be subject to the same standard. The fact that EPA has slightly restricted the definition of light truck for Tier 2 purposes will soon be entirely irrelevant.

In summary, EPA's "tightening" of the light truck category in Tier 2 resulted in the reclassification of less than 20 percent of the number of vehicles reclassified as a result of our tightening the implementation of our vehicle definitions. Further, EPA's action has little relevance to vehicle classification for CAFE purposes. This is proved by the fact that EPA ultimately intends to do away with the distinction between passenger car requirements and light truck requirements in Tier 2, an option which EPCA would not permit NHTSA to implement for CAFE.

With regard to commenters' argument that the existing definitions do not ensure that "vehicles that more closely resemble large cars and station wagons" (which NHTSA takes to refer to crossovers) are classified as passenger cars, we note that as a result of the tightened implementation of our vehicle definitions, many crossovers are in fact now properly classified as passenger cars. To the extent that crossovers are not classified as passenger cars, it is, we believe, only because they either (1) have four-wheel drive and meet 4 out of 5 ground clearance characteristics; (2) are over 6,000 lbs GVWR and meet 4 out of 5 ground clearance characteristics; or (3) have three rows of seats.

[25] *See 40 CFR Part 600.002-93.*

Chapter 11 Index

APPENDIX A

Sources Identified in Scoping Comments and Comments on the Draft Environmental Impact Statement

Table A-1

Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
HIGH PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	Barnett, T.P. et al. 2008. Human-Induced Changes in the Hydrology of the Western U.S. Science 319:1080-1083. http://tenaya.ucsd.edu/~dettinge/barnett08.pdf	Climate change impacts could be more significant than IPCC Report suggests	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Barnett, T.P. et al. 2008. *When will Lake Mead go Dry?* Water Resources Research, doi:10.1029/R006704.	Climate change impacts could be more significant than IPCC Report suggests		No
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Field, C. B., L. D. Mortsch, M. Brklacich, D. L. Forbes, P. Kovacs, J. A. Patz, S. W. Running and M. J. Scott. 2007. North America. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry Martin, Osvaldo Canziani, Jean Palutikof, Paul Van Der Linden and Clair Hanson. Cambridge, UK, Cambridge University Press. Available: http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2chapter14.pdf. Last Accessed February 4, 2008.	Changes in natural systems due to climate change	Yes	No
LOW PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	American Lung Association, *State of the Air*: 2008. http://www.lungusa2.org/sota/SOTA2008.pdf.	Potential health effects		No
NHTSA-2008-0060-0007.1	Attorney General of California	California Blue Ribbon Task Force, *Delta Vision.* 2008. http://deltavision.ca.gov/DeltaVision-DraftTaskForceVision.shtml.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	California Environmental Protection Agency, Climate Action Team Report to Governor Schwarzenegger and the California Legislature, Executive Summary, 2006.	Global warming impacts on different regions		No

Table A-1 (cont'd)

Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	California Environmental Protection Agency, Climate Action Team Report to Governor Schwarzenegger and the California Legislature, Full Report, 2006.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	California Environmental Protection Agency. 2002. *Environmental Protection Indicators for California*.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Cayan, D. et al. 2006. *Projecting Future Sea Level rise*, Report from California Climate Change Center.	Global warming impacts on different regions	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Cayan, D. et al. 2006. *Scenarios of Climate Change in California: An Overview*, a Report from California Climate Change Center.	Global warming impacts on different regions	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Center for Health & the Global Environment. 2006. *Climate Change Futures, Health Ecological and Economic Dimensions.* http://www.climatechangefutures.org/pdf/CCF_Report_Final_10.27.pdf.	"Tipping points" of global warming should be included in EIS		No
NHTSA-2008-0060-0007.1	Attorney General of California	Center for Integrative Environmental Research. 2007. *U.S. Economic Impact of Climate Change and the Costs of Inaction*. http://www.cier.umd.edu/climateadaptation/index.html.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Climate Change Research Center. 2005. *Indicators of Climate Change in the Northeast*. http://www.cleanair-coolplanet.org/information/pdf/indicators.pdf.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Columbia Earth Institute. 2001. *Climate Change and a Global City: The Potential Consequences of Climate Variability and Change*. http://www.ccsr.columbia.edu/cig/mec/.	Global warming impacts on different regions		No

Table A-1 (cont'd)

Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	Dernbach, J.C. et al. 2007. Developing a Comprehensive Approach to Climate Change Policy in the U.S. *Virginia Environmental Law Journal* 26. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1020740.	State and regional efforts to reduce GHG emissions	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Environment New Jersey Research and Policy Center. 2007. *An Unfamiliar State, Local Impacts of Global Warming New Jersey*. http://www.environmentnewjersey.org/uploads/-z/wV/-zwV3Jt9hnScxAwZbMymqQ/An-Unfamiliar-State---Local-Impacts-of-Global-Warming-in-New-Jersey.pdf.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Foster, G. et al. 2008. Comment on "Heat Capacity, time constant, and Sensitivity of Earth's Climate System." *Journal of Geophysical Research* 113. 5 pgs. http://www.jamstec.go.jp/frsgc/research/d5/jdannan/comment_on_schwartz.pdf.	Greenhouse gas concentrations and climate sensitivity	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Fourth Assessment of the IPCC, WG1. 2007. "*The Physical Science Basis,"* Summary for Policymakers. http://www.ipcc.ch/ipccreports/ar4-wg1.htm.	Atmospheric concentration of carbon dioxide/ emissions	Yes	Yes
NHTSA-2008-0060-0007.1	Attorney General of California	Fourth Assessment of the IPCC, WG1. 2007. *Frequently Asked Question 7.1.* http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-faqs.pdf.	Atmospheric concentration of carbon dioxide/ emissions	Yes	Yes
NHTSA-2008-0060-0007.1	Attorney General of California	Franco, G., et al. 2006. *Climate Change and Electricity Demand in California*, Report from California Climate Change Center.	Global warming impacts on different regions	Yes	Yes
NHTSA-2008-0060-0007.1	Attorney General of California	Frumhoff, P.C. et al. 2007. *Confronting Climate Change in the U.S. Northeast*. http://www.climatechoices.org/assets/documents/climatechoices/confronting-climate-change-in-the-u-s-northeast.pdf.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Gutierrez, S. et al. 2007. *Potential for Shoreline Changes due to Sea Level Rise*. http://woodshole.er.usgs.gov/pubs/of2007-1278/images/report.pdf.	Global warming impacts on different regions		No

Table A-1 (cont'd)

Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	Hansen, J.H. et al. 2007. *Climate change and trace gases*. http://pubs.giss.nasa.gov/docs/2007/2007_Hansen_etal_2.pdf.	Atmospheric concentration of carbon dioxide/ emissions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Hansen, J.H. et al. 2007. *Dangerous human-made interference with climate*. http://pubs.giss.nasa. gov/docs/2007/2007_Hansen_etal_1.pdf.	Atmospheric concentration of carbon dioxide/ emissions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Hayhoe, K. et al. 2004. *Emissions pathways, climate change, and impacts on California*, Proceedings of the National Academy of Sciences of the United States of America.	Global warming impacts on different regions		Yes
NHTSA-2008-0060-0007.1	Attorney General of California	ICF International. 2007. *The Potential Impacts on Global Sea Level Rise on Transportation Infrastructure*. http://climate.dot.gov/publications/potential_impacts_of_global_sea_level_rise/index.html.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	IPCC Special Report on+B2 Emissions Scenarios. 2000. Summary for Policymakers. http://www.ipcc.ch/ipccreports/sres/emission/index.htm.	Climate models and greenhouse warming responses	Yes	Yes
NHTSA-2008-0060-0007.1	Attorney General of California	Jacobson, Mark Z. 2008. Testimony to Select Committee on Energy Independence & Global Warming. http://www.stanford.edu/group/efmh/jacobson/Testimony0408%202.pdf.	Potential health effects		No
NHTSA-2008-0060-0007.1	Attorney General of California	Jacobson, Mark Z. 2008. *On the casual link between carbon dioxide and air pollution mortality*. Geophysical Research Letters, 35 L03809. http://www.fypower.org/pdf/stanford_CO2_Jacobson.pdf.	Potential health effects	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Jacobson, Mark Z. 2008. *Effects of Local v Global CO2 Emission on Local Air Quality and Health*. Presentation to EPA-Standford Symposium on Impacts of Climate Change in Air Quality.	Potential health effects		No

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Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	Kleeman, M. et al. 2005. Interim Report, *Impact of Climate Change on Meteorology and Regional Air Quality in California*.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Lovins, B. et al. 2004. *Winning the Oil Endgame*. http://nc.rmi.org/NETCOMMUNITY/Page.aspx?pid=269&srcid=269.	Alternatives; Decreasing the weight of vehicles		No
NHTSA-2008-0060-0007.1	Attorney General of California	Luers, A. et al. 2006. *Our Changing Climate, assessing the Risks to California*, Report from California Climate Change Center.	Global warming impacts on different regions	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Lutsey, N. et al. 2008. *America's bottom-up climate change mitigation policy.* http://pubs.its.ucdavis.edu/publication_detail.php?id=1135.	State and regional efforts to reduce GHG emissions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Mid-Atlantic Regional Assessment Team. 2008. *Preparing for a Changing Climate*. http://www.cira.psu.edu/mara/results/overview_report/index.html#report.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Motallebi, N. et al. 2008. *Climate change Impact on California On-Road Mobil Source Emissions.* Climatic Change 87:293-308.	Global warming impacts on different regions	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Mott, J. et al. 1999. *Wildland forest fire smoke: health effects and intervention evaluation,* Hoopa, California. West J Med 176.	Global warming impacts on different regions	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	National Research Council. 2007. *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability*. http://www.nap.edu/catalog/11857.html.	Global warming impacts on different regions		No

Table A-1 (cont'd)

Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	National Research Council. 2008. *Potential Impacts of Climate Change on U.S. Transportation.* Transportation Research Board. http://www.trb.org/news/blurb_detail.asp?ID=8794.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	New Mexico Office of the State Engineer. 2005. *The Impact of Climate Change on New Mexico's Water Supply*. http://www.nmenv.state.nm.us/cc/.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	New York City Department of Environmental Protection. 2008. Climate Assessment & Action Plan Report. http://www.nyc.gov/html/dep/pdf/climate/climate_complete.pdf.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	NJ Dept. of Envt'l Prot. 2006. *Climate Change in NJ, Trends in Temperature and Sea Level.* http://www.nj.gov/dep/dsr/trends2005/pdfs/climate-change.pdf.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	*On Vehicle Weight, Fuel Economy and Safety*, Expert Report of David L. Greene. 2006. Central Valley Chrysler-Jeep v. Witherspoon (E.D. CA) No. CIV-F-04-6663.	Alternatives; Decreasing the weight of vehicles		No
NHTSA-2008-0060-0007.1	Attorney General of California	Princeton University. 2007. *The Garden State in the Greenhouse, Climate Change Mitigation & Coastal Adaptation Strategies for New Jersey*. http://www.princeton.edu/~mauzeral/teaching/wws591a_report.pdf.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Rahmstorf, S. et al. 2007. Recent Climate Observations Compared to Projections. *Science* 316:709. http://pubs.giss.nasa.gov/docs/2007/2007_Rahmstorf_etal.pdf.	Models used by IPCC may underestimate climate change	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Rahmstorf, S. 2007. *Semi-Empirical Approach to Projecting Future Sea-Level Rise* http://www.pik-potsdam.de/~stefan/Publications/Nature/rahmstorf_science_2007.pdf.	Climate change impacts could be more significant than IPCC Report suggests		No

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Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	Rignot, E. et al. *Recent Antarctic ice mass loss from radar interferometry and regional climate modeling.* http://www.nature.com/ngeo/journal/v1/n2/pdf/ngeo102.pdf;jsessionid=89C973CCC639FF018AE9571AE6394A1F.	Climate change impacts could be more significant than IPCC Report suggests	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Rocky Mountain Climate Organization. 2008. *Hotter and Drier - The West's Changed Climate*. http://www.nrdc.org/globalWarming/west/west.pdf.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Schmidt, C. 2007. *California Out in Front*, *Environmental Health Perspectives*, 115, No. 3, A145-47.	Global warming impacts on different regions	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	Schneider, S.H. 2007. California State Motor Vehicle Pollution Control Standards; Request for Waiver of Federal Preemption: *The Unique Risks to California from Human-Induced Climate Change*.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Stanley, A. et al. 2007. *Holocene Sea Level Rise in New Jersey*. http://www.state.nj.us/dep/dsr/climate/holocene.pdf.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Statement of Howard Frumkin, MD. 2008. Climate Change and Public Health. http://www.cdc.gov/washington/testimony/2008/t20080409.htm.	Potential health effects		No
NHTSA-2008-0060-0007.1	Attorney General of California	Steiner, A. et al. 2006. *Influence of future climate and emissions on regional air quality in California*, Journal of Geophysical Research, 111.	Global warming impacts on different regions	Yes	No
NHTSA-2008-0060-0007.1	Attorney General of California	U.S. Climate Change Science Program. 2008. *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase*. http://climate.dot.gov/publications/impact_of_climate_change/.	Global warming impacts on different regions		No

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Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "*Trends in Atmospheric Carbon Dioxide - Mauna Lo.a.*" http://www.esrl.noaa.gov/gmd/ccgg/trends/.	Atmospheric concentration of carbon dioxide/ emissions		No
NHTSA-2008-0060-0007.1	Attorney General of California	U.S. EPA. 2007. *A Wedge Analysis of the U.S. Transportation Sector*. http://www.epa.gov/ oms/climate/420f07049.htm.	Cumulative impact of emissions on climate change		No
NHTSA-2008-0060-0007.1	Attorney General of California	U.S. National Assessment. 2000. *Climate Change and a Global City: Assessment of Metropolitan East Coast Region*. http://metroeast_climate.ciesin.columbia.edu/reports/ assessmentsynth.pdf.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	UNFCCC. National greenhouse gas inventory data for the period 1990-2005 USA. http://unfccc.int/resource/docs/2007/asr/usa.pdf.	Cumulative impact of emissions on climate change		No
NHTSA-2008-0060-0007.1	Attorney General of California	Union Concerned Scientists. 2007. *Confronting Climate Change in New Jersey*. http://www.climatechoices.org/assets/documents/climatechoices/new-jersey_necia.pdf.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	Union of Concerned Scientists. 2006. *Global Warming and California Wildfires*.	Global warming impacts on different regions		No
NHTSA-2008-0060-0007.1	Attorney General of California	U.S. EPA. *Climate Change and New Jersey.* http://yosemite.epa.gov/oar/ globalwarming.nsf/UniqueKeyLookup/SHSU5BVJH3/$File/nj_impct.pdf	Global warming impacts on different regions		No

Table A-1 (cont'd)

Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	Van Auken, R.M. et al. DRI-TR-03-01 VOLUME 1 *A Further Assessment of the Effects of Vehicle Weight, etc.*, Executive Summary.	Alternatives; Decreasing the weight of vehicles		No
NHTSA-2008-0060-0007.1	Attorney General of California	Van Auken, R.M. et al. DRI-TR-03-01 VOLUME 3 *A Further Assessment of the Effects of Vehicle Weight, etc.*, Appendices.	Alternatives; Decreasing the weight of vehicles		No
NHTSA-2008-0060-0007.1	Attorney General of California	Van Auken, R.M. et al. 2005. *An Assessment of the Effects of Vehicle Weight and Size on Fatality Risk*. http://www.sae.org/technical/papers/2005-01-1354.	Alternatives; Decreasing the weight of vehicles		No
NHTSA-2008-0060-0007.1	Attorney General of California	Van Auken, R.M. et al. DRI-TR-03-01 VOLUME 2 *A Further Assessment of the Effects of Vehicle Weight, etc.,* Technical Report.	Alternatives; Decreasing the weight of vehicles		No
NHTSA-2008-0060-0007.1	Attorney General of California	Van Auken, R.M. et al. 2004. DRI-TR-04-02 *A Review of the Results in the 1997 Kahane … Reports*. http://www.theicct.org/documents/DynamicResearch_WeightFatalityES_2004.pdf.	Alternatives; Decreasing the weight of vehicles		No
NHTSA-2008-0060-0007.1	Attorney General of California	Van Auken, R.M. et al. 2005. DRI-TR-05-01 *Supplemental Results on the Independent Effects of Curb Weight, etc*. http//www.theicct.org/documents/DynamicResearch_ WeightFatality_2005.pdf. :	Alternatives; Decreasing the weight of vehicles		No
NHTSA-2008-0060-0007.1	Attorney General of California	Westerling, A. et al. 2006. *Climate Change and Wildfire In and Around California: Fire Modeling and Loss Modeling*, Report from California Climate Change Center.	Global warming impacts on different regions		No

Table A-1 (cont'd)

Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0007.1	Attorney General of California	Westerling, A. et al. 2006. *Warming and Earlier Spring Increases Western U.S. Forest Wildfire Activity*, *Science Express*.	Global warming impacts on different regions	Yes	Yes
NHTSA-2008-0060-0007.1	Attorney General of California	Wigley, T.M.L. 2005. *The Climate Change Commitment*. Science 307:1766-1769.	Estimating potential temperature changes	Yes	Yes
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Austin, J. A. and S. M. Colman. 2007. "*Lake Superior Summer Water Temperatures Are Increasing More Rapidly Than Regional Air Temperatures: A Positive Ice-Albedo Feedback*." Geophysical Research Letters 34. Available: http://www.d.umn.edu/~jaustin/ICE.html. Last Accessed: May 27, 2008.	Changes in natural systems due to climate change	Yes	No
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Davis, M. B. and R. G. Shaw. 2001. "*Range Shifts and Adaptive Responses to Quaternary Climate Change*." Science 292: 673-9. Available: http://ptolemy.gmu.edu/ ~beall/data/vostok_papers_data/climate_adaption.pdf. Last Accessed: May 27, 2008.	Changes in natural systems due to climate change	Yes	Yes
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Iverson, L. R. and A. M. Prasad. 1998. *Predicting Abundance for 80 Tree Species Following Climate Change in the Eastern United States.* Ecological Monographs 68(4): 465-85. Available: http://www.fs.fed.us/ne/delaware/4153/iverson18.pdf. Last Accessed: May 27, 2008.	Changes in natural systems due to climate change	Yes	No
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Jacobson, M. Z. 2008. *On the Causal Link between Carbon Dioxide and Air Pollution Mortality*. Geophysical Research Letters 35(L03809). Available: http://www.cosis.net/ abstracts/EGU2008/04328/EGU2008-A-04328.pdf?PHPSESSID=. Last Accessed: May 27, 2008.	Changes in natural systems due to climate change	Yes	No
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Johnson, S. L. and H. G. Stefan. 2006. *Indicators of Climate Warming in Minnesota: Lake Ice Covers and Snowmelt Runoff*. Climatic Change 75: 421-53. Available: http://www.springerlink.com/content/58238844v30u8286/. Last Accessed: May 27, 2008.	Changes in natural systems due to climate change	Yes	No

Table A-1 (cont'd)

Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Johnson, W. C., B. V. Millett, T. Gilmanov, R. A. Voldseth, G. R. Guntenspergen, and D. E. Naugle. 2005. *Vulnerability of Northern Prairie Wetlands to Climate Change*. BioScience 55(10): 863-72. Available: http://www.forestry.umt.edu/ research/cesu/NEWCESU/Assets/Individual%20Project%20Reports/USGS%20Projects/ Naugle_wetlands04.pdf. Last Accessed: May 27, 2008.	Changes in natural systems due to climate change	Yes	Yes
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Kirilenko, A. P. and R. A. Sedjo. 2007. *Climate Change Impacts on Forestry*. PNAS 104(50): 19697-702. Available: http://www.pnas.org/cgi/reprint/0701424104v1. Last Accessed: May 27, 2008.	Changes in natural systems due to climate change		No
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Nordhaus, W. 2007. *The Challenge of Global Warming: Economic Models and Environmental Policy*. Connecticut, Yale University. Available: http://nordhaus.econ.yale. edu/dice_mss_072407_all.pdf. Last Accessed May 23, 2008.	Marginal cost estimates for next emitted ton of carbon dioxide		No
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Parmesan, C. 2006. *Ecological and Evolutionary Responses to Recent Climate Change*. Annual Review of Ecology, Evolution, and Systematics 37: 637-69. Available: http://cns.utexas.edu/communications/File/AnnRev_CCimpacts2006.pdf. Last Accessed: May 27, 2008.	Changes in natural systems due to climate change	Yes	Yes
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Rosenzweig, C. 2008. *Attributing Physical and Biological Impacts to Anthropogenic Climate Change*. Nature 453: 353-7. Available: http://www.nature.com/nature/journal/ v453/n7193/full/nature06937.html. Last Accessed: May 20, 2008	Changes in natural systems due to climate change	Yes	No
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Trapp, R. J., N. S. Diffenbaugh, H. E. Brooks, M. E. Baldwin, E. D. Robinson, and J. S. Pal. 2007. *Changes in Severe Thunderstorm Environment Frequency During the 21st Century Caused by Anthropogenically Enhanced Global Radiative Forcing.* PNAS 104(50):19719-23. Available: http://www.pnas.org/cgi/reprint/0705494104v2. Last Accessed: May 27, 2008.	Changes in natural systems due to climate change		No
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	U.S. EPA. 2008. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*. 430-R-08-005. Available: http://www.epa.gov/climatechange/emissions/usinventoryreport. html. Last Accessed: May 27, 2008.	Impacts from various emissions sources		No

Table A-1 (cont'd)

Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Western Regional Climate Center. 2008. *Plot Time History of Single/Multi-Month Precipitation/Temperature*. Available: http://www.wrcc.dri.edu/cgi-bin/divplot1_form.pl?2106. Last Accessed December 18, 2007.	Increase in mean annual air temperatures		No
NHTSA-2008-0060-0011	Minnesota Pollution Control Agency	Williams, J. W., S. T. Jackson, and J. E. Kutzbach. 2007. *Projected Distribution of Novel and Disappearing Climates by 2100 AD*. PNAS 104(14): 5738-42. 10.1073/pnas.06062. Available: http://www.pnas.org/cgi/content/full/104/14/5738. Last Accessed: May 22, 2008.	Novel climates and/or disappearance of extant climates due to emissions		Yes
NHTSA-2008-0060-0014	Yuli and Susan Chew	Economics Group, Defra. 2007. The Social Cost of Carbon and the Shadow Price of Carbon: What They Are, And How to Use Them in Economic Appraisal in the U.K. http://www.defra.gov.uk/environment/climatechange/research/carboncost/pdf/background.pdf.	Social cost of carbon value		No
NHTSA-2008-0060-0014	Yuli and Susan Chew	*Massachusetts et al. v. Environmental Protection Agency et al*. Argued November 29, 2006. Decided April 2, 2007.	Preemption of state rights to carbon dioxide standard		No
NHTSA-2008-0060-0015	Environmental Defense Fund	Confalonieri, U., B. Menne et al. 2007. Human Health. *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. M. Parry, O. Canziani, J. Palutikof, P. van der Linden, and C. Hanson. Cambridge, UK, Cambridge University Press.	Potential health effects	Yes	Yes
NHTSA-2008-0060-0015	Environmental Defense Fund	Ebi, K.L., J. Balbus, P.L. Kinney, et al. 2008. Effects of Global Change on Human Health. In: J.L. Gamble, K.L. Ebi, F.G. Sussman, and T.J. Wilbanks, Editors. *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems (Synthesis and Assessment Product 4.6)*. Washington, DC: U.S. Climate Change Science Program. Available at: http://www.climatescience.gov (accessed 22 May 2008).	Potential health effects		No
NHTSA-2008-0060-0015	Environmental Defense Fund	Haines, A. et al. 2004. *Summary of causal mechanisms for health impacts of climate change*. JAMA. 291:99-103.	Health impacts	Yes	No

Table A-1 (cont'd) Sources Identified in Scoping Comments					
Comment No. (EIS Docket No.)	**Name of Commenter**	**Full Title and Citation of Source (with a URL if available)**	**Issue Addressed by Source**	**Peer Reviewed? (Yes/No)**	**Included in IPCC's Fourth Assessment Report? (Yes/No)**
LOW PRIORITY					
NHTSA-2008-0060-0015	Environmental Defense Fund	McMichael, A., D.H. Campbell-Lendrum, et al. 2004. *Climate change. Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors*. M. Ezzati, A. Lopez, A. Rodgers, and C. Mathers. Geneva, WHO: 1543-1649.	Potential health effects		Yes
NHTSA-2008-0060-0015	Environmental Defense Fund	National Research Council. 2007. *Evaluating Progress of the U.S. Climate Change Science Program: Methods and Preliminary Results*. NRC Committee on Strategic Advice on the U.S. Climate Change Science Program. Washington, DC: The National Academies Press. Available at http://books.nap.edu/openbook.php?record_id= T.J.11934&page=R1 (Accessed 28 May 2008).	Potential health effects		No
NHTSA-2008-0060-0015	Environmental Defense Fund	U.S. Department of Transportation, Federal Highway Administration. 2000. Addendum to the 1997 Federal Highway Cost Allocation Study Final Report.	Health benefits of reducing emissions		No
NHTSA-2008-0060-0140	Department of Health & Human Services	Friedman, MS, K.E. Powell, L. Hutwagner, et al. 2001. *Impact of changes in transportation and commuting behaviors during the 1996 Summer Olympic games in Atlanta on air quality and childhood asthma*. JAMA. 285:897-905.	Potential health effects	Yes	No
NHTSA-2008-0060-0140	Department of Health & Human Services	Centers for Disease Control and Prevention. No date. *CDC Policy on Climate Change and Health*. Accessed at: http://www.cdc.gov/climatechange/pubs/Climate_Change_Policy.pdf.	Potential health effects		No
NHTSA-2008-0060-0140	Department of Health & Human Services	Frumkin, H., J. Hess, and S. Vindigni. 2007. *Peak petroleum and public health*. JAMA 298:1688-1690.	Potential health effects	Yes	No
NHTSA-2008-0060-0140	Department of Health & Human Services	Frumkin, H., J. Hess, G. Luber, J. Malilay, and M. McGeehin. 2008. *Climate change: the public health response*. Am J Public Health 98:435-445.	Potential health effects	Yes	No

Table A-1 (cont'd)

Sources Identified in Scoping Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
LOW PRIORITY					
NHTSA-2008-0060-0140	Department of Health & Human Services	Luber, G. and J. Hess. 2007. *Climate change and human health in the United States.* J of Env Health 70(5):43-44.	Potential health effects	Yes	No
NHTSA-2008-0060-0140	Department of Health & Human Services	Patz, J.A., M. McGeehin, S.M. Bernard, K.L. Ebie, P.R. Epstein, A. Grambsch, D.J. Gubler, P. Reiter, I. Romieu, J.B. Rose, J.M. Samet, and J. Trang. 2008. *The potential health impacts of climate variability and change for the U.S*. Env Helth Pers. 108 (4): 36-54.	Potential health effects	Yes	No

Table A-2

Sources Identified in DEIS Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
NHTSA-2008-0060-0557.1	NRDC	NRDC. 2008. Issue Paper, "The New Energy Economy: Putting America on the Path to Solving Global Warming". Available at http://www.nrdc.org/globalWarming/energy/contents.asp.	Air Quality	No	No
NHTSA-2008-0060-0557.1	NRDC	NRDC. "COMMENTS ON: Notice of Proposed Rulemaking, Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011—2015, Department of Transportation, National Highway Traffic Safety Administration, Docket No. NHTSA—2008—0089," submitted July 1, 2008.	Numerous	No	No
NHTSA-2008-0060-0557.1	NRDC	Long-range Energy Alternatives Planning (LEAP) system stock model available at http://www.seib.org/software/leap.html.	Reducing GHG Emissions	No	No
NHTSA-2008-0060-0559.1	NESCAUM	NEPA guidance document. Considering Cumulative Effects under the National Environmental Policy Act. http://www.nepa.gov/nepa/ccenepa/ccenepa.htm.	Cumulative Impacts under NEPA	No	No
NHTSA-2008-0060-0559.1	NESCAUM	Goulder, L.H. et al. 1999. Induced Technological Change and the Attractiveness of CO_2 Abatement Policies, *Resource and Energy Economics* 21:211-253.	Technology and GHG Reductions	Yes	Yes
NHTSA-2008-0060-0564.1	CFA	Kopp, R. and W. A. Pizer. 2007. *Assessing U.S. Climate Policy Options.* Resources for the Future: November 2007.	Climate Policy	No	No
NHTSA-2008-0060-0564.1	CFA	McKinsey and Company and The Conference Board. 2007. *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?*	Air Quality	No	No
NHTSA-2008-0060-0564.2	CFA	National opinion polls conducted for the Consumer Federation of America by the Opinion Research Corporation. 2008. 2007, see Consumer Federation of America, *No Time to Waste*, available at http://www.consumerfed.org/pdfs/No_Time_To_Waste.pdf 2006 and Consumer Federation of America, *Consumers Still Greatly Concerned About Better Gas Mileage and Oil Imports Despite Falling Gas Prices,* available at http://www.consumerfed.org/pdfs/Gas_Mileage_Consumer_Attitudes_Manu_Performance_Press_Release111 306.pdf	Consumer Demand	No	No
NHTSA-2008-0060-0564.2	CFA	Cooper, M. 2008. *Ending America's Oil Addiction* (Washington, D.C.: Consumer Federation of America). http://www.consumerfed.org/pdfs/First_Quarterly_Gas_Report_2008.pdf.	Reducing Oil Dependency	No	No
NHTSA-2008-0060-0564.2	CFA	National opinion poll conducted for the Consumer Federation of America by the Opinion Research Corporation. 2008. CFA database on miles per gallon.	Fuel Efficiency	No	No

Table A2 (cont'd)

Sources Identified in DEIS Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
NHTSA-2008-0060-0564.2	CFA	Shephardsom, D. "U.S. Auto Fleet Hits MPG Record," *Detroit News.* August 13, 2008.	Fuel Efficiency	No	No
NHTSA-2008-0060-0564.2	CFA	Lieber, R. and T. S. Bernard. "Ditch the Gas Guzzler? Well, Maybe Not Just Yet," *New York Times.* August 2, 2008, p. B-4.	Fuel Efficiency	No	No
NHTSA-2008-0060-0564.2	CFA	Bunkley, N. "An SUV Traffic Jam," *New York Times.* August 13, 2008, p. C-1.	Fuel Efficiency	No	No
NHTSA-2008-0060-0564.2	CFA	University of Michigan Transportation Research Institute, Automotive Analysis Division. "Auto Consumers Restructuring the Auto Industry's Restructuring," *Auto New Service,* Issue 53.	Fleet Composition	No	No
NHTSA-2008-0060-0564.2	CFA	McManus, W. "The Link Between Gasoline Prices and Vehicle Sales," *Business Economics,* January 2007.	Consumer Demand	No	No
NHTSA-2008-0060-0564.2	CFA	Congressional Budget Office. 2008. *Effects of Gasoline Prices on Driving Behavior and Vehicle Markets*.	Consumer Demand	No	No
NHTSA-2008-0060-0564.2	CFA	CBO. Effects of Gasoline Prices, pp. x-xi.	Consumer Demand	No	No
NHTSA-2008-0060-0564.2	CFA	Gillis, J. and M. Cooper. 2007. *Still Stuck in Neutral: America's Continued Failure to Improve Motor Vehicle Fuel Efficiency: 1996:2005.* Available at http://www.consumerfed.org/pdfs/Still_Stuck.pdf.	Fuel Efficiency	No	No
NHTSA-2008-0060-0564.2	CFA	Gillis, J. 2006. Stuck *in Neutral: America's Failure to Improve Motor Vehicle Fuel Efficiency: 1996-2005.* Available at http://www.consumerfed.org/pdfs/Stuck_in_Neutral.pdf.	Fuel Efficiency	No	No
NHTSA-2008-0060-0564.2	CFA	Consumer Federation of America. "Comments and Technical Appendices," in National Highway Traffic Safety Administration, Notice of Proposed Rulemaking, Average Fuel Economy Standards, Passenger Cars and Light Trucks: Model Years 2011-2015, Docket No. HNTSA 2008-0089, RIN 2127-AK29, July 1, 2008.	Numerous	No	No

Table A2 (cont'd)

Sources Identified in DEIS Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
NHTSA-2008-0060-0564.2	CFA	Energy Information Administration, *Impacts of Increased Access to Oil and Natural Gas Resources in the Lower 48 Federal Outer Continental Shelf*. Available at http://www.eia.doe.gov/oiaf/aeo/otheranalysis/ongr.html); Office of Regulatory Analysis and Evaluation, *Corporate Average Fuel Economy for MY 2011-2015: Passenger Cars and Light Trucks* (National Highway Traffic Safety Administration, April 2008.	Fuel Efficiency	No	No
NHTSA-2008-0060-0564.2	CFA	Office of Regulatory Analysis and Evaluation. *Corporate Average Fuel Economy for MY 2011-2015: Passenger Cars and Light Trucks* (National Highway Traffic Safety Administration, April 2008. Vehicle miles traveled (pp. VIII-15, VIII-16) are used to extent the analysis to 2030 assuming fuel savings in each year is proportionate to the weighted average of the vintaged fleet miles traveled by the fleet in existence in 2015. Fuel savings scenarios, p. VIII-51	Vehicle Miles Traveled and Fuel Efficiency	No	No
NHTSA-2008-0060-0565.1	CBD	Downing, T.E. et al. 2005. Social Cost of Carbon: A Closer Look at Uncertainty. Department for Environment, Food, and Rural Affairs. London, England. http://www.defra.gov.uk.	Social Cost of Carbon	No	No
NHTSA-2008-0060-0566.1	CBD	Maslowski, W. 2008. When will Summer Arctic Sea Ice Disappear? Symposium on Drastic Change in the Earth System during Global Warming. Sapporo, Japan. http://hdl.handle.net/2115/34395.	Climate Change, Sea Level Rise	No	No
NHTSA-2008-0060-567.1	CBD	Bernstein, L. et al. 2007. Summary for Policy Makers. Climate Change 2007: Synthesis Report. An Assessment of the Intergovernmental Panel on Climate Change. Valencia, Spain.	Climate Change, Air Quality, Resource Impacts, CO_2 Emissions	Yes	Yes
NHTSA-2008-0060-567.1	CBD	Yohe, G.W. et al. 2007. Perspectives on climate change and sustainability. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 811-841.	Climate Change	Yes	Yes
NHTSA-2008-0060-568.1	CBD	Kleypas, J.A. et al. 2006. Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers: A Guide for Future Research, report of a workshop held 18–20 April 2005, St. Petersburg, FL, sponsored by NSF, NOAA, and the U.S. Geological Survey, 88 pp.	Coastal Systems, Resource Areas	No	No

Table A2 (cont'd)

Sources Identified in DEIS Comments

Comment No. (EIS Docket No.)	Name of Commenter	Full Title and Citation of Source (with a URL if available)	Issue Addressed by Source	Peer Reviewed? (Yes/No)	Included in IPCC's Fourth Assessment Report? (Yes/No)
NHTSA-2008-0060-569.1	CBD	U.S. Environmental Protection Agency (EPA). 2002. Health assessment document for diesel engine exhaust. Prepared by the National Center for Environmental Assessment, Washington, DC, for the Office of Transportation and Air Quality; EPA/600/8-90/057F. Available from: National Technical Information Service, Springfield, VA; PB2002-107661, and http://www.epa.gov/ncea.	Air Quality, Human Health	No	No

APPENDIX B

Energy, Air Quality, and Climate Modeling Data

Appendix B-1

ENERGY MODELING DATA

This appendix accompanies Sections 3.2 and 4.2 of the Final Environmental Impact Statement (FEIS) and presents fuel consumption results from two additional scenarios that NHTSA ran in the Volpe model. As is the case with Reference Case and High Scenario results presented in Sections 3.2 and 4.2, fuel consumption in the Mid-1 and Mid-2 Scenarios encompasses both gasoline and diesel. Like the High Scenario, the Mid-1 and Mid-2 Scenarios use the fuel prices drawn from the High Price Case in the AEO 2008. Results from the Mid-1 and Mid-2 Scenarios fall between those from the Reference Case and High Scenario. Tables B1-1 through B1-4 correspond to Section 3.2 and show the direct effects on fuel consumption of proposed CAFE standards. Tables B1-5 through B1-8 correspond to Section 4.2 and show the cumulative fuel consumption of the vehicle fleet from the onset of the proposed standards.

Table B1-1

Mid-1 Scenario Passenger Car Annual Fuel Consumption and Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Fuel Consumption							
2020	62.1	59.5	59.2	58.8	58.5	57.9	54.5
2030	71.1	66.1	65.5	64.9	64.5	63.4	58.0
2040	81.4	75.4	74.8	74.1	73.6	72.4	66.0
2050	93.2	86.4	85.7	84.9	84.2	82.9	75.6
2060	106.2	98.3	97.5	96.7	95.9	94.4	86.1
Fuel Savings from No Action							
2020	--	2.6	2.9	3.3	3.6	4.3	7.7
2030	--	5.0	5.6	6.1	6.6	7.6	13.1
2040	--	6.0	6.6	7.3	7.9	9.0	15.4
2050	--	6.9	7.6	8.4	9.0	10.3	17.6
2060 a/	--	7.8	8.6	9.5	10.2	11.8	20.1

a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.

Table B1-2

Mid-1 Scenario Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Fuel Consumption							
2020	77.0	74.1	73.8	73.5	73.2	72.5	69.2
2030	84.3	78.5	77.9	77.4	77.0	75.8	69.8
2040	95.8	88.5	87.8	87.1	86.6	85.2	77.8
2050	109.4	100.9	100.0	99.2	98.7	97.0	88.4
2060	124.6	114.9	113.9	113.0	112.4	110.5	100.6
Fuel Savings from No Action							
2020	--	2.8	3.2	3.5	3.8	4.4	7.8
2030	--	5.7	6.3	6.9	7.3	8.4	14.4
2040	--	7.2	8.0	8.7	9.2	10.6	18.0
2050	--	8.5	9.3	10.1	10.7	12.3	21.0
2060 a/	--	9.7	10.7	11.6	12.2	14.1	24.0

a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.

Table B1-3

Mid-2 Scenario Passenger Car Annual Fuel Consumption and Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Fuel Consumption							
2020	62.1	59.4	59.2	58.9	58.6	58.1	54.5
2030	71.1	65.9	65.5	65.1	64.7	63.9	58.0
2040	81.4	75.2	74.8	74.3	73.9	73.0	66.0
2050	93.2	86.2	85.7	85.1	84.6	83.6	75.6
2060	106.2	98.1	97.5	96.9	96.3	95.2	86.1
Fuel Savings from No Action							
2020	--	2.7	2.9	3.2	3.5	4.0	7.7
2030	--	5.2	5.6	6.0	6.4	7.1	13.1
2040	--	6.2	6.6	7.1	7.6	8.4	15.4
2050	--	7.1	7.6	8.1	8.7	9.7	17.6
2060 a/	--	8.1	8.6	9.3	9.9	11.0	20.1

a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.

Table B1-4

Mid-2 Scenario Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2015						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Fuel Consumption							
2020	77.0	75.1	74.6	74.0	73.6	72.7	69.2
2030	84.3	80.9	79.9	78.7	77.9	76.1	69.8
2040	95.8	91.6	90.4	88.8	87.8	85.6	77.8
2050	109.4	104.6	103.1	101.3	100.1	97.5	88.4
2060	124.6	119.1	117.4	115.4	114.0	111.0	100.6
Fuel Savings from No Action							
2020	--	1.9	2.4	3.0	3.4	4.3	7.8
2030	--	3.3	4.3	5.5	6.3	8.1	14.4
2040	--	4.1	5.4	6.9	7.9	10.2	18.0
2050	--	4.8	6.3	8.1	9.2	11.9	21.0
2060 a/	--	5.5	7.2	9.2	10.6	13.6	24.0

a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.

Table B1-5

Mid-1 Scenario Passenger Car Cumulative Annual Fuel Consumption and Cumulative Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2020						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Cumulative Fuel Consumption							
2010-2020	652.7	638.0	635.8	633.9	631.9	628.1	611.5
2010-2030	1,322.1	1,224.8	1,212.9	1,207.1	1,200.8	1,186.6	1,142.4
2010-2040	2,088.5	1,861.5	1,834.5	1,824.6	1,813.1	1,785.3	1,716.4
2010-2050	2,966.7	2,587.2	2,542.4	2,527.8	2,510.4	2,466.8	2,371.1
2010-2060	3,970.2	3,416.2	3,351.2	3,331.3	3,307.2	3,245.5	3,119.1
Cumulative Fuel Savings from No Action							
2010-2020	--	14.7	16.9	18.8	20.8	24.6	41.2
2010-2030	--	97.3	109.2	115.0	121.4	135.5	179.7
2010-2040	--	227.0	254.0	264.0	275.5	303.3	372.1
2010-2050	--	379.6	424.3	438.9	456.3	499.9	595.6
2010-2060 a/	--	554.0	619.0	638.9	663.1	724.7	851.1

a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.

Table B1-6

Mid-1 Scenario Light Truck Cumulative Annual Fuel Consumption and Cumulative Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2020						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Calendar Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Cost Equal Total Benefit	Technology Exhaustion
Cumulative Fuel Consumption							
2010-2020	845.9	828.4	826.3	824.5	822.9	819.3	803.9
2010-2030	1,649.4	1,517.8	1,508.0	1,499.1	1,492.9	1,476.1	1,426.6
2010-2040	2,553.1	2,232.6	2,211.6	2,192.2	2,179.4	2,143.2	2,053.5
2010-2050	3,584.1	3,031.6	2,996.9	2,964.7	2,944.3	2,884.5	2,748.8
2010-2060	4,760.9	3,939.3	3,888.9	3,842.0	3,812.6	3,725.7	3,537.4
Cumulative Fuel Savings from No Action							
2010-2020	--	17.5	19.7	21.5	23.1	26.6	42.1
2010-2030	--	131.6	141.4	150.2	156.5	173.2	222.7
2010-2040	--	320.5	341.5	360.9	373.7	409.9	499.6
2010-2050	--	552.5	587.2	619.4	639.8	699.6	835.3
2010-2060 a/	--	821.5	871.9	918.9	948.2	1,035.1	1,223.4

a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.

Table B1-7

Mid-2 Scenario Passenger Car Cumulative Annual Fuel Consumption and Cumulative Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2020						
	Alt. 1	**Alt. 2**	**Alt. 3**	**Alt. 4**	**Alt. 5**	**Alt. 6**	**Alt. 7**
Calendar Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Cost Equal Total Benefit**	**Technology Exhaustion**
Cumulative Fuel Consumption							
2010-2020	652.7	637.3	635.8	634.1	632.3	629.1	611.5
2010-2030	1,322.1	1,222.0	1,215.1	1,208.7	1,203.0	1,189.9	1,142.4
2010-2040	2,088.5	1,855.7	1,841.1	1,828.4	1,818.1	1,791.1	1,716.4
2010-2050	2,966.7	2,577.9	2,554.1	2,534.1	2,518.6	2,475.4	2,371.1
2010-2060	3,970.2	3,403.0	3,368.7	3,340.4	3,318.9	3,257.2	3,119.1
Cumulative Fuel Savings from No Action							
2010-2020	--	15.4	16.9	18.6	20.4	23.6	41.2
2010-2030	--	100.1	107.0	113.4	119.1	132.2	179.7
2010-2040	--	232.8	247.5	260.2	270.5	297.4	372.1
2010-2050	--	388.8	412.7	432.7	448.2	491.3	595.6
2010-2060 a/	--	567.2	601.5	629.8	651.3	713.0	851.1

a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.

Table B1-8

Mid-2 Scenario Light Truck Cumulative Annual Fuel Consumption and Cumulative Fuel Savings (billion gallons)

	Alternative CAFE Standards for Model Years 2011-2020						
	Alt. 1	**Alt. 2**	**Alt. 3**	**Alt. 4**	**Alt. 5**	**Alt. 6**	**Alt. 7**
Calendar Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Cost Equal Total Benefit**	**Technology Exhaustion**
Cumulative Fuel Consumption							
2010-2020	845.9	831.8	829.4	826.7	824.4	819.9	803.9
2010-2030	1,649.4	1,550.2	1,535.3	1,518.0	1,505.6	1,480.3	1,426.6
2010-2040	2,553.1	2,313.0	2,278.4	2,238.1	2,210.4	2,152.8	2,053.5
2010-2050	3,584.1	3,170.7	3,112.0	3,043.9	2,997.5	2,900.8	2,748.8
2010-2060	4,760.9	4,146.4	4,060.0	3,959.7	3,891.7	3,749.6	3,537.4
Cumulative Fuel Savings from No Action							
2010-2020	--	14.1	16.5	19.3	21.6	26.0	42.1
2010-2030	--	99.1	114.1	131.4	143.8	169.1	222.7
2010-2040	--	240.1	274.8	315.0	342.7	400.3	499.6
2010-2050	--	413.4	472.1	540.2	586.6	683.3	835.3
2010-2060 a/	--	614.5	700.9	801.2	869.2	1,011.2	1,223.4

a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.

Appendix B-2

AIR QUALITY MODELING DATA

This appendix accompanies Sections 3.3 and 4.3 of the Final Environmental Impact Statement (FEIS) and presents the results of the air quality analysis for individual nonattainment areas. Each table provides the estimated reduction in emissions for one pollutant and calendar year of analysis for each nonattainment area by alternative. In each table, the emissions changes are presented for the proposed model year (MY) 2011-2015 CAFE Standards, and also for the cumulative impacts of the proposed MY 2011-2015 standards and the reasonably foreseeable MY 2016-2020 standards. The tables for the Reference Case are presented first, and then the tables for the High Scenario. Following these tables, national-level emissions results for the Mid-1 and Mid-2 Scenarios are presented.

Table B2-1
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.00	0.00	0.04	0.05	0.07	0.67	0.00	0.00	0.00	0.04	0.05	0.07	0.67
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.07	0.00	0.00	0.00	0.00	0.01	0.01	0.07
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.07
Atlanta, GA	x	x	100	100	0.00	0.02	-0.01	0.21	0.26	0.39	3.54	0.00	0.02	-0.01	0.21	0.26	0.39	3.54
Baltimore, MD	x	x	100	100	0.00	0.01	0.00	0.09	0.11	0.16	1.47	0.00	0.01	0.00	0.09	0.11	0.16	1.47
Baton Rouge, LA	x	-	100	-	0.00	-0.15	-0.17	-0.19	-0.21	-0.27	-1.44	0.00	-0.15	-0.17	-0.19	-0.21	-0.27	-1.44
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-0.30	-0.34	-0.42	-0.46	-0.60	-3.38	0.00	-0.30	-0.34	-0.42	-0.46	-0.60	-3.38
Birmingham, AL	-	x	-	100	0.00	0.00	0.00	0.03	0.04	0.06	0.54	0.00	0.00	0.00	0.03	0.04	0.06	0.54
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.01	-0.01	0.14	0.17	0.26	2.40	0.00	0.01	-0.01	0.14	0.17	0.26	2.40
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.04	0.32	0.00	0.00	0.00	0.02	0.02	0.04	0.32
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.00	0.00	0.03	0.04	0.06	0.58	0.00	0.00	0.00	0.03	0.04	0.06	0.58
Canton-Massillon, OH	-	x	-	100	0.00	-0.02	-0.02	-0.02	-0.02	-0.02	-0.07	0.00	-0.02	-0.02	-0.02	-0.02	-0.02	-0.07
Charleston, WV	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.15	0.00	0.00	0.00	0.01	0.01	0.02	0.15
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.00	0.00	0.06	0.07	0.10	0.93	0.00	0.00	0.00	0.06	0.07	0.10	0.93
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.03	0.28	0.00	0.00	0.00	0.02	0.02	0.03	0.28
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.20	-0.25	-0.10	-0.08	-0.05	1.04	0.00	-0.21	-0.26	-0.10	-0.08	-0.05	1.04
Chico, CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.10	0.00	0.00	0.00	0.01	0.01	0.01	0.10
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.00	0.00	0.06	0.07	0.11	0.95	0.00	0.00	0.00	0.06	0.07	0.11	0.95
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.09	0.00	0.00	0.00	0.01	0.01	0.01	0.09
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.01	0.00	0.08	0.10	0.15	1.37	0.00	0.01	0.00	0.08	0.10	0.15	1.37
Columbus, OH	x	x	100	100	0.00	0.00	0.00	0.05	0.06	0.10	0.89	0.00	0.00	0.00	0.05	0.06	0.10	0.89
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.02	-0.01	0.21	0.26	0.40	3.60	0.00	0.02	-0.01	0.21	0.26	0.40	3.60
Dayton-Springfield, OH	-	x	-	100	0.00	0.00	0.00	0.02	0.03	0.05	0.42	0.00	0.00	0.00	0.02	0.03	0.05	0.42
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.02	-0.03	0.06	0.08	0.13	1.37	0.00	-0.02	-0.03	0.06	0.08	0.13	1.37
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.02	-0.04	0.11	0.14	0.22	2.19	0.00	-0.02	-0.04	0.11	0.14	0.22	2.19
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.18	0.00	0.00	0.00	0.01	0.01	0.02	0.18
Greater Connecticut, CT	x	-	100	-	0.00	0.00	0.00	0.05	0.07	0.10	0.91	0.00	0.00	0.00	0.05	0.07	0.10	0.91
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.00	0.00	0.02	0.03	0.05	0.41	0.00	0.00	0.00	0.02	0.03	0.05	0.41
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.00	0.00	0.02	0.03	0.04	0.37	0.00	0.00	0.00	0.02	0.03	0.04	0.37

Table B2-1
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.10	0.00	0.00	0.00	0.01	0.01	0.01	0.10
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-0.61	-0.70	-0.72	-0.78	-0.97	-4.70	0.00	-0.61	-0.70	-0.73	-0.79	-0.98	-4.71
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.06	-0.07	-0.07	-0.08	-0.10	-0.48	0.00	-0.06	-0.07	-0.07	-0.08	-0.10	-0.48
Imperial Co., CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.11	0.00	0.00	0.00	0.01	0.01	0.01	0.11
Indianapolis, IN	-	x	-	100	0.00	0.00	0.00	0.05	0.06	0.09	0.83	0.00	0.00	0.00	0.05	0.06	0.09	0.83
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.08	0.00	0.00	0.00	0.00	0.01	0.01	0.08
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.07	0.00	0.00	0.00	0.00	0.01	0.01	0.07
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.06
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.06
Knoxville, TN	x	x	100	100	0.00	0.00	0.00	0.03	0.04	0.06	0.56	0.00	0.00	0.00	0.03	0.04	0.06	0.56
Lancaster, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.02	0.02	0.22	0.00	0.00	0.00	0.01	0.02	0.02	0.22
Las Vegas, NV	x	-	100	-	0.00	0.00	0.00	0.04	0.05	0.08	0.73	0.00	0.00	0.00	0.04	0.05	0.08	0.73
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-0.30	-0.39	-0.02	0.03	0.16	3.67	0.00	-0.30	-0.39	-0.02	0.03	0.16	3.67
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.00	0.00	0.02	0.03	0.04	0.38	0.00	0.00	0.00	0.02	0.03	0.04	0.38
Louisville, KY-IN	-	x	-	100	0.00	0.00	0.00	0.03	0.04	0.06	0.58	0.00	0.00	0.00	0.03	0.04	0.06	0.58
Macon, GA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.11	0.00	0.00	0.00	0.01	0.01	0.01	0.11
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.06
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.05
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.00	0.00	0.01	0.02	0.02	0.21	0.00	0.00	0.00	0.01	0.02	0.02	0.21
Memphis, TN-AR	x	-	100	-	0.00	-0.05	-0.06	-0.04	-0.04	-0.04	-0.06	0.00	-0.05	-0.06	-0.04	-0.04	-0.04	-0.06
Milwaukee-Racine, WI	x	-	100	-	0.00	0.00	0.00	0.05	0.07	0.10	0.91	0.00	0.00	0.00	0.05	0.07	0.10	0.91
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.05
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.05	-0.12	0.32	0.41	0.65	6.46	0.00	-0.05	-0.12	0.32	0.41	0.65	6.46
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.08	0.00	0.00	0.00	0.00	0.01	0.01	0.08
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-0.30	-0.36	-0.24	-0.24	-0.26	-0.22	0.00	-0.31	-0.37	-0.24	-0.24	-0.26	-0.22
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.01	-0.01	0.12	0.15	0.22	2.03	0.00	0.01	-0.01	0.12	0.15	0.22	2.03
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.00	0.00	0.06	0.07	0.11	1.01	0.00	0.00	0.00	0.06	0.07	0.11	1.01
Poughkeepsie, NY	x	x	100	100	0.00	0.00	0.00	0.04	0.05	0.07	0.66	0.00	0.00	0.00	0.04	0.05	0.07	0.66

Table B2-1
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.00	0.00	0.03	0.03	0.05	0.48	0.00	0.00	0.00	0.03	0.03	0.05	0.48
Reading, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.19	0.00	0.00	0.00	0.01	0.01	0.02	0.19
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.00	0.00	0.02	0.03	0.04	0.38	0.00	0.00	0.00	0.02	0.03	0.04	0.38
Rochester, NY	x	-	100	-	0.00	0.00	0.00	0.04	0.05	0.07	0.67	0.00	0.00	0.00	0.04	0.05	0.07	0.67
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.06
Sacramento Metro, CA	x	-	50	-	0.00	0.00	0.00	0.07	0.08	0.12	1.12	0.00	0.00	0.00	0.07	0.08	0.12	1.12
San Diego, CA	x	-	100	-	0.00	0.01	0.00	0.09	0.11	0.17	1.57	0.00	0.01	0.00	0.09	0.11	0.17	1.57
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.16	-0.21	-0.05	-0.03	0.01	1.32	0.00	-0.16	-0.21	-0.05	-0.03	0.01	1.32
San Joaquin Valley, CA	x	x	50	100	0.00	-0.02	-0.04	0.09	0.12	0.19	1.93	0.00	-0.02	-0.04	0.09	0.12	0.19	1.93
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.06
Springfield (Western MA), MA	x	-	100	-	0.00	0.00	0.00	0.03	0.03	0.05	0.48	0.00	0.00	0.00	0.03	0.03	0.05	0.48
St. Louis, MO-IL	x	x	100	100	0.00	-0.08	-0.10	-0.02	-0.01	0.01	0.61	0.00	-0.08	-0.10	-0.02	-0.01	0.01	0.60
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.01	-0.01	0.00	0.00	0.00	-0.01	0.00	-0.01	-0.01	0.00	0.00	0.00	-0.01
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.03	0.32	0.00	0.00	0.00	0.02	0.02	0.03	0.32
Washington, DC-MD-VA	x	x	100	100	0.00	0.01	-0.01	0.15	0.18	0.28	2.52	0.00	0.01	-0.01	0.15	0.18	0.28	2.52
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.09	0.00	0.00	0.00	0.01	0.01	0.01	0.09
York, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.20	0.00	0.00	0.00	0.01	0.01	0.02	0.20

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.

b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.

c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See Section 3.3.1.)

EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-2
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.04	0.03	0.12	0.14	0.12	1.22	0.00	0.09	0.08	0.18	0.20	0.19	1.40
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.13	0.00	0.01	0.01	0.02	0.02	0.02	0.15
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.13	0.00	0.01	0.01	0.02	0.02	0.02	0.15
Atlanta, GA	x	x	100	100	0.00	0.21	0.18	0.68	0.79	0.70	7.05	0.00	0.50	0.48	1.02	1.16	1.10	8.10
Baltimore, MD	x	x	100	100	0.00	0.08	0.07	0.26	0.30	0.26	2.68	0.00	0.19	0.18	0.39	0.44	0.42	3.07
Baton Rouge, LA	x	-	100	-	0.00	-0.44	-0.48	-0.55	-0.62	-0.77	-3.86	0.00	-1.02	-1.08	-1.17	-1.26	-1.43	-4.41
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-0.90	-1.00	-1.19	-1.35	-1.64	-8.66	0.00	-2.11	-2.24	-2.48	-2.68	-3.01	-9.91
Birmingham, AL	-	x	-	100	0.00	0.03	0.02	0.09	0.11	0.09	0.96	0.00	0.07	0.07	0.14	0.16	0.15	1.10
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.12	0.11	0.40	0.47	0.42	4.19	0.00	0.30	0.29	0.61	0.69	0.65	4.82
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.02	0.01	0.06	0.07	0.06	0.59	0.00	0.04	0.04	0.09	0.10	0.09	0.67
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.03	0.03	0.10	0.11	0.10	1.00	0.00	0.07	0.07	0.15	0.17	0.16	1.15
Canton-Massillon, OH	-	x	-	100	0.00	-0.05	-0.06	-0.05	-0.06	-0.08	-0.30	0.00	-0.12	-0.13	-0.12	-0.13	-0.15	-0.34
Charleston, WV	-	x	-	100	0.00	0.01	0.01	0.03	0.03	0.03	0.26	0.00	0.02	0.02	0.04	0.04	0.04	0.30
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.05	0.05	0.18	0.20	0.18	1.83	0.00	0.13	0.13	0.26	0.30	0.28	2.10
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.01	0.01	0.05	0.05	0.05	0.49	0.00	0.03	0.03	0.07	0.08	0.08	0.56
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.47	-0.56	-0.26	-0.27	-0.56	0.06	0.00	-1.08	-1.19	-0.88	-0.90	-1.20	0.10
Chico, CA	x	-	100	-	0.00	0.01	0.00	0.02	0.02	0.02	0.18	0.00	0.01	0.01	0.03	0.03	0.03	0.21
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.05	0.04	0.16	0.19	0.17	1.71	0.00	0.12	0.12	0.25	0.28	0.26	1.96
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.01	0.02	0.02	0.15	0.00	0.01	0.01	0.02	0.03	0.02	0.18
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.07	0.06	0.23	0.27	0.24	2.38	0.00	0.17	0.16	0.35	0.39	0.37	2.74
Columbus, OH	x	x	100	100	0.00	0.05	0.04	0.16	0.18	0.16	1.65	0.00	0.12	0.11	0.24	0.27	0.26	1.89
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.20	0.18	0.67	0.78	0.69	6.99	0.00	0.50	0.48	1.01	1.15	1.09	8.03
Dayton-Springfield, OH	-	x	-	100	0.00	0.02	0.02	0.07	0.08	0.07	0.72	0.00	0.05	0.05	0.11	0.12	0.11	0.83
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.02	0.00	0.20	0.23	0.17	2.38	0.00	0.04	0.03	0.24	0.29	0.23	2.74
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.05	0.02	0.32	0.37	0.29	3.62	0.00	0.12	0.10	0.42	0.49	0.41	4.16
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.01	0.01	0.03	0.04	0.03	0.32	0.00	0.02	0.02	0.05	0.05	0.05	0.37
Greater Connecticut, CT	x	-	100	-	0.00	0.05	0.04	0.16	0.18	0.16	1.64	0.00	0.12	0.11	0.24	0.27	0.25	1.88
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.01	0.01	0.01	0.04
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.02	0.02	0.07	0.08	0.07	0.74	0.00	0.05	0.05	0.11	0.12	0.12	0.85
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.02	0.02	0.06	0.07	0.07	0.66	0.00	0.05	0.05	0.10	0.11	0.10	0.76

Table B2-2
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Emission Changes a/ by Nonattainment Area

Acetaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Hickory, NC	-	x	-	100	0.00	0.01	0.00	0.02	0.02	0.02	0.18	0.00	0.01	0.01	0.03	0.03	0.03	0.20
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-1.73	-1.94	-2.05	-2.30	-2.96	-13.64	0.00	-4.03	-4.30	-4.48	-4.81	-5.53	-15.58
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.17	-0.19	-0.20	-0.23	-0.29	-1.39	0.00	-0.39	-0.42	-0.44	-0.48	-0.54	-1.59
Imperial Co., CA	x	-	100	-	0.00	0.01	0.01	0.02	0.03	0.02	0.23	0.00	0.02	0.02	0.03	0.04	0.04	0.26
Indianapolis, IN	-	x	-	100	0.00	0.04	0.04	0.15	0.17	0.15	1.53	0.00	0.11	0.11	0.22	0.25	0.24	1.76
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.13	0.00	0.01	0.01	0.02	0.02	0.02	0.15
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.13	0.00	0.01	0.01	0.02	0.02	0.02	0.15
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.11	0.00	0.01	0.01	0.02	0.02	0.02	0.12
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.12	0.00	0.01	0.01	0.02	0.02	0.02	0.14
Knoxville, TN	x	x	100	100	0.00	0.03	0.03	0.10	0.11	0.10	1.03	0.00	0.07	0.07	0.15	0.17	0.16	1.18
Lancaster, PA	-	x	-	100	0.00	0.01	0.01	0.04	0.04	0.04	0.39	0.00	0.03	0.03	0.06	0.06	0.06	0.45
Las Vegas, NV	x	-	100	-	0.00	0.04	0.04	0.14	0.17	0.15	1.50	0.00	0.11	0.10	0.22	0.25	0.23	1.73
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-0.59	-0.75	0.01	0.06	-0.44	4.29	0.00	-1.34	-1.51	-0.73	-0.67	-1.17	4.98
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.02	0.02	0.07	0.08	0.07	0.72	0.00	0.05	0.05	0.10	0.12	0.11	0.83
Louisville, KY-IN	-	x	-	100	0.00	0.03	0.03	0.10	0.11	0.10	1.01	0.00	0.07	0.07	0.15	0.17	0.16	1.16
Macon, GA	-	x	-	100	0.00	0.01	0.00	0.02	0.02	0.02	0.19	0.00	0.01	0.01	0.03	0.03	0.03	0.22
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.01	0.01	0.01	0.10	0.00	0.01	0.01	0.01	0.02	0.01	0.11
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.11	0.00	0.01	0.01	0.02	0.02	0.02	0.12
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.01	0.01	0.04	0.05	0.04	0.42	0.00	0.03	0.03	0.06	0.07	0.07	0.49
Memphis, TN-AR	x	-	100	-	0.00	-0.12	-0.14	-0.11	-0.12	-0.18	-0.55	0.00	-0.28	-0.30	-0.28	-0.29	-0.35	-0.62
Milwaukee-Racine, WI	x	-	100	-	0.00	0.05	0.04	0.15	0.18	0.16	1.60	0.00	0.11	0.11	0.23	0.26	0.25	1.83
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.10	0.00	0.01	0.01	0.01	0.02	0.01	0.11
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.13	0.05	0.92	1.08	0.83	10.62	0.00	0.33	0.26	1.20	1.40	1.18	12.21
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.01	0.02	0.01	0.14	0.00	0.01	0.01	0.02	0.02	0.02	0.16
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-0.77	-0.89	-0.67	-0.74	-1.13	-3.04	0.00	-1.79	-1.94	-1.73	-1.82	-2.23	-3.45
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.12	0.10	0.39	0.46	0.40	4.09	0.00	0.29	0.28	0.59	0.67	0.64	4.70
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.05	0.04	0.17	0.19	0.17	1.72	0.00	0.12	0.12	0.25	0.28	0.27	1.98
Poughkeepsie, NY	x	x	100	100	0.00	0.04	0.03	0.12	0.13	0.12	1.21	0.00	0.09	0.08	0.18	0.20	0.19	1.39

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Acetaldehyde 2020

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					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.02	0.02	0.08	0.09	0.08	0.83	0.00	0.06	0.06	0.12	0.14	0.13	0.96
Reading, PA	-	x	-	100	0.00	0.01	0.01	0.03	0.04	0.04	0.36	0.00	0.03	0.02	0.05	0.06	0.06	0.41
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.02	0.02	0.08	0.09	0.08	0.84	0.00	0.06	0.06	0.12	0.14	0.13	0.97
Rochester, NY	x	-	100	-	0.00	0.03	0.03	0.11	0.13	0.12	1.18	0.00	0.08	0.08	0.17	0.19	0.18	1.35
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.10	0.00	0.01	0.01	0.01	0.02	0.02	0.12
Sacramento Metro, CA	x	-	50	-	0.00	0.06	0.05	0.20	0.24	0.21	2.13	0.00	0.15	0.15	0.31	0.35	0.33	2.44
San Diego, CA	x	-	100	-	0.00	0.08	0.07	0.26	0.31	0.27	2.74	0.00	0.19	0.19	0.40	0.45	0.43	3.15
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.36	-0.44	-0.14	-0.14	-0.39	0.76	0.00	-0.83	-0.91	-0.61	-0.61	-0.86	0.90
San Joaquin Valley, CA	x	x	50	100	0.00	0.04	0.02	0.31	0.37	0.28	3.60	0.00	0.11	0.09	0.40	0.47	0.40	4.15
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.11	0.00	0.01	0.01	0.02	0.02	0.02	0.13
Springfield (Western MA), MA	x	-	100	-	0.00	0.02	0.02	0.08	0.10	0.08	0.85	0.00	0.06	0.06	0.12	0.14	0.13	0.98
St. Louis, MO-IL	x	x	100	100	0.00	-0.17	-0.20	-0.07	-0.07	-0.18	0.34	0.00	-0.38	-0.42	-0.28	-0.28	-0.40	0.40
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.01	-0.02	-0.01	-0.01	-0.02	-0.07	0.00	-0.03	-0.03	-0.03	-0.03	-0.04	-0.08
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.01	0.01	0.05	0.06	0.05	0.56	0.00	0.04	0.03	0.08	0.09	0.08	0.64
Washington, DC-MD-VA	x	x	100	100	0.00	0.14	0.12	0.45	0.52	0.46	4.63	0.00	0.33	0.32	0.67	0.76	0.72	5.33
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.01	0.02	0.01	0.15	0.00	0.01	0.01	0.02	0.02	0.02	0.17
York, PA	-	x	-	100	0.00	0.01	0.01	0.04	0.04	0.04	0.38	0.00	0.03	0.03	0.06	0.06	0.06	0.44

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See Section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-3
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.07	0.07	0.14	0.17	0.11	0.73	0.00	0.25	0.26	0.34	0.38	0.33	1.31
Allegan Co., MI	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.01	0.08	0.00	0.03	0.03	0.04	0.04	0.04	0.14
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.01	0.08	0.00	0.03	0.03	0.04	0.04	0.04	0.15
Atlanta, GA	x	x	100	100	0.00	0.45	0.46	0.92	1.06	0.69	4.64	0.00	1.60	1.66	2.17	2.41	2.10	8.40
Baltimore, MD	x	x	100	100	0.00	0.15	0.16	0.32	0.36	0.24	1.59	0.00	0.55	0.57	0.74	0.83	0.72	2.88
Baton Rouge, LA	x	-	100	-	0.00	-0.68	-0.74	-0.87	-0.99	-1.22	-6.35	0.00	-2.22	-2.33	-2.51	-2.69	-2.96	-7.75
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1.41	-1.55	-1.86	-2.11	-2.54	-13.34	0.00	-4.66	-4.88	-5.32	-5.69	-6.21	-16.61
Birmingham, AL	-	x	-	100	0.00	0.05	0.06	0.11	0.13	0.08	0.56	0.00	0.19	0.20	0.26	0.29	0.25	1.01
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.23	0.24	0.48	0.55	0.36	2.40	0.00	0.83	0.86	1.13	1.25	1.09	4.35
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.03	0.03	0.07	0.08	0.05	0.35	0.00	0.12	0.12	0.16	0.18	0.16	0.63
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.05	0.06	0.11	0.13	0.09	0.57	0.00	0.20	0.20	0.27	0.30	0.26	1.03
Canton-Massillon, OH	-	x	-	100	0.00	-0.08	-0.09	-0.09	-0.10	-0.14	-0.72	0.00	-0.25	-0.26	-0.28	-0.29	-0.33	-0.81
Charleston, WV	-	x	-	100	0.00	0.01	0.01	0.03	0.03	0.02	0.15	0.00	0.05	0.05	0.07	0.08	0.07	0.27
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.11	0.12	0.23	0.27	0.18	1.17	0.00	0.40	0.42	0.55	0.61	0.53	2.12
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.03	0.03	0.06	0.06	0.04	0.28	0.00	0.10	0.10	0.13	0.15	0.13	0.51
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.66	-0.75	-0.60	-0.66	-1.27	-5.88	0.00	-2.07	-2.18	-2.08	-2.16	-2.78	-5.17
Chico, CA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.02	0.11	0.00	0.04	0.04	0.05	0.06	0.05	0.19
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.10	0.10	0.20	0.23	0.15	1.01	0.00	0.35	0.36	0.47	0.52	0.46	1.83
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.01	0.09	0.00	0.03	0.03	0.04	0.04	0.04	0.15
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.13	0.13	0.27	0.31	0.20	1.35	0.00	0.47	0.48	0.63	0.70	0.61	2.44
Columbus, OH	x	x	100	100	0.00	0.10	0.10	0.20	0.23	0.15	1.00	0.00	0.35	0.36	0.47	0.52	0.45	1.81
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.43	0.45	0.89	1.02	0.67	4.47	0.00	1.54	1.60	2.10	2.32	2.03	8.09
Dayton-Springfield, OH	-	x	-	100	0.00	0.04	0.04	0.08	0.09	0.06	0.41	0.00	0.14	0.15	0.19	0.21	0.19	0.74
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.07	0.06	0.23	0.26	0.08	0.80	0.00	0.27	0.28	0.46	0.52	0.35	2.09
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.12	0.11	0.34	0.39	0.15	1.34	0.00	0.46	0.47	0.71	0.81	0.59	3.10
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.03
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.02	0.02	0.04	0.04	0.03	0.19	0.00	0.06	0.07	0.09	0.10	0.08	0.34
Greater Connecticut, CT	x	-	100	-	0.00	0.09	0.10	0.19	0.22	0.14	0.96	0.00	0.33	0.34	0.45	0.50	0.43	1.74
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.03
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.04	0.04	0.09	0.10	0.07	0.44	0.00	0.15	0.16	0.20	0.23	0.20	0.79
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.04	0.04	0.08	0.09	0.06	0.38	0.00	0.13	0.14	0.18	0.20	0.17	0.69

Table B2-3
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.02	0.11	0.00	0.04	0.04	0.05	0.06	0.05	0.19
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-2.66	-2.93	-3.31	-3.75	-4.82	-24.81	0.00	-8.68	-9.10	-9.73	-10.36	-11.58	-29.49
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.26	-0.29	-0.33	-0.37	-0.47	-2.45	0.00	-0.86	-0.90	-0.96	-1.03	-1.14	-2.95
Imperial Co., CA	x	-	100	-	0.00	0.01	0.01	0.03	0.03	0.02	0.15	0.00	0.05	0.05	0.07	0.08	0.07	0.27
Indianapolis, IN	-	x	-	100	0.00	0.09	0.09	0.18	0.21	0.14	0.93	0.00	0.32	0.33	0.44	0.48	0.42	1.69
Jamestown, NY	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.01	0.08	0.00	0.03	0.03	0.04	0.04	0.03	0.14
Jefferson Co., NY	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.01	0.08	0.00	0.03	0.03	0.04	0.04	0.04	0.15
Johnstown, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.01	0.06	0.00	0.02	0.02	0.03	0.03	0.03	0.11
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.01	0.08	0.00	0.03	0.03	0.04	0.04	0.03	0.14
Knoxville, TN	x	x	100	100	0.00	0.06	0.06	0.12	0.14	0.09	0.61	0.00	0.21	0.22	0.29	0.32	0.28	1.11
Lancaster, PA	-	x	-	100	0.00	0.02	0.02	0.05	0.05	0.03	0.23	0.00	0.08	0.08	0.11	0.12	0.10	0.41
Las Vegas, NV	x	-	100	-	0.00	0.10	0.10	0.20	0.23	0.15	1.01	0.00	0.35	0.36	0.47	0.52	0.46	1.83
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-0.74	-0.86	-0.36	-0.38	-1.52	-6.18	0.00	-2.20	-2.33	-1.87	-1.85	-2.98	-2.87
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.04	0.05	0.09	0.10	0.07	0.45	0.00	0.16	0.16	0.21	0.23	0.20	0.82
Louisville, KY-IN	-	x	-	100	0.00	0.06	0.06	0.11	0.13	0.09	0.57	0.00	0.20	0.21	0.27	0.30	0.26	1.04
Macon, GA	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.02	0.11	0.00	0.04	0.04	0.05	0.06	0.05	0.20
Manitowoc Co., WI	x	-		-	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.00	0.02	0.02	0.03	0.03	0.02	0.10
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.01	0.07	0.00	0.02	0.02	0.03	0.04	0.03	0.12
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.03	0.03	0.06	0.06	0.04	0.28	0.00	0.10	0.10	0.13	0.15	0.13	0.51
Memphis, TN-AR	x	-	100	-	0.00	-0.18	-0.20	-0.20	-0.23	-0.33	-1.65	0.00	-0.58	-0.61	-0.63	-0.66	-0.78	-1.79
Milwaukee-Racine, WI	x	-	100	-	0.00	0.09	0.09	0.18	0.21	0.14	0.92	0.00	0.32	0.33	0.43	0.48	0.42	1.66
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	0.06	0.00	0.02	0.02	0.03	0.03	0.03	0.10
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.33	0.31	0.97	1.12	0.41	3.75	0.00	1.28	1.32	2.02	2.30	1.66	8.93
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.01	0.08	0.00	0.03	0.03	0.04	0.04	0.04	0.14
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-1.14	-1.27	-1.24	-1.40	-2.13	-10.43	0.00	-3.66	-3.85	-3.91	-4.12	-4.90	-10.94
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.26	0.27	0.53	0.61	0.40	2.69	0.00	0.93	0.96	1.26	1.40	1.22	4.87
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.09	0.10	0.19	0.22	0.14	0.96	0.00	0.33	0.34	0.45	0.50	0.43	1.73
Poughkeepsie, NY	x	x	100	100	0.00	0.07	0.07	0.14	0.17	0.11	0.72	0.00	0.25	0.26	0.34	0.38	0.33	1.31

Table B2-3
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.05	0.05	0.09	0.11	0.07	0.48	0.00	0.16	0.17	0.22	0.25	0.22	0.87
Reading, PA	-	x	-	100	0.00	0.02	0.02	0.04	0.05	0.03	0.21	0.00	0.07	0.08	0.10	0.11	0.10	0.39
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.06	0.06	0.12	0.14	0.09	0.61	0.00	0.21	0.22	0.28	0.31	0.27	1.10
Rochester, NY	x	-	100	-	0.00	0.07	0.07	0.13	0.16	0.10	0.68	0.00	0.23	0.24	0.32	0.35	0.31	1.23
Rome, GA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.01	0.06	0.00	0.02	0.02	0.03	0.03	0.03	0.11
Sacramento Metro, CA	x	-	50	-	0.00	0.13	0.13	0.26	0.30	0.20	1.32	0.00	0.46	0.47	0.62	0.69	0.60	2.40
San Diego, CA	x	-	100	-	0.00	0.15	0.16	0.31	0.36	0.23	1.56	0.00	0.54	0.56	0.73	0.81	0.71	2.83
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.51	-0.58	-0.42	-0.47	-0.99	-4.46	0.00	-1.58	-1.66	-1.54	-1.59	-2.12	-3.64
San Joaquin Valley, CA	x	x	50	100	0.00	0.14	0.13	0.39	0.45	0.18	1.56	0.00	0.53	0.55	0.82	0.93	0.69	3.57
Sheboygan, WI	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	0.06	0.00	0.02	0.02	0.03	0.03	0.03	0.12
Springfield (Western MA), MA	x	-	100	-	0.00	0.05	0.05	0.10	0.11	0.07	0.50	0.00	0.17	0.18	0.23	0.26	0.23	0.90
St. Louis, MO-IL	x	x	100	100	0.00	-0.23	-0.27	-0.20	-0.22	-0.46	-2.07	0.00	-0.73	-0.77	-0.72	-0.74	-0.98	-1.69
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.02	-0.02	-0.02	-0.03	-0.04	-0.19	0.00	-0.07	-0.07	-0.07	-0.08	-0.09	-0.21
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.03	0.03	0.06	0.07	0.04	0.30	0.00	0.10	0.11	0.14	0.16	0.14	0.56
Washington, DC-MD-VA	x	x	100	100	0.00	0.27	0.28	0.56	0.64	0.42	2.82	0.00	0.97	1.01	1.32	1.46	1.28	5.10
Wheeling, WV-OH	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.01	0.08	0.00	0.03	0.03	0.04	0.04	0.04	0.15
York, PA	-	x	-	100	0.00	0.02	0.02	0.05	0.05	0.04	0.24	0.00	0.08	0.08	0.11	0.12	0.11	0.43

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-4
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.11	0.13	0.12	0.14	0.05	-0.69	0.00	0.54	0.58	0.56	0.61	0.53	0.60
Allegan Co., MI	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	-0.07	0.00	0.06	0.06	0.06	0.07	0.06	0.07
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.02	0.02	0.02	0.01	-0.09	0.00	0.07	0.07	0.07	0.08	0.07	0.08
Atlanta, GA	x	x	100	100	0.00	0.88	1.02	0.95	1.09	0.39	-5.48	0.00	4.33	4.65	4.46	4.83	4.24	4.78
Baltimore, MD	x	x	100	100	0.00	0.24	0.28	0.26	0.30	0.11	-1.49	0.00	1.18	1.27	1.22	1.32	1.15	1.30
Baton Rouge, LA	x	-	100	-	0.00	-0.94	-1.02	-1.26	-1.43	-1.75	-9.58	0.00	-3.75	-3.90	-4.27	-4.54	-4.93	-12.04
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1.98	-2.16	-2.63	-2.99	-3.56	-18.73	0.00	-8.00	-8.34	-9.05	-9.64	-10.37	-24.74
Birmingham, AL	-	x	-	100	0.00	0.08	0.10	0.09	0.10	0.04	-0.51	0.00	0.41	0.43	0.42	0.45	0.40	0.45
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.34	0.40	0.37	0.42	0.15	-2.12	0.00	1.67	1.80	1.72	1.87	1.64	1.85
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.05	0.06	0.06	0.06	0.02	-0.32	0.00	0.25	0.27	0.26	0.28	0.25	0.28
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.08	0.09	0.08	0.10	0.03	-0.49	0.00	0.39	0.41	0.40	0.43	0.38	0.43
Canton-Massillon, OH	-	x	-	100	0.00	-0.11	-0.12	-0.15	-0.17	-0.22	-1.34	0.00	-0.42	-0.43	-0.48	-0.51	-0.57	-1.49
Charleston, WV	-	x	-	100	0.00	0.02	0.02	0.02	0.02	0.01	-0.12	0.00	0.10	0.10	0.10	0.11	0.09	0.11
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.21	0.24	0.22	0.26	0.09	-1.30	0.00	1.02	1.10	1.06	1.14	1.00	1.13
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.04	0.05	0.04	0.05	0.02	-0.25	0.00	0.20	0.21	0.20	0.22	0.19	0.22
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.84	-0.87	-1.26	-1.43	-2.32	-17.30	0.00	-2.85	-2.88	-3.53	-3.70	-4.63	-14.68
Chico, CA	x	-	100	-	0.00	0.02	0.02	0.02	0.02	0.01	-0.10	0.00	0.08	0.08	0.08	0.09	0.08	0.09
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.16	0.18	0.17	0.19	0.07	-0.98	0.00	0.77	0.83	0.80	0.86	0.76	0.85
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.00	-0.07	0.00	0.06	0.06	0.06	0.06	0.05	0.06
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.18	0.22	0.20	0.23	0.08	-1.15	0.00	0.91	0.98	0.94	1.02	0.89	1.01
Columbus, OH	x	x	100	100	0.00	0.16	0.19	0.17	0.20	0.07	-1.00	0.00	0.79	0.85	0.82	0.88	0.78	0.88
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.80	0.93	0.86	0.99	0.35	-4.97	0.00	3.93	4.22	4.05	4.39	3.85	4.34
Dayton-Springfield, OH	-	x	-	100	0.00	0.06	0.07	0.06	0.07	0.02	-0.35	0.00	0.28	0.30	0.29	0.31	0.27	0.31
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.15	0.19	0.12	0.15	-0.16	-3.55	0.00	0.90	0.99	0.86	0.95	0.67	-0.33
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.18	0.23	0.15	0.18	-0.16	-3.90	0.00	1.06	1.16	1.02	1.11	0.81	-0.25
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.03	0.03	0.03	0.03	0.01	-0.17	0.00	0.13	0.14	0.14	0.15	0.13	0.15
Greater Connecticut, CT	x	-	100	-	0.00	0.14	0.16	0.15	0.17	0.06	-0.88	0.00	0.69	0.74	0.71	0.77	0.68	0.76
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.06	0.07	0.07	0.08	0.03	-0.40	0.00	0.32	0.34	0.33	0.35	0.31	0.35
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.05	0.06	0.06	0.07	0.02	-0.34	0.00	0.27	0.29	0.28	0.30	0.26	0.30

Table B2-4
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.02	0.02	0.02	0.02	0.01	-0.10	0.00	0.08	0.09	0.08	0.09	0.08	0.09
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-3.64	-3.96	-4.94	-5.62	-7.11	-40.89	0.00	-14.36	-14.91	-16.46	-17.50	-19.26	-48.43
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.36	-0.40	-0.49	-0.56	-0.69	-3.85	0.00	-1.45	-1.51	-1.66	-1.76	-1.92	-4.74
Imperial Co., CA	x	-	100	-	0.00	0.03	0.03	0.03	0.03	0.01	-0.17	0.00	0.13	0.14	0.14	0.15	0.13	0.14
Indianapolis, IN	-	x	-	100	0.00	0.15	0.17	0.16	0.19	0.07	-0.94	0.00	0.74	0.79	0.76	0.83	0.72	0.82
Jamestown, NY	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.00	-0.06	0.00	0.05	0.05	0.05	0.06	0.05	0.06
Jefferson Co., NY	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.01	-0.08	0.00	0.06	0.07	0.06	0.07	0.06	0.07
Johnstown, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.00	-0.05	0.00	0.04	0.04	0.04	0.04	0.04	0.04
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.01	0.02	0.01	0.02	0.01	-0.09	0.00	0.07	0.07	0.07	0.08	0.07	0.07
Knoxville, TN	x	x	100	100	0.00	0.09	0.11	0.10	0.11	0.04	-0.58	0.00	0.46	0.49	0.47	0.51	0.45	0.50
Lancaster, PA	-	x	-	100	0.00	0.03	0.04	0.04	0.04	0.01	-0.20	0.00	0.16	0.17	0.17	0.18	0.16	0.18
Las Vegas, NV	x	-	100	-	0.00	0.19	0.23	0.21	0.24	0.09	-1.21	0.00	0.96	1.03	0.99	1.07	0.94	1.06
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-0.76	-0.73	-1.37	-1.54	-3.30	-29.47	0.00	-1.83	-1.70	-2.79	-2.84	-4.60	-19.56
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.08	0.09	0.08	0.09	0.03	-0.47	0.00	0.37	0.40	0.38	0.42	0.37	0.41
Louisville, KY-IN	-	x	-	100	0.00	0.08	0.09	0.09	0.10	0.03	-0.50	0.00	0.39	0.42	0.40	0.44	0.38	0.43
Macon, GA	-	x	-	100	0.00	0.01	0.02	0.02	0.02	0.01	-0.09	0.00	0.07	0.08	0.08	0.08	0.07	0.08
Manitowoc Co., WI	x	-		-	0.00	0.01	0.01	0.01	0.01	0.00	-0.05	0.00	0.04	0.04	0.04	0.04	0.04	0.04
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.01	-0.08	0.00	0.06	0.06	0.06	0.07	0.06	0.07
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.05	0.06	0.06	0.06	0.02	-0.32	0.00	0.26	0.27	0.26	0.29	0.25	0.28
Memphis, TN-AR	x	-	100	-	0.00	-0.25	-0.27	-0.35	-0.40	-0.54	-3.41	0.00	-0.95	-0.98	-1.11	-1.18	-1.34	-3.59
Milwaukee-Racine, WI	x	-	100	-	0.00	0.13	0.15	0.14	0.16	0.06	-0.81	0.00	0.64	0.69	0.66	0.71	0.62	0.71
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.00	-0.06	0.00	0.04	0.05	0.05	0.05	0.04	0.05
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.50	0.63	0.40	0.48	-0.54	-11.92	0.00	2.99	3.27	2.84	3.12	2.20	-1.20
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.00	-0.06	0.00	0.05	0.05	0.05	0.06	0.05	0.06
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-1.53	-1.64	-2.17	-2.47	-3.51	-23.14	0.00	-5.72	-5.88	-6.75	-7.14	-8.28	-23.07
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.50	0.58	0.53	0.62	0.22	-3.10	0.00	2.45	2.63	2.52	2.73	2.40	2.70
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.13	0.15	0.14	0.16	0.06	-0.79	0.00	0.62	0.67	0.64	0.69	0.61	0.69
Poughkeepsie, NY	x	x	100	100	0.00	0.11	0.13	0.12	0.14	0.05	-0.69	0.00	0.55	0.59	0.56	0.61	0.54	0.61

Table B2-4
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.07	0.08	0.07	0.08	0.03	-0.42	0.00	0.33	0.35	0.34	0.37	0.32	0.36
Reading, PA	-	x	-	100	0.00	0.03	0.04	0.04	0.04	0.01	-0.20	0.00	0.16	0.17	0.17	0.18	0.16	0.18
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.13	0.15	0.14	0.17	0.06	-0.83	0.00	0.66	0.70	0.67	0.73	0.64	0.72
Rochester, NY	x	-	100	-	0.00	0.10	0.11	0.10	0.12	0.04	-0.60	0.00	0.48	0.51	0.49	0.53	0.47	0.53
Rome, GA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.00	-0.05	0.00	0.04	0.04	0.04	0.04	0.04	0.04
Sacramento Metro, CA	x	-	50	-	0.00	0.22	0.26	0.24	0.28	0.10	-1.38	0.00	1.09	1.17	1.12	1.22	1.07	1.21
San Diego, CA	x	-	100	-	0.00	0.22	0.25	0.23	0.27	0.10	-1.35	0.00	1.07	1.15	1.10	1.19	1.04	1.18
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.68	-0.71	-1.02	-1.16	-1.88	-14.05	0.00	-2.32	-2.35	-2.87	-3.02	-3.77	-11.93
San Joaquin Valley, CA	x	x	50	100	0.00	0.31	0.38	0.29	0.34	-0.13	-5.03	0.00	1.73	1.88	1.70	1.85	1.44	0.34
Sheboygan, WI	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.00	-0.06	0.00	0.05	0.05	0.05	0.05	0.04	0.05
Springfield (Western MA), MA	x	-	100	-	0.00	0.07	0.08	0.08	0.09	0.03	-0.45	0.00	0.35	0.38	0.36	0.39	0.35	0.39
St. Louis, MO-IL	x	x	100	100	0.00	-0.31	-0.33	-0.47	-0.53	-0.87	-6.49	0.00	-1.07	-1.08	-1.32	-1.39	-1.74	-5.50
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.03	-0.03	-0.04	-0.05	-0.06	-0.37	0.00	-0.11	-0.12	-0.13	-0.14	-0.16	-0.41
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.04	0.05	0.04	0.05	0.01	-0.34	0.00	0.21	0.23	0.22	0.24	0.20	0.20
Washington, DC-MD-VA	x	x	100	100	0.00	0.46	0.54	0.50	0.57	0.20	-2.87	0.00	2.27	2.43	2.33	2.53	2.22	2.50
Wheeling, WV-OH	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.00	-0.07	0.00	0.05	0.06	0.06	0.06	0.05	0.06
York, PA	-	x	-	100	0.00	0.04	0.04	0.04	0.05	0.02	-0.24	0.00	0.19	0.20	0.19	0.21	0.18	0.21

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.

b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.

c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)

EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-5
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.02	0.23	0.00	0.00	0.00	0.01	0.01	0.02	0.23
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Atlanta, GA	x	x	100	100	0.00	0.00	-0.01	0.04	0.05	0.10	1.20	0.00	0.00	-0.01	0.04	0.05	0.10	1.20
Baltimore, MD	x	x	100	100	0.00	0.00	0.00	0.02	0.02	0.04	0.50	0.00	0.00	0.00	0.02	0.02	0.04	0.50
Baton Rouge, LA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.12	0.00	0.00	0.00	0.00	0.00	0.01	0.12
Beaumont/Port Arthur, TX	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.07
Birmingham, AL	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.18	0.00	0.00	0.00	0.01	0.01	0.02	0.18
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.00	-0.01	0.03	0.03	0.07	0.81	0.00	0.00	-0.01	0.03	0.03	0.07	0.81
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.11	0.00	0.00	0.00	0.00	0.00	0.01	0.11
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.02	0.20	0.00	0.00	0.00	0.01	0.01	0.02	0.20
Canton-Massillon, OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Charleston, WV	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.03	0.32	0.00	0.00	0.00	0.01	0.01	0.03	0.32
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.00	0.00	0.01	0.09
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	0.00	-0.01	0.04	0.05	0.10	1.24	0.00	0.00	-0.01	0.04	0.05	0.10	1.24
Chico, CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.00	0.00	0.01	0.01	0.03	0.32	0.00	0.00	0.00	0.01	0.01	0.03	0.32
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.00	0.00	0.02	0.02	0.04	0.47	0.00	0.00	0.00	0.02	0.02	0.04	0.47
Columbus, OH	x	x	100	100	0.00	0.00	0.00	0.01	0.01	0.03	0.30	0.00	0.00	0.00	0.01	0.01	0.03	0.30
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.00	-0.01	0.04	0.05	0.10	1.22	0.00	0.00	-0.01	0.04	0.05	0.10	1.22
Dayton-Springfield, OH	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.14	0.00	0.00	0.00	0.00	0.01	0.01	0.14
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.05	0.57	0.00	0.00	0.00	0.02	0.02	0.05	0.57
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.00	-0.01	0.03	0.03	0.07	0.85	0.00	0.00	-0.01	0.03	0.03	0.07	0.85
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.06
Greater Connecticut, CT	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.03	0.31	0.00	0.00	0.00	0.01	0.01	0.03	0.31
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.14	0.00	0.00	0.00	0.00	0.01	0.01	0.14
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.13	0.00	0.00	0.00	0.00	0.01	0.01	0.13

Table B2-5
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	0.00	-0.01	0.03	0.04	0.08	0.90	0.00	0.00	-0.01	0.03	0.04	0.08	0.90
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.01	0.08
Imperial Co., CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Indianapolis, IN	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.28	0.00	0.00	0.00	0.01	0.01	0.02	0.28
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Knoxville, TN	x	x	100	100	0.00	0.00	0.00	0.01	0.01	0.02	0.19	0.00	0.00	0.00	0.01	0.01	0.02	0.19
Lancaster, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.07
Las Vegas, NV	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.02	0.25	0.00	0.00	0.00	0.01	0.01	0.02	0.25
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-0.01	-0.02	0.08	0.10	0.22	2.59	0.00	-0.01	-0.02	0.08	0.10	0.22	2.59
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.13	0.00	0.00	0.00	0.00	0.01	0.01	0.13
Louisville, KY-IN	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.20	0.00	0.00	0.00	0.01	0.01	0.02	0.20
Macon, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.07
Memphis, TN-AR	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.17	0.00	0.00	0.00	0.01	0.01	0.01	0.17
Milwaukee-Racine, WI	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.03	0.31	0.00	0.00	0.00	0.01	0.01	0.03	0.31
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.01	-0.02	0.08	0.10	0.21	2.54	0.00	-0.01	-0.02	0.08	0.10	0.21	2.54
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	0.00	-0.01	0.04	0.05	0.10	1.21	0.00	0.00	-0.01	0.04	0.05	0.10	1.21
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.00	-0.01	0.02	0.03	0.06	0.69	0.00	0.00	-0.01	0.02	0.03	0.06	0.69
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.00	0.00	0.01	0.01	0.03	0.34	0.00	0.00	0.00	0.01	0.01	0.03	0.34
Poughkeepsie, NY	x	x	100	100	0.00	0.00	0.00	0.01	0.01	0.02	0.22	0.00	0.00	0.00	0.01	0.01	0.02	0.22

Table B2-5
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.16	0.00	0.00	0.00	0.01	0.01	0.01	0.16
Reading, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.07
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.13	0.00	0.00	0.00	0.00	0.01	0.01	0.13
Rochester, NY	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.02	0.23	0.00	0.00	0.00	0.01	0.01	0.02	0.23
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Sacramento Metro, CA	x	-	50	-	0.00	0.00	0.00	0.01	0.02	0.03	0.38	0.00	0.00	0.00	0.01	0.02	0.03	0.38
San Diego, CA	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.04	0.53	0.00	0.00	0.00	0.02	0.02	0.04	0.53
San Francisco Bay Area, CA	x	-	100	-	0.00	0.00	-0.01	0.04	0.05	0.10	1.17	0.00	0.00	-0.01	0.04	0.05	0.10	1.17
San Joaquin Valley, CA	x	x	50	100	0.00	0.00	-0.01	0.03	0.03	0.06	0.78	0.00	0.00	-0.01	0.03	0.03	0.06	0.78
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Springfield (Western MA), MA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.16	0.00	0.00	0.00	0.01	0.01	0.01	0.16
St. Louis, MO-IL	x	x	100	100	0.00	0.00	0.00	0.02	0.02	0.04	0.54	0.00	0.00	0.00	0.02	0.02	0.04	0.54
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.11	0.00	0.00	0.00	0.00	0.00	0.01	0.11
Washington, DC-MD-VA	x	x	100	100	0.00	0.00	-0.01	0.03	0.03	0.07	0.86	0.00	0.00	-0.01	0.03	0.03	0.07	0.86
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
York, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.07

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-6
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.00	0.00	0.03	0.03	0.05	0.66	0.00	0.01	0.00	0.03	0.04	0.06	0.68
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.07
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.07
Atlanta, GA	x	x	100	100	0.00	0.02	0.00	0.15	0.18	0.28	3.83	0.00	0.04	0.02	0.19	0.22	0.33	3.96
Baltimore, MD	x	x	100	100	0.00	0.01	0.00	0.06	0.07	0.11	1.45	0.00	0.02	0.01	0.07	0.08	0.12	1.50
Baton Rouge, LA	x	-	100	-	0.00	0.00	0.00	0.01	0.02	0.03	0.34	0.00	0.00	0.00	0.02	0.02	0.03	0.36
Beaumont/Port Arthur, TX	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.02	0.21	0.00	0.00	0.00	0.01	0.01	0.02	0.21
Birmingham, AL	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.04	0.52	0.00	0.01	0.00	0.03	0.03	0.04	0.54
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.01	0.00	0.09	0.11	0.17	2.28	0.00	0.02	0.01	0.11	0.13	0.19	2.35
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.00	0.00	0.01	0.02	0.02	0.32	0.00	0.00	0.00	0.02	0.02	0.03	0.33
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.00	0.00	0.02	0.03	0.04	0.54	0.00	0.01	0.00	0.03	0.03	0.05	0.56
Canton-Massillon, OH	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.16	0.00	0.00	0.00	0.01	0.01	0.01	0.16
Charleston, WV	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.14	0.00	0.00	0.00	0.01	0.01	0.01	0.15
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.00	0.00	0.04	0.05	0.07	0.99	0.00	0.01	0.01	0.05	0.06	0.08	1.03
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.26	0.00	0.00	0.00	0.01	0.02	0.02	0.27
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	0.01	0.00	0.14	0.17	0.26	3.59	0.00	0.04	0.02	0.18	0.21	0.31	3.71
Chico, CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.00	0.01	0.01	0.10
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.00	0.00	0.04	0.04	0.07	0.93	0.00	0.01	0.01	0.05	0.05	0.08	0.96
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.01	0.09
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.01	0.00	0.05	0.06	0.10	1.29	0.00	0.01	0.01	0.06	0.07	0.11	1.34
Columbus, OH	x	x	100	100	0.00	0.00	0.00	0.04	0.04	0.07	0.90	0.00	0.01	0.01	0.04	0.05	0.08	0.92
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.02	0.00	0.15	0.18	0.28	3.80	0.00	0.04	0.02	0.19	0.22	0.32	3.93
Dayton-Springfield, OH	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.03	0.39	0.00	0.00	0.00	0.02	0.02	0.03	0.41
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.01	0.00	0.07	0.08	0.13	1.70	0.00	0.02	0.01	0.08	0.10	0.15	1.76
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.01	0.00	0.10	0.11	0.18	2.40	0.00	0.03	0.01	0.12	0.14	0.21	2.48
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.17	0.00	0.00	0.00	0.01	0.01	0.01	0.18
Greater Connecticut, CT	x	-	100	-	0.00	0.00	0.00	0.04	0.04	0.07	0.89	0.00	0.01	0.01	0.04	0.05	0.08	0.92
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.03	0.40	0.00	0.00	0.00	0.02	0.02	0.03	0.42
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.02	0.03	0.36	0.00	0.00	0.00	0.02	0.02	0.03	0.37

Table B2-6
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.00	0.01	0.01	0.10
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	0.01	0.00	0.11	0.13	0.19	2.64	0.00	0.03	0.02	0.13	0.15	0.23	2.73
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.21	0.00	0.00	0.00	0.01	0.01	0.02	0.22
Imperial Co., CA	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.12	0.00	0.00	0.00	0.01	0.01	0.01	0.13
Indianapolis, IN	-	x	-	100	0.00	0.00	0.00	0.03	0.04	0.06	0.83	0.00	0.01	0.01	0.04	0.05	0.07	0.86
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.07
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.07
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.07
Knoxville, TN	x	x	100	100	0.00	0.00	0.00	0.02	0.03	0.04	0.56	0.00	0.01	0.00	0.03	0.03	0.05	0.58
Lancaster, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.21	0.00	0.00	0.00	0.01	0.01	0.02	0.22
Las Vegas, NV	x	-	100	-	0.00	0.00	0.00	0.03	0.04	0.06	0.82	0.00	0.01	0.01	0.04	0.05	0.07	0.84
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	0.03	0.00	0.31	0.37	0.57	7.75	0.00	0.08	0.05	0.38	0.45	0.66	8.00
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.03	0.39	0.00	0.00	0.00	0.02	0.02	0.03	0.40
Louisville, KY-IN	-	x	-	100	0.00	0.00	0.00	0.02	0.03	0.04	0.55	0.00	0.01	0.00	0.03	0.03	0.05	0.57
Macon, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.01	0.01	0.01	0.11
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.23	0.00	0.00	0.00	0.01	0.01	0.02	0.24
Memphis, TN-AR	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.04	0.49	0.00	0.01	0.00	0.02	0.03	0.04	0.50
Milwaukee-Racine, WI	x	-	100	-	0.00	0.00	0.00	0.03	0.04	0.06	0.87	0.00	0.01	0.01	0.04	0.05	0.07	0.90
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.05
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.03	0.00	0.29	0.34	0.53	7.16	0.00	0.07	0.04	0.35	0.41	0.61	7.40
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.01	0.08
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	0.01	0.00	0.14	0.17	0.26	3.52	0.00	0.04	0.02	0.17	0.20	0.30	3.64
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.01	0.00	0.09	0.11	0.16	2.22	0.00	0.02	0.01	0.11	0.13	0.19	2.30
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.00	0.00	0.04	0.04	0.07	0.94	0.00	0.01	0.01	0.05	0.05	0.08	0.97
Poughkeepsie, NY	x	x	100	100	0.00	0.00	0.00	0.03	0.03	0.05	0.66	0.00	0.01	0.00	0.03	0.04	0.06	0.68

Table B2-6
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.03	0.45	0.00	0.00	0.00	0.02	0.03	0.04	0.47
Reading, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.19	0.00	0.00	0.00	0.01	0.01	0.02	0.20
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.03	0.46	0.00	0.00	0.00	0.02	0.03	0.04	0.47
Rochester, NY	x	-	100	-	0.00	0.00	0.00	0.03	0.03	0.05	0.64	0.00	0.01	0.00	0.03	0.04	0.05	0.66
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Sacramento Metro, CA	x	-	50	-	0.00	0.00	0.00	0.05	0.05	0.09	1.16	0.00	0.01	0.01	0.06	0.07	0.10	1.19
San Diego, CA	x	-	100	-	0.00	0.01	0.00	0.06	0.07	0.11	1.49	0.00	0.02	0.01	0.07	0.09	0.13	1.54
San Francisco Bay Area, CA	x	-	100	-	0.00	0.01	0.00	0.13	0.16	0.24	3.31	0.00	0.03	0.02	0.16	0.19	0.28	3.42
San Joaquin Valley, CA	x	x	50	100	0.00	0.01	0.00	0.10	0.12	0.18	2.44	0.00	0.03	0.02	0.12	0.14	0.21	2.53
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.06
Springfield (Western MA), MA	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.03	0.46	0.00	0.00	0.00	0.02	0.03	0.04	0.48
St. Louis, MO-IL	x	x	100	100	0.00	0.01	0.00	0.06	0.07	0.11	1.52	0.00	0.02	0.01	0.07	0.09	0.13	1.57
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.02	0.32	0.00	0.00	0.00	0.02	0.02	0.03	0.33
Washington, DC-MD-VA	x	x	100	100	0.00	0.01	0.00	0.10	0.12	0.19	2.52	0.00	0.03	0.02	0.12	0.14	0.21	2.60
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.01	0.08
York, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.21	0.00	0.00	0.00	0.01	0.01	0.02	0.22

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-7
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.01	0.00	0.04	0.05	0.08	1.03	0.00	0.02	0.02	0.06	0.07	0.10	1.10
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.11	0.00	0.00	0.00	0.01	0.01	0.01	0.12
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.12	0.00	0.00	0.00	0.01	0.01	0.01	0.12
Atlanta, GA	x	x	100	100	0.00	0.04	0.02	0.27	0.32	0.48	6.60	0.00	0.13	0.10	0.39	0.45	0.63	7.04
Baltimore, MD	x	x	100	100	0.00	0.01	0.01	0.09	0.11	0.16	2.26	0.00	0.04	0.04	0.13	0.15	0.22	2.41
Baton Rouge, LA	x	-	100	-	0.00	0.00	0.00	0.02	0.03	0.04	0.54	0.00	0.01	0.01	0.03	0.04	0.05	0.58
Beaumont/Port Arthur, TX	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.02	0.31	0.00	0.01	0.00	0.02	0.02	0.03	0.33
Birmingham, AL	-	x	-	100	0.00	0.00	0.00	0.03	0.04	0.06	0.79	0.00	0.02	0.01	0.05	0.05	0.08	0.85
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.02	0.01	0.14	0.16	0.25	3.42	0.00	0.07	0.05	0.20	0.23	0.33	3.65
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.04	0.49	0.00	0.01	0.01	0.03	0.03	0.05	0.53
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.00	0.00	0.03	0.04	0.06	0.81	0.00	0.02	0.01	0.05	0.06	0.08	0.86
Canton-Massillon, OH	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.23	0.00	0.00	0.00	0.01	0.02	0.02	0.25
Charleston, WV	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.21	0.00	0.00	0.00	0.01	0.01	0.02	0.22
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.01	0.00	0.07	0.08	0.12	1.67	0.00	0.03	0.03	0.10	0.11	0.16	1.78
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.03	0.40	0.00	0.01	0.01	0.02	0.03	0.04	0.43
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	0.03	0.01	0.23	0.27	0.41	5.62	0.00	0.11	0.09	0.33	0.38	0.54	5.99
Chico, CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.15	0.00	0.00	0.00	0.01	0.01	0.01	0.16
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.01	0.00	0.06	0.07	0.10	1.44	0.00	0.03	0.02	0.08	0.10	0.14	1.53
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.12	0.00	0.00	0.00	0.01	0.01	0.01	0.13
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.01	0.00	0.08	0.09	0.14	1.92	0.00	0.04	0.03	0.11	0.13	0.18	2.05
Columbus, OH	x	x	100	100	0.00	0.01	0.00	0.06	0.07	0.10	1.43	0.00	0.03	0.02	0.08	0.10	0.14	1.52
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.04	0.01	0.26	0.30	0.46	6.36	0.00	0.12	0.10	0.37	0.43	0.61	6.78
Dayton-Springfield, OH	-	x	-	100	0.00	0.00	0.00	0.02	0.03	0.04	0.59	0.00	0.01	0.01	0.03	0.04	0.06	0.62
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.02	0.01	0.11	0.13	0.20	2.76	0.00	0.05	0.04	0.16	0.19	0.26	2.94
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.02	0.01	0.15	0.17	0.26	3.62	0.00	0.07	0.06	0.21	0.25	0.35	3.86
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.26	0.00	0.01	0.00	0.02	0.02	0.03	0.28
Greater Connecticut, CT	x	-	100	-	0.00	0.01	0.00	0.06	0.07	0.10	1.37	0.00	0.03	0.02	0.08	0.09	0.13	1.46
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.00	0.00	0.03	0.03	0.05	0.62	0.00	0.01	0.01	0.04	0.04	0.06	0.66
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.00	0.00	0.02	0.03	0.04	0.55	0.00	0.01	0.01	0.03	0.04	0.05	0.58

Table B2-7
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.15	0.00	0.00	0.00	0.01	0.01	0.01	0.16
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	0.03	0.01	0.17	0.20	0.30	4.18	0.00	0.08	0.07	0.25	0.28	0.40	4.46
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	0.00	0.00	0.01	0.02	0.02	0.32	0.00	0.01	0.01	0.02	0.02	0.03	0.34
Imperial Co., CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.02	0.21	0.00	0.00	0.00	0.01	0.01	0.02	0.23
Indianapolis, IN	-	x	-	100	0.00	0.01	0.00	0.05	0.06	0.10	1.33	0.00	0.03	0.02	0.08	0.09	0.13	1.42
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.11	0.00	0.00	0.00	0.01	0.01	0.01	0.11
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.11	0.00	0.00	0.00	0.01	0.01	0.01	0.12
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.01	0.01	0.09
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.11	0.00	0.00	0.00	0.01	0.01	0.01	0.12
Knoxville, TN	x	x	100	100	0.00	0.01	0.00	0.04	0.04	0.06	0.87	0.00	0.02	0.01	0.05	0.06	0.08	0.93
Lancaster, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.02	0.02	0.32	0.00	0.01	0.01	0.02	0.02	0.03	0.35
Las Vegas, NV	x	-	100	-	0.00	0.01	0.00	0.06	0.07	0.10	1.44	0.00	0.03	0.02	0.08	0.10	0.14	1.53
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	0.08	0.03	0.51	0.60	0.91	12.48	0.00	0.24	0.20	0.73	0.85	1.20	13.31
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.00	0.00	0.03	0.03	0.05	0.64	0.00	0.01	0.01	0.04	0.04	0.06	0.68
Louisville, KY-IN	-	x	-	100	0.00	0.00	0.00	0.03	0.04	0.06	0.82	0.00	0.02	0.01	0.05	0.06	0.08	0.87
Macon, GA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.15	0.00	0.00	0.00	0.01	0.01	0.01	0.16
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.01	0.01	0.08
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.01	0.01	0.01	0.10
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.03	0.40	0.00	0.01	0.01	0.02	0.03	0.04	0.42
Memphis, TN-AR	x	-	100	-	0.00	0.00	0.00	0.03	0.04	0.05	0.73	0.00	0.01	0.01	0.04	0.05	0.07	0.78
Milwaukee-Racine, WI	x	-	100	-	0.00	0.01	0.00	0.05	0.06	0.09	1.31	0.00	0.03	0.02	0.08	0.09	0.13	1.39
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.01	0.01	0.09
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.07	0.02	0.44	0.52	0.79	10.80	0.00	0.21	0.17	0.63	0.73	1.03	11.52
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.11	0.00	0.00	0.00	0.01	0.01	0.01	0.12
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	0.03	0.01	0.22	0.26	0.40	5.48	0.00	0.11	0.09	0.32	0.37	0.52	5.84
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.02	0.01	0.16	0.18	0.28	3.83	0.00	0.07	0.06	0.22	0.26	0.37	4.09
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.01	0.00	0.06	0.07	0.10	1.36	0.00	0.03	0.02	0.08	0.09	0.13	1.45
Poughkeepsie, NY	x	x	100	100	0.00	0.01	0.00	0.04	0.05	0.08	1.03	0.00	0.02	0.02	0.06	0.07	0.10	1.10

Table B2-7
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.00	0.00	0.03	0.03	0.05	0.68	0.00	0.01	0.01	0.04	0.05	0.07	0.73
Reading, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.30	0.00	0.01	0.00	0.02	0.02	0.03	0.32
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.01	0.00	0.04	0.04	0.06	0.86	0.00	0.02	0.01	0.05	0.06	0.08	0.92
Rochester, NY	x	-	100	-	0.00	0.01	0.00	0.04	0.05	0.07	0.97	0.00	0.02	0.02	0.06	0.07	0.09	1.03
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.01	0.01	0.09
Sacramento Metro, CA	x	-	50	-	0.00	0.01	0.00	0.08	0.09	0.14	1.88	0.00	0.04	0.03	0.11	0.13	0.18	2.01
San Diego, CA	x	-	100	-	0.00	0.01	0.01	0.09	0.11	0.16	2.22	0.00	0.04	0.04	0.13	0.15	0.21	2.37
San Francisco Bay Area, CA	x	-	100	-	0.00	0.03	0.01	0.20	0.24	0.36	5.01	0.00	0.10	0.08	0.29	0.34	0.48	5.34
San Joaquin Valley, CA	x	x	50	100	0.00	0.03	0.01	0.17	0.20	0.30	4.12	0.00	0.08	0.06	0.24	0.28	0.39	4.40
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.01	0.01	0.01	0.10
Springfield (Western MA), MA	x	-	100	-	0.00	0.00	0.00	0.03	0.03	0.05	0.71	0.00	0.01	0.01	0.04	0.05	0.07	0.75
St. Louis, MO-IL	x	x	100	100	0.00	0.01	0.01	0.09	0.11	0.17	2.30	0.00	0.04	0.04	0.14	0.16	0.22	2.46
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.08
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.03	0.48	0.00	0.01	0.01	0.03	0.03	0.05	0.51
Washington, DC-MD-VA	x	x	100	100	0.00	0.02	0.01	0.16	0.19	0.29	4.01	0.00	0.08	0.06	0.24	0.27	0.38	4.28
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.12	0.00	0.00	0.00	0.01	0.01	0.01	0.13
York, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.02	0.02	0.34	0.00	0.01	0.01	0.02	0.02	0.03	0.36

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.

b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.

c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)

EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-8
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.01	0.01	0.06	0.07	0.10	1.39	0.00	0.04	0.04	0.10	0.11	0.15	1.54
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.15	0.00	0.00	0.00	0.01	0.01	0.02	0.17
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.18	0.00	0.01	0.00	0.01	0.01	0.02	0.20
Atlanta, GA	x	x	100	100	0.00	0.08	0.04	0.46	0.54	0.81	11.08	0.00	0.33	0.30	0.77	0.89	1.21	12.24
Baltimore, MD	x	x	100	100	0.00	0.02	0.01	0.13	0.15	0.22	3.02	0.00	0.09	0.08	0.21	0.24	0.33	3.33
Baton Rouge, LA	x	-	100	-	0.00	0.01	0.00	0.03	0.04	0.06	0.77	0.00	0.02	0.02	0.05	0.06	0.08	0.85
Beaumont/Port Arthur, TX	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.03	0.40	0.00	0.01	0.01	0.03	0.03	0.04	0.44
Birmingham, AL	-	x	-	100	0.00	0.01	0.00	0.04	0.05	0.08	1.04	0.00	0.03	0.03	0.07	0.08	0.11	1.14
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.03	0.02	0.18	0.21	0.31	4.28	0.00	0.13	0.11	0.30	0.34	0.47	4.73
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.00	0.00	0.03	0.03	0.05	0.65	0.00	0.02	0.02	0.05	0.05	0.07	0.72
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.01	0.00	0.04	0.05	0.07	0.99	0.00	0.03	0.03	0.07	0.08	0.11	1.09
Canton-Massillon, OH	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.29	0.00	0.01	0.01	0.02	0.02	0.03	0.32
Charleston, WV	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.02	0.25	0.00	0.01	0.01	0.02	0.02	0.03	0.27
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.02	0.01	0.11	0.13	0.19	2.62	0.00	0.08	0.07	0.18	0.21	0.29	2.90
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.04	0.50	0.00	0.02	0.01	0.04	0.04	0.06	0.56
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	0.06	0.03	0.33	0.38	0.57	7.82	0.00	0.23	0.21	0.55	0.63	0.85	8.64
Chico, CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.20	0.00	0.01	0.01	0.01	0.02	0.02	0.22
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.01	0.01	0.08	0.10	0.14	1.98	0.00	0.06	0.05	0.14	0.16	0.22	2.18
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.14	0.00	0.00	0.00	0.01	0.01	0.02	0.16
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.02	0.01	0.10	0.11	0.17	2.33	0.00	0.07	0.06	0.16	0.19	0.25	2.58
Columbus, OH	x	x	100	100	0.00	0.02	0.01	0.08	0.10	0.15	2.03	0.00	0.06	0.05	0.14	0.16	0.22	2.24
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.08	0.04	0.42	0.49	0.74	10.06	0.00	0.30	0.27	0.70	0.81	1.10	11.11
Dayton-Springfield, OH	-	x	-	100	0.00	0.01	0.00	0.03	0.03	0.05	0.71	0.00	0.02	0.02	0.05	0.06	0.08	0.79
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.03	0.02	0.17	0.20	0.30	4.06	0.00	0.12	0.11	0.28	0.33	0.44	4.48
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.03	0.02	0.19	0.22	0.33	4.56	0.00	0.14	0.12	0.32	0.37	0.50	5.03
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	0.00	0.01	0.02	0.02	0.34	0.00	0.01	0.01	0.02	0.03	0.04	0.38
Greater Connecticut, CT	x	-	100	-	0.00	0.01	0.01	0.07	0.09	0.13	1.77	0.00	0.05	0.05	0.12	0.14	0.19	1.96
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.01	0.00	0.03	0.04	0.06	0.81	0.00	0.02	0.02	0.06	0.06	0.09	0.89
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.01	0.00	0.03	0.03	0.05	0.69	0.00	0.02	0.02	0.05	0.06	0.08	0.76

Table B2-8
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Hickory, NC	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.20	0.00	0.01	0.01	0.01	0.02	0.02	0.23
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	0.04	0.02	0.25	0.29	0.44	5.95	0.00	0.18	0.16	0.42	0.48	0.65	6.58
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.03	0.39	0.00	0.01	0.01	0.03	0.03	0.04	0.44
Imperial Co., CA	x	-	100	-	0.00	0.00	0.00	0.01	0.02	0.02	0.34	0.00	0.01	0.01	0.02	0.03	0.04	0.37
Indianapolis, IN	-	x	-	100	0.00	0.01	0.01	0.08	0.09	0.14	1.89	0.00	0.06	0.05	0.13	0.15	0.21	2.09
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.13	0.00	0.00	0.00	0.01	0.01	0.01	0.14
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.16	0.00	0.00	0.00	0.01	0.01	0.02	0.18
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.01	0.01	0.01	0.11
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.17	0.00	0.01	0.00	0.01	0.01	0.02	0.19
Knoxville, TN	x	x	100	100	0.00	0.01	0.00	0.05	0.06	0.09	1.17	0.00	0.03	0.03	0.08	0.09	0.13	1.29
Lancaster, PA	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.03	0.41	0.00	0.01	0.01	0.03	0.03	0.05	0.46
Las Vegas, NV	x	-	100	-	0.00	0.02	0.01	0.10	0.12	0.18	2.45	0.00	0.07	0.07	0.17	0.20	0.27	2.71
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	0.14	0.07	0.76	0.90	1.34	18.29	0.00	0.55	0.49	1.28	1.47	2.00	20.20
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.01	0.00	0.04	0.05	0.07	0.96	0.00	0.03	0.03	0.07	0.08	0.10	1.06
Louisville, KY-IN	-	x	-	100	0.00	0.01	0.00	0.04	0.05	0.07	1.00	0.00	0.03	0.03	0.07	0.08	0.11	1.11
Macon, GA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.19	0.00	0.01	0.01	0.01	0.02	0.02	0.21
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.01	0.01	0.01	0.10
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.15	0.00	0.00	0.00	0.01	0.01	0.02	0.17
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.00	0.00	0.03	0.03	0.05	0.66	0.00	0.02	0.02	0.05	0.05	0.07	0.72
Memphis, TN-AR	x	-	100	-	0.00	0.01	0.00	0.04	0.04	0.07	0.90	0.00	0.03	0.02	0.06	0.07	0.10	1.00
Milwaukee-Racine, WI	x	-	100	-	0.00	0.01	0.01	0.07	0.08	0.12	1.63	0.00	0.05	0.04	0.11	0.13	0.18	1.80
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.11	0.00	0.00	0.00	0.01	0.01	0.01	0.13
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.10	0.05	0.56	0.66	0.99	13.53	0.00	0.40	0.36	0.94	1.08	1.48	14.94
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.13	0.00	0.00	0.00	0.01	0.01	0.01	0.14
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	0.06	0.03	0.30	0.36	0.54	7.33	0.00	0.22	0.20	0.51	0.59	0.80	8.10
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.05	0.03	0.26	0.31	0.46	6.26	0.00	0.19	0.17	0.44	0.50	0.68	6.92
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.01	0.01	0.07	0.08	0.12	1.59	0.00	0.05	0.04	0.11	0.13	0.17	1.76
Poughkeepsie, NY	x	x	100	100	0.00	0.01	0.01	0.06	0.07	0.10	1.40	0.00	0.04	0.04	0.10	0.11	0.15	1.55

Table B2-8
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.01	0.00	0.04	0.04	0.06	0.84	0.00	0.03	0.02	0.06	0.07	0.09	0.93
Reading, PA	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.03	0.41	0.00	0.01	0.01	0.03	0.03	0.05	0.46
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.01	0.01	0.07	0.08	0.12	1.68	0.00	0.05	0.04	0.12	0.13	0.18	1.85
Rochester, NY	x	-	100	-	0.00	0.01	0.00	0.05	0.06	0.09	1.22	0.00	0.04	0.03	0.08	0.10	0.13	1.35
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.10	0.00	0.00	0.00	0.01	0.01	0.01	0.11
Sacramento Metro, CA	x	-	50	-	0.00	0.02	0.01	0.12	0.14	0.20	2.79	0.00	0.08	0.07	0.19	0.22	0.30	3.08
San Diego, CA	x	-	100	-	0.00	0.02	0.01	0.11	0.13	0.20	2.73	0.00	0.08	0.07	0.19	0.22	0.30	3.02
San Francisco Bay Area, CA	x	-	100	-	0.00	0.05	0.03	0.26	0.31	0.46	6.34	0.00	0.19	0.17	0.44	0.51	0.69	7.00
San Joaquin Valley, CA	x	x	50	100	0.00	0.05	0.03	0.27	0.32	0.47	6.47	0.00	0.19	0.17	0.45	0.52	0.71	7.15
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.12	0.00	0.00	0.00	0.01	0.01	0.01	0.13
Springfield (Western MA), MA	x	-	100	-	0.00	0.01	0.00	0.04	0.04	0.07	0.90	0.00	0.03	0.02	0.06	0.07	0.10	1.00
St. Louis, MO-IL	x	x	100	100	0.00	0.02	0.01	0.12	0.14	0.22	2.94	0.00	0.09	0.08	0.21	0.24	0.32	3.25
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.01	0.01	0.01	0.09
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.00	0.00	0.02	0.03	0.04	0.60	0.00	0.02	0.02	0.04	0.05	0.07	0.66
Washington, DC-MD-VA	x	x	100	100	0.00	0.04	0.02	0.24	0.28	0.42	5.80	0.00	0.17	0.15	0.40	0.46	0.63	6.40
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.14	0.00	0.00	0.00	0.01	0.01	0.02	0.15
York, PA	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.04	0.48	0.00	0.01	0.01	0.03	0.04	0.05	0.53

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-9
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.07	0.10	-0.07	-0.08	-0.29	-4.19	0.00	0.07	0.10	-0.07	-0.08	-0.29	-4.19
Allegan Co., MI	x	-	100	-	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.46	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.46
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.42	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.42
Atlanta, GA	x	x	100	100	0.00	0.39	0.54	-0.35	-0.45	-1.57	-22.28	0.00	0.39	0.54	-0.35	-0.45	-1.57	-22.28
Baltimore, MD	x	x	100	100	0.00	0.16	0.22	-0.15	-0.19	-0.65	-9.26	0.00	0.16	0.22	-0.15	-0.19	-0.65	-9.26
Baton Rouge, LA	x	-	100	-	0.00	-0.98	-1.06	-1.60	-1.80	-2.55	-18.59	0.00	-0.98	-1.06	-1.60	-1.80	-2.56	-18.59
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-2.02	-2.20	-3.17	-3.56	-4.93	-34.43	0.00	-2.03	-2.21	-3.18	-3.57	-4.94	-34.44
Birmingham, AL	-	x	-	100	0.00	0.06	0.08	-0.05	-0.07	-0.24	-3.39	0.00	0.06	0.08	-0.05	-0.07	-0.24	-3.39
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.27	0.36	-0.24	-0.30	-1.06	-15.06	0.00	0.27	0.36	-0.24	-0.30	-1.06	-15.06
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.04	0.05	-0.03	-0.04	-0.14	-2.04	0.00	0.04	0.05	-0.03	-0.04	-0.14	-2.04
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.06	0.09	-0.06	-0.07	-0.25	-3.62	0.00	0.06	0.09	-0.06	-0.07	-0.25	-3.62
Canton-Massillon, OH	-	x	-	100	0.00	-0.11	-0.12	-0.22	-0.25	-0.39	-3.18	0.00	-0.11	-0.12	-0.22	-0.25	-0.39	-3.18
Charleston, WV	-	x	-	100	0.00	0.02	0.02	-0.02	-0.02	-0.07	-0.97	0.00	0.02	0.02	-0.02	-0.02	-0.07	-0.97
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.10	0.14	-0.09	-0.12	-0.41	-5.86	0.00	0.10	0.14	-0.09	-0.12	-0.41	-5.86
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.03	0.04	-0.03	-0.03	-0.12	-1.73	0.00	0.03	0.04	-0.03	-0.03	-0.12	-1.73
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-1.07	-1.07	-2.65	-3.02	-5.12	-46.89	0.00	-1.08	-1.08	-2.65	-3.03	-5.12	-46.90
Chico, CA	x	-	100	-	0.00	0.01	0.02	-0.01	-0.01	-0.04	-0.63	0.00	0.01	0.02	-0.01	-0.01	-0.04	-0.63
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.11	0.14	-0.10	-0.12	-0.42	-6.00	0.00	0.11	0.14	-0.10	-0.12	-0.42	-6.00
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.01	0.01	-0.01	-0.01	-0.04	-0.57	0.00	0.01	0.01	-0.01	-0.01	-0.04	-0.57
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.15	0.21	-0.14	-0.17	-0.61	-8.64	0.00	0.15	0.21	-0.14	-0.17	-0.61	-8.64
Columbus, OH	x	x	100	100	0.00	0.10	0.13	-0.09	-0.11	-0.39	-5.59	0.00	0.10	0.13	-0.09	-0.11	-0.39	-5.59
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.40	0.54	-0.36	-0.45	-1.59	-22.63	0.00	0.40	0.54	-0.36	-0.45	-1.59	-22.63
Dayton-Springfield, OH	-	x	-	100	0.00	0.05	0.06	-0.04	-0.05	-0.18	-2.62	0.00	0.05	0.06	-0.04	-0.05	-0.18	-2.62
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.01	0.07	-0.43	-0.51	-1.14	-13.25	0.00	0.01	0.06	-0.43	-0.51	-1.14	-13.25
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.10	0.18	-0.53	-0.63	-1.54	-18.72	0.00	0.10	0.18	-0.53	-0.63	-1.54	-18.72
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.11	0.00	0.00	0.00	0.00	0.00	-0.01	-0.11
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.02	0.03	-0.02	-0.02	-0.08	-1.12	0.00	0.02	0.03	-0.02	-0.02	-0.08	-1.12
Greater Connecticut, CT	x	-	100	-	0.00	0.10	0.14	-0.09	-0.12	-0.40	-5.73	0.00	0.10	0.14	-0.09	-0.12	-0.40	-5.73
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.13	0.00	0.00	0.00	0.00	0.00	-0.01	-0.13
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.05	0.06	-0.04	-0.05	-0.18	-2.59	0.00	0.05	0.06	-0.04	-0.05	-0.18	-2.59
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.04	0.06	-0.04	-0.05	-0.17	-2.35	0.00	0.04	0.06	-0.04	-0.05	-0.17	-2.35

Table B2-9
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.02
Hickory, NC	-	x	-	100	0.00	0.01	0.01	-0.01	-0.01	-0.04	-0.61	0.00	0.01	0.01	-0.01	-0.01	-0.04	-0.61
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-3.88	-4.17	-6.71	-7.56	-11.07	-84.42	0.00	-3.91	-4.20	-6.74	-7.58	-11.10	-84.44
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.38	-0.41	-0.64	-0.72	-1.05	-7.95	0.00	-0.38	-0.41	-0.65	-0.73	-1.06	-7.95
Imperial Co., CA	x	-	100	-	0.00	0.01	0.02	-0.01	-0.01	-0.05	-0.72	0.00	0.01	0.02	-0.01	-0.01	-0.05	-0.72
Indianapolis, IN	-	x	-	100	0.00	0.09	0.13	-0.08	-0.10	-0.37	-5.21	0.00	0.09	0.13	-0.08	-0.10	-0.37	-5.21
Jamestown, NY	x	-	100	-	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.48	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.48
Jefferson Co., NY	x	-	100	-	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.45	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.45
Johnstown, PA	-	x	-	100	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.40	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.40
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.38	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.38
Knoxville, TN	x	x	100	100	0.00	0.06	0.09	-0.06	-0.07	-0.25	-3.54	0.00	0.06	0.09	-0.06	-0.07	-0.25	-3.54
Lancaster, PA	-	x	-	100	0.00	0.02	0.03	-0.02	-0.03	-0.10	-1.38	0.00	0.02	0.03	-0.02	-0.03	-0.10	-1.38
Las Vegas, NV	x	-	100	-	0.00	0.08	0.11	-0.07	-0.09	-0.32	-4.59	0.00	0.08	0.11	-0.07	-0.09	-0.32	-4.59
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.02
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	-0.04
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-1.40	-1.31	-4.23	-4.85	-8.70	-84.43	0.00	-1.41	-1.32	-4.24	-4.87	-8.71	-84.44
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.04	0.06	-0.04	-0.05	-0.17	-2.36	0.00	0.04	0.06	-0.04	-0.05	-0.17	-2.36
Louisville, KY-IN	-	x	-	100	0.00	0.06	0.09	-0.06	-0.07	-0.26	-3.64	0.00	0.06	0.09	-0.06	-0.07	-0.26	-3.64
Macon, GA	-	x	-	100	0.00	0.01	0.02	-0.01	-0.01	-0.05	-0.68	0.00	0.01	0.02	-0.01	-0.01	-0.05	-0.68
Manitowoc Co., WI	x	-		-	0.00	0.01	0.01	-0.01	-0.01	-0.02	-0.35	0.00	0.01	0.01	-0.01	-0.01	-0.02	-0.35
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	-0.01	-0.01	-0.02	-0.34	0.00	0.01	0.01	-0.01	-0.01	-0.02	-0.34
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.02	0.03	-0.02	-0.03	-0.09	-1.33	0.00	0.02	0.03	-0.02	-0.03	-0.09	-1.33
Memphis, TN-AR	x	-	100	-	0.00	-0.27	-0.28	-0.55	-0.63	-1.00	-8.51	0.00	-0.27	-0.28	-0.56	-0.63	-1.00	-8.51
Milwaukee-Racine, WI	x	-	100	-	0.00	0.10	0.14	-0.09	-0.11	-0.40	-5.71	0.00	0.10	0.14	-0.09	-0.11	-0.40	-5.71
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.01	-0.01	-0.01	-0.02	-0.32	0.00	0.01	0.01	-0.01	-0.01	-0.02	-0.32
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.25	0.50	-1.64	-1.94	-4.67	-56.33	0.00	0.25	0.49	-1.64	-1.94	-4.67	-56.33
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.01	0.01	-0.01	-0.01	-0.04	-0.51	0.00	0.01	0.01	-0.01	-0.01	-0.04	-0.51
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-1.75	-1.81	-3.67	-4.17	-6.67	-57.28	0.00	-1.76	-1.83	-3.68	-4.18	-6.68	-57.29
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.23	0.31	-0.20	-0.26	-0.90	-12.75	0.00	0.23	0.31	-0.20	-0.26	-0.90	-12.75
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.11	0.15	-0.10	-0.13	-0.45	-6.38	0.00	0.11	0.15	-0.10	-0.13	-0.45	-6.38
Poughkeepsie, NY	x	x	100	100	0.00	0.07	0.10	-0.07	-0.08	-0.29	-4.13	0.00	0.07	0.10	-0.07	-0.08	-0.29	-4.13

Table B2-9
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.05	0.07	-0.05	-0.06	-0.21	-2.99	0.00	0.05	0.07	-0.05	-0.06	-0.21	-2.99
Reading, PA	-	x	-	100	0.00	0.02	0.03	-0.02	-0.02	-0.09	-1.21	0.00	0.02	0.03	-0.02	-0.02	-0.09	-1.21
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.04	0.06	-0.04	-0.05	-0.17	-2.41	0.00	0.04	0.06	-0.04	-0.05	-0.17	-2.41
Rochester, NY	x	-	100	-	0.00	0.07	0.10	-0.07	-0.08	-0.29	-4.19	0.00	0.07	0.10	-0.07	-0.08	-0.29	-4.19
Rome, GA	-	x	-	100	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.37	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.37
Sacramento Metro, CA	x	-	50	-	0.00	0.12	0.17	-0.11	-0.14	-0.49	-7.04	0.00	0.12	0.17	-0.11	-0.14	-0.49	-7.04
San Diego, CA	x	-	100	-	0.00	0.17	0.24	-0.16	-0.20	-0.69	-9.85	0.00	0.17	0.24	-0.16	-0.20	-0.69	-9.85
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.82	-0.80	-2.20	-2.51	-4.37	-41.10	0.00	-0.83	-0.80	-2.20	-2.52	-4.37	-41.11
San Joaquin Valley, CA	x	x	50	100	0.00	0.05	0.12	-0.54	-0.64	-1.49	-17.62	0.00	0.05	0.12	-0.54	-0.64	-1.49	-17.62
Sheboygan, WI	x	-	100	-	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.39	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.39
Springfield (Western MA), MA	x	-	100	-	0.00	0.05	0.07	-0.05	-0.06	-0.21	-3.01	0.00	0.05	0.07	-0.05	-0.06	-0.21	-3.01
St. Louis, MO-IL	x	x	100	100	0.00	-0.38	-0.37	-1.01	-1.16	-2.01	-18.95	0.00	-0.38	-0.37	-1.02	-1.16	-2.02	-18.95
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.03	-0.03	-0.06	-0.07	-0.11	-0.94	0.00	-0.03	-0.03	-0.06	-0.07	-0.11	-0.94
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.03	0.04	-0.04	-0.05	-0.16	-2.15	0.00	0.03	0.04	-0.04	-0.05	-0.16	-2.15
Washington, DC-MD-VA	x	x	100	100	0.00	0.28	0.38	-0.25	-0.32	-1.11	-15.83	0.00	0.28	0.38	-0.25	-0.32	-1.11	-15.83
Wheeling, WV-OH	-	x	-	100	0.00	0.01	0.01	-0.01	-0.01	-0.04	-0.55	0.00	0.01	0.01	-0.01	-0.01	-0.04	-0.55
York, PA	-	x	-	100	0.00	0.02	0.03	-0.02	-0.03	-0.09	-1.28	0.00	0.02	0.03	-0.02	-0.03	-0.09	-1.28

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-10
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.19	0.30	-0.43	-0.51	-1.06	-16.68	0.00	0.37	0.50	-0.28	-0.36	-0.91	-16.33
Allegan Co., MI	x	-	100	-	0.00	0.02	0.03	-0.05	-0.06	-0.12	-1.82	0.00	0.04	0.05	-0.03	-0.04	-0.10	-1.79
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.03	-0.05	-0.05	-0.11	-1.77	0.00	0.04	0.05	-0.03	-0.04	-0.10	-1.73
Atlanta, GA	x	x	100	100	0.00	1.10	1.76	-2.48	-2.97	-6.14	-96.69	0.00	2.15	2.88	-1.62	-2.09	-5.30	-94.65
Baltimore, MD	x	x	100	100	0.00	0.42	0.67	-0.94	-1.13	-2.33	-36.67	0.00	0.81	1.09	-0.61	-0.79	-2.01	-35.90
Baton Rouge, LA	x	-	100	-	0.00	-3.03	-3.23	-4.73	-5.41	-7.02	-50.70	0.00	-7.11	-7.43	-9.03	-9.88	-11.62	-54.63
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-6.23	-6.73	-9.21	-10.51	-13.36	-89.83	0.00	-14.60	-15.32	-17.99	-19.62	-22.72	-97.99
Birmingham, AL	-	x	-	100	0.00	0.15	0.24	-0.34	-0.40	-0.83	-13.10	0.00	0.29	0.39	-0.22	-0.28	-0.72	-12.82
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.66	1.04	-1.47	-1.77	-3.65	-57.48	0.00	1.28	1.71	-0.96	-1.24	-3.15	-56.27
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.09	0.15	-0.21	-0.25	-0.51	-8.04	0.00	0.18	0.24	-0.13	-0.17	-0.44	-7.87
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.16	0.25	-0.35	-0.42	-0.87	-13.74	0.00	0.31	0.41	-0.23	-0.30	-0.75	-13.45
Canton-Massillon, OH	-	x	-	100	0.00	-0.36	-0.37	-0.69	-0.79	-1.10	-9.42	0.00	-0.87	-0.89	-1.23	-1.35	-1.67	-9.88
Charleston, WV	-	x	-	100	0.00	0.04	0.07	-0.09	-0.11	-0.23	-3.61	0.00	0.08	0.11	-0.06	-0.08	-0.20	-3.53
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.29	0.45	-0.64	-0.77	-1.59	-25.02	0.00	0.56	0.74	-0.42	-0.54	-1.37	-24.49
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.08	0.12	-0.17	-0.20	-0.42	-6.67	0.00	0.15	0.20	-0.11	-0.14	-0.37	-6.52
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-3.53	-3.30	-8.90	-10.29	-15.20	-151.91	0.00	-8.65	-8.52	-14.48	-16.10	-21.22	-155.99
Chico, CA	x	-	100	-	0.00	0.03	0.04	-0.06	-0.08	-0.16	-2.47	0.00	0.05	0.07	-0.04	-0.05	-0.14	-2.42
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.27	0.42	-0.60	-0.72	-1.48	-23.38	0.00	0.52	0.70	-0.39	-0.51	-1.28	-22.89
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.02	0.04	-0.05	-0.06	-0.13	-2.11	0.00	0.05	0.06	-0.04	-0.05	-0.12	-2.06
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.37	0.59	-0.84	-1.00	-2.07	-32.65	0.00	0.73	0.97	-0.55	-0.71	-1.79	-31.96
Columbus, OH	x	x	100	100	0.00	0.26	0.41	-0.58	-0.69	-1.43	-22.57	0.00	0.50	0.67	-0.38	-0.49	-1.24	-22.09
Dallas-Fort Worth, TX	x	-	100	-	0.00	1.09	1.74	-2.46	-2.95	-6.08	-95.83	0.00	2.13	2.85	-1.60	-2.07	-5.25	-93.81
Dayton-Springfield, OH	-	x	-	100	0.00	0.11	0.18	-0.25	-0.31	-0.63	-9.93	0.00	0.22	0.30	-0.17	-0.21	-0.54	-9.72
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.03	0.21	-1.86	-2.19	-3.82	-50.05	0.00	-0.27	-0.01	-2.21	-2.56	-4.23	-49.83
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.13	0.49	-2.36	-2.78	-5.00	-68.10	0.00	0.04	0.43	-2.60	-3.04	-5.31	-67.56
Door Co., WI	x	-	100	-	0.00	0.00	0.01	-0.01	-0.01	-0.03	-0.40	0.00	0.01	0.01	-0.01	-0.01	-0.02	-0.39
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.02
Evansville, IN	-	x	-	100	0.00	0.05	0.08	-0.11	-0.13	-0.28	-4.37	0.00	0.10	0.13	-0.07	-0.09	-0.24	-4.28
Greater Connecticut, CT	x	-	100	-	0.00	0.26	0.41	-0.58	-0.69	-1.42	-22.43	0.00	0.50	0.67	-0.37	-0.49	-1.23	-21.95
Greene Co., PA	x	-	100	-	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.48	0.00	0.01	0.01	-0.01	-0.01	-0.03	-0.47
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.12	0.18	-0.26	-0.31	-0.65	-10.17	0.00	0.23	0.30	-0.17	-0.22	-0.56	-9.95
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.10	0.16	-0.23	-0.28	-0.58	-9.08	0.00	0.20	0.27	-0.15	-0.20	-0.50	-8.88

Table B2-10
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.06	0.00	0.00	0.00	0.00	0.00	0.00	-0.06
Hickory, NC	-	x	-	100	0.00	0.03	0.04	-0.06	-0.07	-0.15	-2.43	0.00	0.05	0.07	-0.04	-0.05	-0.13	-2.38
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-12.12	-12.75	-20.29	-23.24	-30.91	-239.93	0.00	-28.63	-29.69	-37.75	-41.38	-49.57	-255.45
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-1.18	-1.25	-1.93	-2.21	-2.91	-22.11	0.00	-2.78	-2.89	-3.62	-3.97	-4.72	-23.62
Imperial Co., CA	x	-	100	-	0.00	0.04	0.06	-0.08	-0.10	-0.20	-3.13	0.00	0.07	0.09	-0.05	-0.07	-0.17	-3.07
Indianapolis, IN	-	x	-	100	0.00	0.24	0.38	-0.54	-0.65	-1.33	-21.02	0.00	0.47	0.63	-0.35	-0.45	-1.15	-20.58
Jamestown, NY	x	-	100	-	0.00	0.02	0.03	-0.05	-0.06	-0.12	-1.83	0.00	0.04	0.05	-0.03	-0.04	-0.10	-1.79
Jefferson Co., NY	x	-	100	-	0.00	0.02	0.03	-0.05	-0.06	-0.12	-1.82	0.00	0.04	0.05	-0.03	-0.04	-0.10	-1.78
Johnstown, PA	-	x	-	100	0.00	0.02	0.03	-0.04	-0.04	-0.09	-1.46	0.00	0.03	0.04	-0.02	-0.03	-0.08	-1.43
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.02	0.03	-0.04	-0.05	-0.10	-1.63	0.00	0.04	0.05	-0.03	-0.04	-0.09	-1.60
Knoxville, TN	x	x	100	100	0.00	0.16	0.26	-0.36	-0.43	-0.89	-14.07	0.00	0.31	0.42	-0.24	-0.30	-0.77	-13.77
Lancaster, PA	-	x	-	100	0.00	0.06	0.10	-0.14	-0.17	-0.34	-5.37	0.00	0.12	0.16	-0.09	-0.12	-0.29	-5.26
Las Vegas, NV	x	-	100	-	0.00	0.23	0.37	-0.53	-0.63	-1.31	-20.59	0.00	0.46	0.61	-0.34	-0.45	-1.13	-20.15
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	-0.01	-0.09	0.00	0.00	0.00	0.00	0.00	0.00	-0.09
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	-0.01	-0.16	0.00	0.00	0.00	0.00	0.00	-0.01	-0.15
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-4.70	-3.97	-15.01	-17.41	-26.77	-288.64	0.00	-11.87	-11.24	-22.99	-25.72	-35.43	-293.62
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.11	0.18	-0.25	-0.30	-0.63	-9.87	0.00	0.22	0.29	-0.16	-0.21	-0.54	-9.66
Louisville, KY-IN	-	x	-	100	0.00	0.16	0.25	-0.35	-0.42	-0.88	-13.83	0.00	0.31	0.41	-0.23	-0.30	-0.76	-13.53
Macon, GA	-	x	-	100	0.00	0.03	0.05	-0.07	-0.08	-0.16	-2.59	0.00	0.06	0.08	-0.04	-0.06	-0.14	-2.53
Manitowoc Co., WI	x	-		-	0.00	0.02	0.02	-0.03	-0.04	-0.08	-1.32	0.00	0.03	0.04	-0.02	-0.03	-0.07	-1.29
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.03	-0.04	-0.04	-0.09	-1.46	0.00	0.03	0.04	-0.02	-0.03	-0.08	-1.43
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.07	0.11	-0.15	-0.18	-0.37	-5.82	0.00	0.13	0.17	-0.10	-0.13	-0.32	-5.70
Memphis, TN-AR	x	-	100	-	0.00	-0.87	-0.87	-1.77	-2.03	-2.87	-25.85	0.00	-2.08	-2.11	-3.07	-3.39	-4.26	-26.91
Milwaukee-Racine, WI	x	-	100	-	0.00	0.25	0.40	-0.56	-0.67	-1.39	-21.87	0.00	0.49	0.65	-0.37	-0.47	-1.20	-21.41
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.02	-0.03	-0.04	-0.08	-1.31	0.00	0.03	0.04	-0.02	-0.03	-0.07	-1.28
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.28	1.35	-7.20	-8.47	-15.15	-204.48	0.00	-0.14	1.00	-8.07	-9.42	-16.24	-203.01
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.02	0.03	-0.05	-0.06	-0.12	-1.92	0.00	0.04	0.06	-0.03	-0.04	-0.11	-1.88
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-5.61	-5.57	-11.83	-13.63	-19.36	-177.94	0.00	-13.52	-13.65	-20.33	-22.46	-28.49	-184.77
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.64	1.02	-1.44	-1.72	-3.56	-56.04	0.00	1.25	1.67	-0.94	-1.21	-3.07	-54.86
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.27	0.43	-0.61	-0.73	-1.50	-23.63	0.00	0.53	0.70	-0.39	-0.51	-1.30	-23.13
Poughkeepsie, NY	x	x	100	100	0.00	0.19	0.30	-0.42	-0.51	-1.05	-16.56	0.00	0.37	0.49	-0.28	-0.36	-0.91	-16.21

Table B2-10
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.13	0.21	-0.29	-0.35	-0.73	-11.44	0.00	0.25	0.34	-0.19	-0.25	-0.63	-11.19
Reading, PA	-	x	-	100	0.00	0.06	0.09	-0.13	-0.15	-0.31	-4.87	0.00	0.11	0.14	-0.08	-0.11	-0.27	-4.77
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.13	0.21	-0.30	-0.36	-0.73	-11.56	0.00	0.26	0.34	-0.19	-0.25	-0.63	-11.32
Rochester, NY	x	-	100	-	0.00	0.18	0.29	-0.41	-0.50	-1.02	-16.14	0.00	0.36	0.48	-0.27	-0.35	-0.88	-15.80
Rome, GA	-	x	-	100	0.00	0.02	0.03	-0.04	-0.04	-0.09	-1.40	0.00	0.03	0.04	-0.02	-0.03	-0.08	-1.37
Sacramento Metro, CA	x	-	50	-	0.00	0.33	0.53	-0.75	-0.90	-1.85	-29.13	0.00	0.65	0.87	-0.49	-0.63	-1.60	-28.52
San Diego, CA	x	-	100	-	0.00	0.43	0.68	-0.96	-1.15	-2.38	-37.53	0.00	0.83	1.12	-0.63	-0.81	-2.06	-36.74
San Francisco Bay Area, CA	x	-	100	-	0.00	-2.75	-2.50	-7.48	-8.66	-12.97	-133.25	0.00	-6.81	-6.63	-11.93	-13.29	-17.78	-136.35
San Joaquin Valley, CA	x	x	50	100	0.00	0.08	0.45	-2.48	-2.92	-5.20	-69.99	0.00	-0.08	0.31	-2.80	-3.26	-5.59	-69.51
Sheboygan, WI	x	-	100	-	0.00	0.02	0.03	-0.04	-0.05	-0.10	-1.51	0.00	0.03	0.04	-0.03	-0.03	-0.08	-1.48
Springfield (Western MA), MA	x	-	100	-	0.00	0.13	0.21	-0.30	-0.36	-0.74	-11.69	0.00	0.26	0.35	-0.20	-0.25	-0.64	-11.44
St. Louis, MO-IL	x	x	100	100	0.00	-1.27	-1.16	-3.45	-3.99	-5.98	-61.34	0.00	-3.15	-3.07	-5.51	-6.13	-8.20	-62.78
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.10	-0.10	-0.19	-0.22	-0.31	-2.79	0.00	-0.23	-0.24	-0.34	-0.37	-0.47	-2.91
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.08	0.13	-0.23	-0.27	-0.54	-8.16	0.00	0.14	0.20	-0.18	-0.22	-0.49	-8.01
Washington, DC-MD-VA	x	x	100	100	0.00	0.73	1.15	-1.63	-1.95	-4.03	-63.53	0.00	1.41	1.89	-1.06	-1.37	-3.48	-62.19
Wheeling, WV-OH	-	x	-	100	0.00	0.02	0.04	-0.05	-0.06	-0.13	-2.05	0.00	0.05	0.06	-0.03	-0.04	-0.11	-2.01
York, PA	-	x	-	100	0.00	0.06	0.10	-0.14	-0.16	-0.33	-5.27	0.00	0.12	0.16	-0.09	-0.11	-0.29	-5.16

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-11
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.32	0.54	-0.94	-1.11	-2.03	-33.14	0.00	1.01	1.28	-0.37	-0.54	-1.49	-31.81
Allegan Co., MI	x	-	100	-	0.00	0.03	0.06	-0.10	-0.12	-0.22	-3.62	0.00	0.11	0.14	-0.04	-0.06	-0.16	-3.47
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.04	0.06	-0.11	-0.13	-0.23	-3.73	0.00	0.11	0.14	-0.04	-0.06	-0.17	-3.58
Atlanta, GA	x	x	100	100	0.00	2.04	3.45	-5.98	-7.09	-12.95	-211.61	0.00	6.44	8.17	-2.39	-3.45	-9.51	-203.12
Baltimore, MD	x	x	100	100	0.00	0.70	1.18	-2.05	-2.43	-4.44	-72.51	0.00	2.21	2.80	-0.82	-1.18	-3.26	-69.60
Baton Rouge, LA	x	-	100	-	0.00	-4.75	-5.04	-7.48	-8.58	-10.95	-80.75	0.00	-15.68	-16.24	-19.01	-20.55	-23.25	-90.95
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-9.81	-10.56	-14.34	-16.43	-20.51	-137.46	0.00	-32.33	-33.67	-37.99	-40.96	-45.67	-159.00
Birmingham, AL	-	x	-	100	0.00	0.24	0.41	-0.72	-0.85	-1.55	-25.41	0.00	0.77	0.98	-0.29	-0.41	-1.14	-24.39
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	1.06	1.79	-3.10	-3.68	-6.71	-109.74	0.00	3.34	4.24	-1.24	-1.79	-4.93	-105.34
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.15	0.26	-0.45	-0.53	-0.97	-15.82	0.00	0.48	0.61	-0.18	-0.26	-0.71	-15.18
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.25	0.42	-0.73	-0.87	-1.59	-25.98	0.00	0.79	1.00	-0.29	-0.42	-1.17	-24.94
Canton-Massillon, OH	-	x	-	100	0.00	-0.57	-0.57	-1.12	-1.29	-1.75	-15.73	0.00	-1.89	-1.92	-2.54	-2.77	-3.27	-16.86
Charleston, WV	-	x	-	100	0.00	0.06	0.11	-0.19	-0.22	-0.41	-6.69	0.00	0.20	0.26	-0.08	-0.11	-0.30	-6.42
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.51	0.87	-1.51	-1.79	-3.27	-53.46	0.00	1.63	2.06	-0.60	-0.87	-2.40	-51.32
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.12	0.21	-0.36	-0.43	-0.78	-12.80	0.00	0.39	0.49	-0.14	-0.21	-0.57	-12.28
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-5.45	-4.83	-15.28	-17.70	-25.44	-272.47	0.00	-18.17	-17.73	-29.48	-32.50	-40.86	-281.15
Chico, CA	x	-	100	-	0.00	0.05	0.08	-0.14	-0.16	-0.30	-4.87	0.00	0.15	0.19	-0.06	-0.08	-0.22	-4.68
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.44	0.75	-1.30	-1.54	-2.82	-46.08	0.00	1.40	1.78	-0.52	-0.75	-2.07	-44.23
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.04	0.06	-0.11	-0.13	-0.24	-3.90	0.00	0.12	0.15	-0.04	-0.06	-0.18	-3.75
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.59	1.00	-1.74	-2.06	-3.77	-61.56	0.00	1.87	2.38	-0.70	-1.00	-2.77	-59.09
Columbus, OH	x	x	100	100	0.00	0.44	0.74	-1.29	-1.53	-2.80	-45.72	0.00	1.39	1.76	-0.52	-0.75	-2.05	-43.88
Dallas-Fort Worth, TX	x	-	100	-	0.00	1.96	3.32	-5.76	-6.83	-12.48	-203.93	0.00	6.20	7.87	-2.30	-3.32	-9.16	-195.75
Dayton-Springfield, OH	-	x	-	100	0.00	0.18	0.31	-0.53	-0.63	-1.15	-18.76	0.00	0.57	0.72	-0.21	-0.31	-0.84	-18.01
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.02	0.54	-3.67	-4.31	-7.07	-99.05	0.00	-0.04	0.57	-4.16	-4.85	-7.75	-97.33
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.24	0.94	-4.53	-5.32	-8.87	-127.47	0.00	0.63	1.46	-4.68	-5.52	-9.24	-124.76
Door Co., WI	x	-	100	-	0.00	0.01	0.01	-0.02	-0.03	-0.05	-0.76	0.00	0.02	0.03	-0.01	-0.01	-0.03	-0.73
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	0.00	0.00	0.00	-0.03
Evansville, IN	-	x	-	100	0.00	0.08	0.14	-0.24	-0.28	-0.52	-8.48	0.00	0.26	0.33	-0.10	-0.14	-0.38	-8.14
Greater Connecticut, CT	x	-	100	-	0.00	0.42	0.71	-1.24	-1.47	-2.68	-43.77	0.00	1.33	1.69	-0.49	-0.71	-1.97	-42.02
Greene Co., PA	x	-	100	-	0.00	0.01	0.01	-0.02	-0.03	-0.05	-0.87	0.00	0.03	0.03	-0.01	-0.01	-0.04	-0.84
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.19	0.32	-0.56	-0.67	-1.22	-19.89	0.00	0.61	0.77	-0.22	-0.32	-0.89	-19.09
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.17	0.29	-0.49	-0.59	-1.07	-17.50	0.00	0.53	0.68	-0.20	-0.29	-0.79	-16.80

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Benzene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.12	0.00	0.00	0.00	0.00	0.00	-0.01	-0.12
Hickory, NC	-	x	-	100	0.00	0.05	0.08	-0.14	-0.16	-0.30	-4.84	0.00	0.15	0.19	-0.05	-0.08	-0.22	-4.65
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-18.99	-19.76	-32.57	-37.45	-48.94	-395.00	0.00	-62.72	-64.54	-79.04	-85.69	-98.60	-434.54
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-1.86	-1.95	-3.06	-3.52	-4.55	-35.41	0.00	-6.12	-6.32	-7.59	-8.21	-9.38	-39.32
Imperial Co., CA	x	-	100	-	0.00	0.07	0.11	-0.19	-0.23	-0.41	-6.77	0.00	0.21	0.26	-0.08	-0.11	-0.30	-6.49
Indianapolis, IN	-	x	-	100	0.00	0.41	0.69	-1.20	-1.43	-2.60	-42.54	0.00	1.29	1.64	-0.48	-0.69	-1.91	-40.84
Jamestown, NY	x	-	100	-	0.00	0.03	0.06	-0.10	-0.12	-0.21	-3.44	0.00	0.10	0.13	-0.04	-0.06	-0.15	-3.31
Jefferson Co., NY	x	-	100	-	0.00	0.04	0.06	-0.10	-0.12	-0.23	-3.68	0.00	0.11	0.14	-0.04	-0.06	-0.17	-3.53
Johnstown, PA	-	x	-	100	0.00	0.03	0.04	-0.08	-0.09	-0.16	-2.69	0.00	0.08	0.10	-0.03	-0.04	-0.12	-2.58
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.03	0.06	-0.10	-0.12	-0.22	-3.51	0.00	0.11	0.14	-0.04	-0.06	-0.16	-3.37
Knoxville, TN	x	x	100	100	0.00	0.27	0.45	-0.79	-0.93	-1.71	-27.87	0.00	0.85	1.08	-0.31	-0.45	-1.25	-26.75
Lancaster, PA	-	x	-	100	0.00	0.10	0.17	-0.29	-0.35	-0.64	-10.39	0.00	0.32	0.40	-0.12	-0.17	-0.47	-9.98
Las Vegas, NV	x	-	100	-	0.00	0.44	0.75	-1.30	-1.54	-2.82	-46.07	0.00	1.40	1.78	-0.52	-0.75	-2.07	-44.22
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.17	0.00	0.01	0.01	0.00	0.00	-0.01	-0.17
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.28	0.00	0.01	0.01	0.00	0.00	-0.01	-0.27
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-7.07	-5.30	-26.80	-31.14	-46.39	-540.35	0.00	-23.79	-22.10	-46.25	-51.47	-67.80	-548.49
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.20	0.34	-0.58	-0.69	-1.26	-20.57	0.00	0.63	0.79	-0.23	-0.34	-0.92	-19.75
Louisville, KY-IN	-	x	-	100	0.00	0.25	0.43	-0.74	-0.88	-1.60	-26.21	0.00	0.80	1.01	-0.30	-0.43	-1.18	-25.16
Macon, GA	-	x	-	100	0.00	0.05	0.08	-0.14	-0.16	-0.30	-4.92	0.00	0.15	0.19	-0.06	-0.08	-0.22	-4.72
Manitowoc Co., WI	x	-		-	0.00	0.02	0.04	-0.07	-0.08	-0.15	-2.48	0.00	0.08	0.10	-0.03	-0.04	-0.11	-2.38
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.03	0.05	-0.09	-0.11	-0.19	-3.14	0.00	0.10	0.12	-0.04	-0.05	-0.14	-3.01
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.12	0.21	-0.36	-0.43	-0.78	-12.76	0.00	0.39	0.49	-0.14	-0.21	-0.57	-12.25
Memphis, TN-AR	x	-	100	-	0.00	-1.36	-1.33	-2.91	-3.36	-4.62	-43.84	0.00	-4.51	-4.54	-6.32	-6.91	-8.29	-46.41
Milwaukee-Racine, WI	x	-	100	-	0.00	0.40	0.68	-1.18	-1.40	-2.56	-41.86	0.00	1.27	1.62	-0.47	-0.68	-1.88	-40.18
Nevada (Western Part), CA	x	-	100	-	0.00	0.03	0.04	-0.07	-0.09	-0.16	-2.65	0.00	0.08	0.10	-0.03	-0.04	-0.12	-2.54
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.53	2.61	-13.76	-16.14	-26.80	-382.14	0.00	1.31	3.74	-14.61	-17.17	-28.33	-374.45
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.03	0.06	-0.10	-0.12	-0.22	-3.57	0.00	0.11	0.14	-0.04	-0.06	-0.16	-3.42
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-8.74	-8.43	-19.77	-22.83	-31.69	-309.76	0.00	-29.02	-29.09	-41.87	-45.82	-55.51	-325.83
Phoenix-Mesa, AZ	x	-	100	-	0.00	1.18	2.00	-3.47	-4.11	-7.51	-122.81	0.00	3.74	4.74	-1.39	-2.00	-5.52	-117.89
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.42	0.71	-1.23	-1.46	-2.67	-43.67	0.00	1.33	1.69	-0.49	-0.71	-1.96	-41.92
Poughkeepsie, NY	x	x	100	100	0.00	0.32	0.54	-0.93	-1.11	-2.02	-33.07	0.00	1.01	1.28	-0.37	-0.54	-1.49	-31.74

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Benzene 2025

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	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.21	0.36	-0.62	-0.73	-1.33	-21.80	0.00	0.66	0.84	-0.25	-0.36	-0.98	-20.93
Reading, PA	-	x	-	100	0.00	0.09	0.16	-0.28	-0.33	-0.60	-9.74	0.00	0.30	0.38	-0.11	-0.16	-0.44	-9.35
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.27	0.45	-0.78	-0.93	-1.69	-27.62	0.00	0.84	1.07	-0.31	-0.45	-1.24	-26.52
Rochester, NY	x	-	100	-	0.00	0.30	0.51	-0.88	-1.04	-1.90	-31.02	0.00	0.94	1.20	-0.35	-0.51	-1.39	-29.78
Rome, GA	-	x	-	100	0.00	0.03	0.04	-0.08	-0.09	-0.16	-2.66	0.00	0.08	0.10	-0.03	-0.04	-0.12	-2.55
Sacramento Metro, CA	x	-	50	-	0.00	0.58	0.98	-1.71	-2.02	-3.69	-60.37	0.00	1.84	2.33	-0.68	-0.98	-2.71	-57.95
San Diego, CA	x	-	100	-	0.00	0.69	1.16	-2.01	-2.39	-4.36	-71.28	0.00	2.17	2.75	-0.81	-1.16	-3.20	-68.42
San Francisco Bay Area, CA	x	-	100	-	0.00	-4.29	-3.70	-12.82	-14.86	-21.54	-235.61	0.00	-14.33	-13.86	-24.11	-26.64	-33.84	-242.09
San Joaquin Valley, CA	x	x	50	100	0.00	0.29	1.10	-5.12	-6.01	-10.04	-144.68	0.00	0.80	1.74	-5.23	-6.18	-10.39	-141.54
Sheboygan, WI	x	-	100	-	0.00	0.03	0.05	-0.08	-0.10	-0.18	-2.91	0.00	0.09	0.11	-0.03	-0.05	-0.13	-2.80
Springfield (Western MA), MA	x	-	100	-	0.00	0.22	0.37	-0.64	-0.76	-1.39	-22.66	0.00	0.69	0.87	-0.26	-0.37	-1.02	-21.75
St. Louis, MO-IL	x	x	100	100	0.00	-1.98	-1.71	-5.91	-6.85	-9.93	-108.49	0.00	-6.63	-6.41	-11.13	-12.29	-15.61	-111.49
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.15	-0.15	-0.32	-0.36	-0.50	-4.61	0.00	-0.51	-0.51	-0.70	-0.76	-0.91	-4.90
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.12	0.22	-0.47	-0.55	-0.98	-15.57	0.00	0.38	0.50	-0.27	-0.35	-0.80	-15.01
Washington, DC-MD-VA	x	x	100	100	0.00	1.24	2.09	-3.63	-4.31	-7.87	-128.57	0.00	3.91	4.96	-1.45	-2.10	-5.78	-123.41
Wheeling, WV-OH	-	x	-	100	0.00	0.04	0.06	-0.11	-0.13	-0.23	-3.80	0.00	0.12	0.15	-0.04	-0.06	-0.17	-3.65
York, PA	-	x	-	100	0.00	0.10	0.18	-0.31	-0.36	-0.66	-10.80	0.00	0.33	0.42	-0.12	-0.18	-0.48	-10.36

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-12
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area)

Benzene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.49	0.90	-1.91	-2.23	-3.51	-58.41	0.00	2.34	2.88	-0.41	-0.72	-2.10	-54.92
Allegan Co., MI	x	-	100	-	0.00	0.05	0.10	-0.21	-0.24	-0.38	-6.36	0.00	0.25	0.31	-0.04	-0.08	-0.23	-5.98
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.06	0.11	-0.24	-0.29	-0.45	-7.46	0.00	0.30	0.37	-0.05	-0.09	-0.27	-7.01
Atlanta, GA	x	x	100	100	0.00	3.90	7.12	-15.17	-17.77	-27.96	-464.85	0.00	18.63	22.95	-3.29	-5.76	-16.70	-437.04
Baltimore, MD	x	x	100	100	0.00	1.06	1.94	-4.14	-4.84	-7.62	-126.69	0.00	5.08	6.25	-0.90	-1.57	-4.55	-119.11
Baton Rouge, LA	x	-	100	-	0.00	-6.62	-6.97	-10.83	-12.47	-15.64	-118.99	0.00	-26.61	-27.44	-32.02	-34.46	-38.26	-137.23
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-13.74	-14.76	-20.23	-23.27	-28.61	-191.58	0.00	-55.50	-57.63	-64.12	-68.78	-75.32	-231.18
Birmingham, AL	-	x	-	100	0.00	0.37	0.67	-1.42	-1.66	-2.62	-43.49	0.00	1.74	2.15	-0.31	-0.54	-1.56	-40.89
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	1.51	2.75	-5.86	-6.87	-10.80	-179.62	0.00	7.20	8.87	-1.27	-2.23	-6.45	-168.88
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.23	0.42	-0.89	-1.04	-1.64	-27.28	0.00	1.09	1.35	-0.19	-0.34	-0.98	-25.65
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.35	0.64	-1.35	-1.58	-2.49	-41.43	0.00	1.66	2.05	-0.29	-0.51	-1.49	-38.96
Canton-Massillon, OH	-	x	-	100	0.00	-0.80	-0.79	-1.67	-1.93	-2.51	-23.34	0.00	-3.16	-3.20	-4.24	-4.60	-5.28	-25.26
Charleston, WV	-	x	-	100	0.00	0.09	0.16	-0.34	-0.39	-0.62	-10.31	0.00	0.41	0.51	-0.07	-0.13	-0.37	-9.69
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.92	1.69	-3.59	-4.20	-6.61	-109.99	0.00	4.41	5.43	-0.78	-1.36	-3.95	-103.41
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.18	0.32	-0.69	-0.81	-1.27	-21.17	0.00	0.85	1.05	-0.15	-0.26	-0.76	-19.90
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-7.30	-5.85	-24.98	-28.95	-39.74	-455.02	0.00	-27.55	-26.15	-48.70	-53.76	-65.94	-464.80
Chico, CA	x	-	100	-	0.00	0.07	0.13	-0.27	-0.32	-0.51	-8.42	0.00	0.34	0.42	-0.06	-0.10	-0.30	-7.92
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.70	1.27	-2.71	-3.17	-4.99	-82.89	0.00	3.32	4.09	-0.59	-1.03	-2.98	-77.93
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.05	0.09	-0.19	-0.23	-0.36	-5.97	0.00	0.24	0.29	-0.04	-0.07	-0.21	-5.62
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.82	1.50	-3.19	-3.74	-5.89	-97.86	0.00	3.92	4.83	-0.69	-1.21	-3.52	-92.00
Columbus, OH	x	x	100	100	0.00	0.72	1.31	-2.78	-3.26	-5.12	-85.17	0.00	3.41	4.20	-0.60	-1.06	-3.06	-80.07
Dallas-Fort Worth, TX	x	-	100	-	0.00	3.54	6.47	-13.78	-16.13	-25.39	-422.10	0.00	16.92	20.84	-2.99	-5.23	-15.17	-396.85
Dayton-Springfield, OH	-	x	-	100	0.00	0.25	0.46	-0.97	-1.14	-1.80	-29.87	0.00	1.20	1.47	-0.21	-0.37	-1.07	-28.08
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.27	1.35	-7.20	-8.39	-12.54	-184.78	0.00	2.13	3.52	-6.55	-7.84	-12.36	-177.99
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.37	1.60	-7.99	-9.32	-13.95	-206.77	0.00	2.67	4.25	-7.04	-8.46	-13.51	-198.93
Door Co., WI	x	-	100	-	0.00	0.01	0.02	-0.04	-0.05	-0.07	-1.21	0.00	0.05	0.06	-0.01	-0.01	-0.04	-1.14
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	-0.05
Evansville, IN	-	x	-	100	0.00	0.12	0.22	-0.47	-0.55	-0.86	-14.27	0.00	0.57	0.70	-0.10	-0.18	-0.51	-13.42
Greater Connecticut, CT	x	-	100	-	0.00	0.62	1.14	-2.43	-2.84	-4.47	-74.36	0.00	2.98	3.67	-0.53	-0.92	-2.67	-69.91
Greene Co., PA	x	-	100	-	0.00	0.01	0.02	-0.04	-0.05	-0.08	-1.29	0.00	0.05	0.06	-0.01	-0.02	-0.05	-1.22
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.29	0.52	-1.11	-1.30	-2.04	-33.95	0.00	1.36	1.68	-0.24	-0.42	-1.22	-31.92
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.24	0.44	-0.95	-1.11	-1.75	-29.03	0.00	1.16	1.43	-0.21	-0.36	-1.04	-27.29

Table B2-12
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area)

Benzene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.21	0.00	0.01	0.01	0.00	0.00	-0.01	-0.20
Hickory, NC	-	x	-	100	0.00	0.07	0.13	-0.28	-0.33	-0.52	-8.57	0.00	0.34	0.42	-0.06	-0.11	-0.31	-8.06
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-26.30	-26.91	-48.45	-55.87	-71.53	-607.89	0.00	-104.97	-107.31	-132.78	-143.48	-161.93	-676.04
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-2.60	-2.71	-4.42	-5.10	-6.44	-51.05	0.00	-10.42	-10.71	-12.74	-13.73	-15.33	-58.07
Imperial Co., CA	x	-	100	-	0.00	0.12	0.22	-0.46	-0.54	-0.85	-14.08	0.00	0.56	0.70	-0.10	-0.17	-0.51	-13.24
Indianapolis, IN	-	x	-	100	0.00	0.67	1.22	-2.59	-3.04	-4.78	-79.42	0.00	3.18	3.92	-0.56	-0.98	-2.85	-74.67
Jamestown, NY	x	-	100	-	0.00	0.05	0.08	-0.18	-0.21	-0.33	-5.47	0.00	0.22	0.27	-0.04	-0.07	-0.20	-5.14
Jefferson Co., NY	x	-	100	-	0.00	0.06	0.10	-0.22	-0.26	-0.40	-6.73	0.00	0.27	0.33	-0.05	-0.08	-0.24	-6.32
Johnstown, PA	-	x	-	100	0.00	0.03	0.06	-0.13	-0.15	-0.24	-4.05	0.00	0.16	0.20	-0.03	-0.05	-0.15	-3.81
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.06	0.11	-0.24	-0.28	-0.44	-7.24	0.00	0.29	0.36	-0.05	-0.09	-0.26	-6.81
Knoxville, TN	x	x	100	100	0.00	0.41	0.75	-1.60	-1.87	-2.94	-48.91	0.00	1.96	2.41	-0.35	-0.61	-1.76	-45.98
Lancaster, PA	-	x	-	100	0.00	0.15	0.27	-0.57	-0.66	-1.04	-17.33	0.00	0.69	0.86	-0.12	-0.21	-0.62	-16.30
Las Vegas, NV	x	-	100	-	0.00	0.86	1.58	-3.36	-3.93	-6.18	-102.80	0.00	4.12	5.07	-0.73	-1.27	-3.69	-96.65
Libby, MT	-	x	-	100	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.29	0.00	0.01	0.01	0.00	0.00	-0.01	-0.27
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.01	-0.01	-0.01	-0.02	-0.38	0.00	0.02	0.02	0.00	0.00	-0.01	-0.36
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-8.84	-4.78	-46.74	-54.28	-76.58	-960.30	0.00	-31.13	-26.52	-75.95	-85.08	-109.92	-959.11
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.34	0.61	-1.31	-1.53	-2.41	-40.12	0.00	1.61	1.98	-0.28	-0.50	-1.44	-37.72
Louisville, KY-IN	-	x	-	100	0.00	0.35	0.64	-1.37	-1.61	-2.53	-42.06	0.00	1.69	2.08	-0.30	-0.52	-1.51	-39.55
Macon, GA	-	x	-	100	0.00	0.07	0.12	-0.26	-0.30	-0.48	-7.93	0.00	0.32	0.39	-0.06	-0.10	-0.28	-7.45
Manitowoc Co., WI	x	-		-	0.00	0.03	0.06	-0.13	-0.15	-0.24	-3.94	0.00	0.16	0.19	-0.03	-0.05	-0.14	-3.71
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.05	0.10	-0.21	-0.25	-0.39	-6.47	0.00	0.26	0.32	-0.05	-0.08	-0.23	-6.08
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.23	0.42	-0.90	-1.05	-1.65	-27.51	0.00	1.10	1.36	-0.19	-0.34	-0.99	-25.87
Memphis, TN-AR	x	-	100	-	0.00	-1.90	-1.82	-4.39	-5.07	-6.70	-65.95	0.00	-7.46	-7.47	-10.50	-11.44	-13.31	-70.17
Milwaukee-Racine, WI	x	-	100	-	0.00	0.58	1.05	-2.24	-2.62	-4.12	-68.55	0.00	2.75	3.38	-0.48	-0.85	-2.46	-64.45
Nevada (Western Part), CA	x	-	100	-	0.00	0.04	0.07	-0.16	-0.18	-0.29	-4.82	0.00	0.19	0.24	-0.03	-0.06	-0.17	-4.53
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.85	4.46	-24.09	-28.09	-41.94	-617.11	0.00	6.89	11.51	-22.10	-26.41	-41.51	-594.62
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.05	0.08	-0.18	-0.21	-0.33	-5.50	0.00	0.22	0.27	-0.04	-0.07	-0.20	-5.17
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-12.03	-11.10	-30.77	-35.59	-47.57	-491.78	0.00	-46.82	-46.37	-69.57	-76.03	-89.74	-516.13
Phoenix-Mesa, AZ	x	-	100	-	0.00	2.21	4.03	-8.58	-10.05	-15.81	-262.87	0.00	10.54	12.98	-1.86	-3.26	-9.45	-247.15
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.56	1.02	-2.18	-2.55	-4.01	-66.71	0.00	2.67	3.29	-0.47	-0.83	-2.40	-62.72
Poughkeepsie, NY	x	x	100	100	0.00	0.49	0.90	-1.92	-2.25	-3.54	-58.81	0.00	2.36	2.90	-0.42	-0.73	-2.11	-55.29

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Benzene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.30	0.54	-1.15	-1.35	-2.13	-35.34	0.00	1.42	1.74	-0.25	-0.44	-1.27	-33.23
Reading, PA	-	x	-	100	0.00	0.15	0.27	-0.57	-0.66	-1.04	-17.36	0.00	0.70	0.86	-0.12	-0.22	-0.62	-16.32
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.59	1.08	-2.29	-2.69	-4.23	-70.31	0.00	2.82	3.47	-0.50	-0.87	-2.53	-66.10
Rochester, NY	x	-	100	-	0.00	0.43	0.78	-1.67	-1.95	-3.08	-51.13	0.00	2.05	2.52	-0.36	-0.63	-1.84	-48.07
Rome, GA	-	x	-	100	0.00	0.04	0.07	-0.14	-0.16	-0.26	-4.28	0.00	0.17	0.21	-0.03	-0.05	-0.15	-4.03
Sacramento Metro, CA	x	-	50	-	0.00	0.98	1.80	-3.82	-4.48	-7.05	-117.15	0.00	4.70	5.78	-0.83	-1.45	-4.21	-110.14
San Diego, CA	x	-	100	-	0.00	0.96	1.76	-3.74	-4.38	-6.89	-114.60	0.00	4.59	5.66	-0.81	-1.42	-4.12	-107.74
San Francisco Bay Area, CA	x	-	100	-	0.00	-5.94	-4.77	-20.27	-23.49	-32.24	-368.88	0.00	-22.42	-21.29	-39.57	-43.67	-53.55	-376.88
San Joaquin Valley, CA	x	x	50	100	0.00	0.91	2.68	-10.81	-12.61	-19.06	-288.82	0.00	5.35	7.64	-8.23	-10.13	-17.13	-276.58
Sheboygan, WI	x	-	100	-	0.00	0.04	0.07	-0.16	-0.19	-0.29	-4.85	0.00	0.19	0.24	-0.03	-0.06	-0.17	-4.56
Springfield (Western MA), MA	x	-	100	-	0.00	0.32	0.58	-1.24	-1.45	-2.28	-37.96	0.00	1.52	1.87	-0.27	-0.47	-1.36	-35.69
St. Louis, MO-IL	x	x	100	100	0.00	-2.74	-2.19	-9.38	-10.87	-14.93	-171.02	0.00	-10.32	-9.80	-18.27	-20.17	-24.75	-174.67
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.22	-0.21	-0.46	-0.54	-0.70	-6.60	0.00	-0.86	-0.87	-1.16	-1.26	-1.45	-7.11
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.18	0.35	-0.87	-1.01	-1.57	-25.46	0.00	0.86	1.09	-0.34	-0.48	-1.09	-24.06
Washington, DC-MD-VA	x	x	100	100	0.00	2.04	3.73	-7.94	-9.30	-14.63	-243.29	0.00	9.75	12.01	-1.72	-3.02	-8.74	-228.74
Wheeling, WV-OH	-	x	-	100	0.00	0.05	0.09	-0.19	-0.22	-0.35	-5.84	0.00	0.23	0.29	-0.04	-0.07	-0.21	-5.49
York, PA	-	x	-	100	0.00	0.17	0.31	-0.66	-0.77	-1.21	-20.17	0.00	0.81	1.00	-0.14	-0.25	-0.72	-18.97

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-13
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area)

Butadiene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.01	0.01	0.02	0.02	0.03	0.10
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Atlanta, GA	x	x	100	100	0.00	0.07	0.08	0.10	0.12	0.14	0.54	0.00	0.07	0.08	0.10	0.12	0.14	0.54
Baltimore, MD	x	x	100	100	0.00	0.03	0.03	0.04	0.05	0.06	0.22	0.00	0.03	0.03	0.04	0.05	0.06	0.22
Baton Rouge, LA	x	-	100	-	0.00	-0.12	-0.14	-0.16	-0.19	-0.23	-0.56	0.00	-0.12	-0.14	-0.16	-0.19	-0.23	-0.56
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-0.25	-0.29	-0.34	-0.40	-0.49	-1.19	0.00	-0.25	-0.29	-0.34	-0.40	-0.49	-1.19
Birmingham, AL	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.02	0.08	0.00	0.01	0.01	0.02	0.02	0.02	0.08
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.05	0.05	0.07	0.08	0.09	0.37	0.00	0.05	0.05	0.07	0.08	0.09	0.37
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.00	0.01	0.01	0.01	0.01	0.01	0.05
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.02	0.09	0.00	0.01	0.01	0.02	0.02	0.02	0.09
Canton-Massillon, OH	-	x	-	100	0.00	-0.01	-0.02	-0.02	-0.02	-0.03	-0.05	0.00	-0.01	-0.02	-0.02	-0.02	-0.03	-0.05
Charleston, WV	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.04	0.14	0.00	0.02	0.02	0.03	0.03	0.04	0.14
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.01	0.04	0.00	0.01	0.01	0.01	0.01	0.01	0.04
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.11	-0.13	-0.15	-0.17	-0.22	-0.33	0.00	-0.11	-0.13	-0.15	-0.17	-0.22	-0.33
Chico, CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.02	0.02	0.03	0.03	0.04	0.15	0.00	0.02	0.02	0.03	0.03	0.04	0.15
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.03	0.03	0.04	0.05	0.05	0.21	0.00	0.03	0.03	0.04	0.05	0.05	0.21
Columbus, OH	x	x	100	100	0.00	0.02	0.02	0.03	0.03	0.03	0.14	0.00	0.02	0.02	0.03	0.03	0.03	0.14
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.07	0.08	0.10	0.12	0.14	0.55	0.00	0.07	0.08	0.10	0.12	0.14	0.55
Dayton-Springfield, OH	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.01	0.01	0.02	0.06
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.02	0.15	0.00	0.01	0.01	0.02	0.02	0.02	0.15
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.03	0.03	0.04	0.05	0.05	0.27	0.00	0.03	0.03	0.04	0.05	0.05	0.27
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Greater Connecticut, CT	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.04	0.14	0.00	0.02	0.02	0.03	0.03	0.04	0.14
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.01	0.01	0.02	0.06
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.01	0.06	0.00	0.01	0.01	0.01	0.01	0.01	0.06

Table B2-13
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area)

Butadiene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-0.48	-0.54	-0.64	-0.74	-0.92	-2.11	0.00	-0.48	-0.54	-0.64	-0.74	-0.92	-2.11
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.05	-0.05	-0.06	-0.07	-0.09	-0.21	0.00	-0.05	-0.05	-0.06	-0.07	-0.09	-0.21
Imperial Co., CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Indianapolis, IN	-	x	-	100	0.00	0.02	0.02	0.02	0.03	0.03	0.13	0.00	0.02	0.02	0.02	0.03	0.03	0.13
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Knoxville, TN	x	x	100	100	0.00	0.01	0.01	0.02	0.02	0.02	0.09	0.00	0.01	0.01	0.02	0.02	0.02	0.09
Lancaster, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Las Vegas, NV	x	-	100	-	0.00	0.01	0.02	0.02	0.03	0.03	0.11	0.00	0.01	0.02	0.02	0.03	0.03	0.11
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-0.13	-0.15	-0.17	-0.18	-0.25	-0.19	0.00	-0.13	-0.15	-0.17	-0.18	-0.25	-0.19
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	0.06	0.00	0.01	0.01	0.01	0.01	0.01	0.06
Louisville, KY-IN	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.02	0.09	0.00	0.01	0.01	0.02	0.02	0.02	0.09
Macon, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Memphis, TN-AR	x	-	100	-	0.00	-0.03	-0.04	-0.04	-0.05	-0.06	-0.12	0.00	-0.03	-0.04	-0.04	-0.05	-0.06	-0.12
Milwaukee-Racine, WI	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.04	0.14	0.00	0.02	0.02	0.03	0.03	0.04	0.14
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.08	0.08	0.11	0.14	0.15	0.79	0.00	0.08	0.08	0.11	0.14	0.15	0.79
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-0.20	-0.23	-0.26	-0.30	-0.39	-0.75	0.00	-0.20	-0.23	-0.27	-0.30	-0.39	-0.75
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.04	0.05	0.06	0.07	0.08	0.31	0.00	0.04	0.05	0.06	0.07	0.08	0.31
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.02	0.02	0.03	0.03	0.04	0.15	0.00	0.02	0.02	0.03	0.03	0.04	0.15
Poughkeepsie, NY	x	x	100	100	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.01	0.01	0.02	0.02	0.03	0.10

Table B2-13
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Emission Changes a/ by Nonattainment Area)

Butadiene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.01	0.02	0.02	0.07
Reading, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	0.06	0.00	0.01	0.01	0.01	0.01	0.01	0.06
Rochester, NY	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.01	0.01	0.02	0.02	0.03	0.10
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Sacramento Metro, CA	x	-	50	-	0.00	0.02	0.03	0.03	0.04	0.04	0.17	0.00	0.02	0.03	0.03	0.04	0.04	0.17
San Diego, CA	x	-	100	-	0.00	0.03	0.04	0.04	0.05	0.06	0.24	0.00	0.03	0.04	0.04	0.05	0.06	0.24
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.08	-0.10	-0.11	-0.12	-0.16	-0.20	0.00	-0.08	-0.10	-0.11	-0.12	-0.16	-0.20
San Joaquin Valley, CA	x	x	50	100	0.00	0.02	0.02	0.03	0.04	0.04	0.23	0.00	0.02	0.02	0.03	0.04	0.04	0.23
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Springfield (Western MA), MA	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.01	0.02	0.02	0.07
St. Louis, MO-IL	x	x	100	100	0.00	-0.04	-0.04	-0.05	-0.06	-0.07	-0.09	0.00	-0.04	-0.04	-0.05	-0.06	-0.07	-0.09
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.00	0.01	0.01	0.01	0.01	0.01	0.05
Washington, DC-MD-VA	x	x	100	100	0.00	0.05	0.06	0.07	0.09	0.10	0.38	0.00	0.05	0.06	0.07	0.09	0.10	0.38
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
York, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-14
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	-0.13	0.00	0.03	0.04	0.04	0.05	0.04	-0.08
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.01	0.00	-0.01
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Atlanta, GA	x	x	100	100	0.00	0.04	0.06	0.07	0.08	0.03	-0.78	0.00	0.18	0.21	0.24	0.27	0.25	-0.45
Baltimore, MD	x	x	100	100	0.00	0.01	0.02	0.02	0.03	0.01	-0.30	0.00	0.07	0.08	0.09	0.10	0.10	-0.17
Baton Rouge, LA	x	-	100	-	0.00	-0.34	-0.39	-0.46	-0.51	-0.63	-1.58	0.00	-0.56	-0.63	-0.71	-0.78	-0.92	-1.76
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-0.69	-0.79	-0.93	-1.05	-1.28	-3.08	0.00	-1.16	-1.29	-1.46	-1.60	-1.88	-3.48
Birmingham, AL	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.00	-0.11	0.00	0.02	0.03	0.03	0.04	0.03	-0.06
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.02	0.04	0.04	0.05	0.02	-0.46	0.00	0.11	0.13	0.14	0.16	0.15	-0.26
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.00	0.01	0.01	0.01	0.00	-0.07	0.00	0.01	0.02	0.02	0.02	0.02	-0.04
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.00	-0.11	0.00	0.03	0.03	0.03	0.04	0.04	-0.06
Canton-Massillon, OH	-	x	-	100	0.00	-0.04	-0.05	-0.06	-0.06	-0.08	-0.23	0.00	-0.07	-0.08	-0.09	-0.09	-0.11	-0.24
Charleston, WV	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.01	0.01	0.01	0.01	0.01	-0.02
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.01	0.02	0.02	0.02	0.01	-0.20	0.00	0.05	0.06	0.06	0.07	0.07	-0.12
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.00	-0.05	0.00	0.01	0.01	0.02	0.02	0.02	-0.03
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.46	-0.52	-0.62	-0.68	-0.90	-2.94	0.00	-0.68	-0.74	-0.85	-0.91	-1.13	-2.92
Chico, CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.01	0.01	0.01	-0.01
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.01	0.01	0.02	0.02	0.01	-0.19	0.00	0.04	0.05	0.06	0.07	0.06	-0.11
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.01	0.01	0.01	-0.01
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.01	0.02	0.02	0.03	0.01	-0.26	0.00	0.06	0.07	0.08	0.09	0.09	-0.15
Columbus, OH	x	x	100	100	0.00	0.01	0.01	0.02	0.02	0.01	-0.18	0.00	0.04	0.05	0.06	0.06	0.06	-0.10
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.04	0.06	0.07	0.08	0.03	-0.77	0.00	0.18	0.21	0.24	0.27	0.25	-0.44
Dayton-Springfield, OH	-	x	-	100	0.00	0.00	0.01	0.01	0.01	0.00	-0.08	0.00	0.02	0.02	0.02	0.03	0.03	-0.05
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.04	-0.04	-0.05	-0.05	-0.09	-0.60	0.00	-0.02	-0.01	-0.02	-0.01	-0.05	-0.49
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.04	-0.03	-0.04	-0.04	-0.10	-0.76	0.00	0.01	0.02	0.02	0.03	-0.01	-0.59
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.01	0.01	0.01	0.01	0.01	-0.02
Greater Connecticut, CT	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.01	-0.18	0.00	0.04	0.05	0.06	0.06	0.06	-0.10
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.00	0.01	0.01	0.01	0.00	-0.08	0.00	0.02	0.02	0.03	0.03	0.03	-0.05
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.00	0.01	0.01	0.01	0.00	-0.07	0.00	0.02	0.02	0.02	0.03	0.02	-0.04

Table B2-14
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.01	0.01	0.01	-0.01
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-1.38	-1.58	-1.87	-2.09	-2.61	-6.77	0.00	-2.27	-2.52	-2.86	-3.11	-3.70	-7.38
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.13	-0.15	-0.18	-0.20	-0.25	-0.64	0.00	-0.22	-0.24	-0.28	-0.30	-0.36	-0.71
Imperial Co., CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.01	0.01	0.01	0.01	0.01	-0.01
Indianapolis, IN	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.01	-0.17	0.00	0.04	0.05	0.05	0.06	0.06	-0.10
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.01	0.00	-0.01
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.01	0.00	-0.01
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Knoxville, TN	x	x	100	100	0.00	0.01	0.01	0.01	0.01	0.00	-0.11	0.00	0.03	0.03	0.03	0.04	0.04	-0.06
Lancaster, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.01	0.01	0.01	0.02	0.01	-0.02
Las Vegas, NV	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.01	-0.17	0.00	0.04	0.05	0.05	0.06	0.05	-0.09
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-0.68	-0.75	-0.90	-0.99	-1.35	-4.93	0.00	-0.93	-1.00	-1.14	-1.23	-1.57	-4.71
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.00	0.01	0.01	0.01	0.00	-0.08	0.00	0.02	0.02	0.02	0.03	0.03	-0.05
Louisville, KY-IN	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.00	-0.11	0.00	0.03	0.03	0.03	0.04	0.04	-0.06
Macon, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.01	0.01	0.01	-0.01
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.00	-0.05	0.00	0.01	0.01	0.01	0.02	0.02	-0.03
Memphis, TN-AR	x	-	100	-	0.00	-0.11	-0.12	-0.14	-0.16	-0.20	-0.59	0.00	-0.16	-0.18	-0.21	-0.22	-0.27	-0.61
Milwaukee-Racine, WI	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.01	-0.18	0.00	0.04	0.05	0.05	0.06	0.06	-0.10
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.12	-0.11	-0.14	-0.14	-0.31	-2.32	0.00	0.00	0.03	0.03	0.05	-0.06	-1.81
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.01	0.01	-0.01
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-0.69	-0.78	-0.92	-1.03	-1.32	-3.92	0.00	-1.07	-1.17	-1.33	-1.45	-1.76	-4.05
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.02	0.04	0.04	0.05	0.02	-0.45	0.00	0.10	0.12	0.14	0.16	0.15	-0.26
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.01	0.01	0.02	0.02	0.01	-0.19	0.00	0.04	0.05	0.06	0.07	0.06	-0.11
Poughkeepsie, NY	x	x	100	100	0.00	0.01	0.01	0.01	0.01	0.01	-0.13	0.00	0.03	0.04	0.04	0.05	0.04	-0.08

Table B2-14
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.00	0.01	0.01	0.01	0.00	-0.09	0.00	0.02	0.03	0.03	0.03	0.03	-0.05
Reading, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.01	0.01	0.01	0.01	0.01	-0.02
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.00	0.01	0.01	0.01	0.00	-0.09	0.00	0.02	0.03	0.03	0.03	0.03	-0.05
Rochester, NY	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.00	-0.13	0.00	0.03	0.04	0.04	0.05	0.04	-0.07
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Sacramento Metro, CA	x	-	50	-	0.00	0.01	0.02	0.02	0.03	0.01	-0.24	0.00	0.05	0.06	0.07	0.08	0.08	-0.13
San Diego, CA	x	-	100	-	0.00	0.01	0.02	0.03	0.03	0.01	-0.30	0.00	0.07	0.08	0.09	0.11	0.10	-0.17
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.37	-0.41	-0.49	-0.55	-0.73	-2.47	0.00	-0.54	-0.58	-0.66	-0.71	-0.90	-2.42
San Joaquin Valley, CA	x	x	50	100	0.00	-0.04	-0.04	-0.05	-0.05	-0.11	-0.80	0.00	0.00	0.01	0.01	0.01	-0.02	-0.62
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Springfield (Western MA), MA	x	-	100	-	0.00	0.00	0.01	0.01	0.01	0.00	-0.09	0.00	0.02	0.03	0.03	0.03	0.03	-0.05
St. Louis, MO-IL	x	x	100	100	0.00	-0.17	-0.19	-0.23	-0.25	-0.34	-1.14	0.00	-0.25	-0.27	-0.31	-0.33	-0.41	-1.12
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.06	0.00	-0.02	-0.02	-0.02	-0.03	-0.03	-0.07
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	0.00	0.01	0.01	0.02	0.02	0.02	-0.05
Washington, DC-MD-VA	x	x	100	100	0.00	0.02	0.04	0.04	0.05	0.02	-0.51	0.00	0.12	0.14	0.16	0.18	0.17	-0.29
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.01	0.01	0.01	-0.01
York, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.01	0.01	0.01	0.01	0.01	-0.02

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-15
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-0.03	-0.02	-0.04	-0.03	-0.07	-0.81	0.00	0.06	0.07	0.07	0.07	0.05	-0.61
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.09	0.00	0.01	0.01	0.01	0.01	0.01	-0.07
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.09	0.00	0.01	0.01	0.01	0.01	0.01	-0.07
Atlanta, GA	x	x	100	100	0.00	-0.18	-0.14	-0.22	-0.22	-0.47	-5.20	0.00	0.36	0.46	0.42	0.48	0.31	-3.89
Baltimore, MD	x	x	100	100	0.00	-0.06	-0.05	-0.08	-0.08	-0.16	-1.78	0.00	0.12	0.16	0.14	0.16	0.10	-1.33
Baton Rouge, LA	x	-	100	-	0.00	-0.53	-0.61	-0.72	-0.80	-0.99	-2.67	0.00	-1.12	-1.23	-1.39	-1.49	-1.73	-3.10
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1.06	-1.21	-1.43	-1.59	-1.94	-4.76	0.00	-2.30	-2.54	-2.84	-3.05	-3.53	-5.78
Birmingham, AL	-	x	-	100	0.00	-0.02	-0.02	-0.03	-0.03	-0.06	-0.62	0.00	0.04	0.05	0.05	0.06	0.04	-0.47
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-0.09	-0.07	-0.12	-0.11	-0.24	-2.69	0.00	0.19	0.24	0.22	0.25	0.16	-2.02
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.39	0.00	0.03	0.03	0.03	0.04	0.02	-0.29
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-0.02	-0.02	-0.03	-0.03	-0.06	-0.64	0.00	0.04	0.06	0.05	0.06	0.04	-0.48
Canton-Massillon, OH	-	x	-	100	0.00	-0.07	-0.08	-0.10	-0.11	-0.14	-0.48	0.00	-0.14	-0.15	-0.17	-0.18	-0.22	-0.50
Charleston, WV	-	x	-	100	0.00	-0.01	0.00	-0.01	-0.01	-0.01	-0.16	0.00	0.01	0.01	0.01	0.02	0.01	-0.12
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-0.05	-0.04	-0.06	-0.06	-0.12	-1.31	0.00	0.09	0.12	0.11	0.12	0.08	-0.98
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.03	-0.31	0.00	0.02	0.03	0.03	0.03	0.02	-0.24
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.91	-0.99	-1.22	-1.33	-1.79	-7.69	0.00	-1.38	-1.47	-1.71	-1.82	-2.30	-7.37
Chico, CA	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.12	0.00	0.01	0.01	0.01	0.01	0.01	-0.09
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-0.04	-0.03	-0.05	-0.05	-0.10	-1.13	0.00	0.08	0.10	0.09	0.10	0.07	-0.85
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.10	0.00	0.01	0.01	0.01	0.01	0.01	-0.07
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-0.05	-0.04	-0.07	-0.06	-0.14	-1.51	0.00	0.10	0.13	0.12	0.14	0.09	-1.13
Columbus, OH	x	x	100	100	0.00	-0.04	-0.03	-0.05	-0.05	-0.10	-1.12	0.00	0.08	0.10	0.09	0.10	0.07	-0.84
Dallas-Fort Worth, TX	x	-	100	-	0.00	-0.17	-0.13	-0.22	-0.21	-0.45	-5.01	0.00	0.35	0.44	0.41	0.46	0.30	-3.75
Dayton-Springfield, OH	-	x	-	100	0.00	-0.02	-0.01	-0.02	-0.02	-0.04	-0.46	0.00	0.03	0.04	0.04	0.04	0.03	-0.34
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.16	-0.16	-0.21	-0.22	-0.36	-2.55	0.00	-0.04	-0.02	-0.06	-0.06	-0.17	-2.09
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.19	-0.18	-0.25	-0.26	-0.43	-3.25	0.00	-0.01	0.02	-0.02	-0.01	-0.15	-2.63
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.21	0.00	0.01	0.02	0.02	0.02	0.01	-0.16
Greater Connecticut, CT	x	-	100	-	0.00	-0.04	-0.03	-0.05	-0.05	-0.10	-1.07	0.00	0.07	0.09	0.09	0.10	0.06	-0.80
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.02
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-0.02	-0.01	-0.02	-0.02	-0.04	-0.49	0.00	0.03	0.04	0.04	0.04	0.03	-0.37
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.02	-0.04	-0.43	0.00	0.03	0.04	0.03	0.04	0.03	-0.32

Table B2-15
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.12	0.00	0.01	0.01	0.01	0.01	0.01	-0.09
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-2.26	-2.55	-3.05	-3.38	-4.23	-12.53	0.00	-4.52	-4.95	-5.58	-5.99	-7.05	-13.92
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.22	-0.24	-0.29	-0.32	-0.40	-1.14	0.00	-0.44	-0.48	-0.54	-0.58	-0.68	-1.29
Imperial Co., CA	x	-	100	-	0.00	-0.01	0.00	-0.01	-0.01	-0.01	-0.17	0.00	0.01	0.01	0.01	0.02	0.01	-0.12
Indianapolis, IN	-	x	-	100	0.00	-0.04	-0.03	-0.05	-0.04	-0.09	-1.04	0.00	0.07	0.09	0.08	0.10	0.06	-0.78
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.08	0.00	0.01	0.01	0.01	0.01	0.00	-0.06
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.09	0.00	0.01	0.01	0.01	0.01	0.01	-0.07
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	-0.01	-0.07	0.00	0.00	0.01	0.01	0.01	0.00	-0.05
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.09	0.00	0.01	0.01	0.01	0.01	0.01	-0.06
Knoxville, TN	x	x	100	100	0.00	-0.02	-0.02	-0.03	-0.03	-0.06	-0.68	0.00	0.05	0.06	0.06	0.06	0.04	-0.51
Lancaster, PA	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.26	0.00	0.02	0.02	0.02	0.02	0.02	-0.19
Las Vegas, NV	x	-	100	-	0.00	-0.04	-0.03	-0.05	-0.05	-0.10	-1.13	0.00	0.08	0.10	0.09	0.10	0.07	-0.85
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-1.50	-1.59	-1.99	-2.16	-3.00	-14.79	0.00	-1.88	-1.96	-2.35	-2.48	-3.32	-13.52
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-0.02	-0.01	-0.02	-0.02	-0.05	-0.51	0.00	0.03	0.04	0.04	0.05	0.03	-0.38
Louisville, KY-IN	-	x	-	100	0.00	-0.02	-0.02	-0.03	-0.03	-0.06	-0.64	0.00	0.04	0.06	0.05	0.06	0.04	-0.48
Macon, GA	-	x	-	100	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.12	0.00	0.01	0.01	0.01	0.01	0.01	-0.09
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.06	0.00	0.00	0.01	0.00	0.01	0.00	-0.05
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.08	0.00	0.01	0.01	0.01	0.01	0.00	-0.06
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.03	-0.31	0.00	0.02	0.03	0.03	0.03	0.02	-0.23
Memphis, TN-AR	x	-	100	-	0.00	-0.19	-0.21	-0.25	-0.28	-0.36	-1.30	0.00	-0.33	-0.36	-0.41	-0.44	-0.53	-1.33
Milwaukee-Racine, WI	x	-	100	-	0.00	-0.04	-0.03	-0.04	-0.04	-0.09	-1.03	0.00	0.07	0.09	0.08	0.09	0.06	-0.77
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.06	0.00	0.00	0.01	0.01	0.01	0.00	-0.05
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.59	-0.57	-0.77	-0.81	-1.31	-9.77	0.00	-0.07	0.02	-0.12	-0.09	-0.50	-7.94
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	-0.01	-0.09	0.00	0.01	0.01	0.01	0.01	0.01	-0.07
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-1.25	-1.38	-1.68	-1.85	-2.41	-9.06	0.00	-2.15	-2.32	-2.66	-2.84	-3.47	-9.12
Phoenix-Mesa, AZ	x	-	100	-	0.00	-0.11	-0.08	-0.13	-0.13	-0.27	-3.02	0.00	0.21	0.26	0.24	0.28	0.18	-2.26
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-0.04	-0.03	-0.05	-0.05	-0.10	-1.07	0.00	0.07	0.09	0.09	0.10	0.06	-0.80
Poughkeepsie, NY	x	x	100	100	0.00	-0.03	-0.02	-0.04	-0.03	-0.07	-0.81	0.00	0.06	0.07	0.07	0.07	0.05	-0.61

Table B2-15
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-0.02	-0.01	-0.02	-0.02	-0.05	-0.54	0.00	0.04	0.05	0.04	0.05	0.03	-0.40
Reading, PA	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.24	0.00	0.02	0.02	0.02	0.02	0.01	-0.18
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-0.02	-0.02	-0.03	-0.03	-0.06	-0.68	0.00	0.05	0.06	0.06	0.06	0.04	-0.51
Rochester, NY	x	-	100	-	0.00	-0.03	-0.02	-0.03	-0.03	-0.07	-0.76	0.00	0.05	0.07	0.06	0.07	0.04	-0.57
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	-0.01	-0.07	0.00	0.00	0.01	0.01	0.01	0.00	-0.05
Sacramento Metro, CA	x	-	50	-	0.00	-0.05	-0.04	-0.06	-0.06	-0.13	-1.48	0.00	0.10	0.13	0.12	0.14	0.09	-1.11
San Diego, CA	x	-	100	-	0.00	-0.06	-0.05	-0.08	-0.07	-0.16	-1.75	0.00	0.12	0.15	0.14	0.16	0.10	-1.31
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.75	-0.81	-1.01	-1.10	-1.49	-6.60	0.00	-1.09	-1.16	-1.36	-1.45	-1.85	-6.25
San Joaquin Valley, CA	x	x	50	100	0.00	-0.22	-0.21	-0.28	-0.29	-0.48	-3.69	0.00	0.00	0.03	-0.02	0.00	-0.16	-2.98
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.07	0.00	0.00	0.01	0.01	0.01	0.00	-0.05
Springfield (Western MA), MA	x	-	100	-	0.00	-0.02	-0.01	-0.02	-0.02	-0.05	-0.56	0.00	0.04	0.05	0.05	0.05	0.03	-0.42
St. Louis, MO-IL	x	x	100	100	0.00	-0.35	-0.38	-0.46	-0.51	-0.69	-3.04	0.00	-0.51	-0.54	-0.63	-0.67	-0.86	-2.88
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.02	-0.02	-0.03	-0.03	-0.04	-0.14	0.00	-0.04	-0.04	-0.05	-0.05	-0.06	-0.14
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-0.02	-0.01	-0.02	-0.02	-0.04	-0.39	0.00	0.02	0.03	0.02	0.03	0.01	-0.29
Washington, DC-MD-VA	x	x	100	100	0.00	-0.11	-0.08	-0.14	-0.13	-0.28	-3.16	0.00	0.22	0.28	0.26	0.29	0.19	-2.36
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	-0.01	-0.09	0.00	0.01	0.01	0.01	0.01	0.01	-0.07
York, PA	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.27	0.00	0.02	0.02	0.02	0.02	0.02	-0.20

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-16
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-0.11	-0.10	-0.14	-0.14	-0.24	-2.12	0.00	0.10	0.13	0.09	0.11	0.02	-1.62
Allegan Co., MI	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.23	0.00	0.01	0.01	0.01	0.01	0.00	-0.18
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.27	0.00	0.01	0.02	0.01	0.01	0.00	-0.21
Atlanta, GA	x	x	100	100	0.00	-0.86	-0.79	-1.12	-1.10	-1.90	-16.83	0.00	0.77	1.00	0.75	0.90	0.14	-12.91
Baltimore, MD	x	x	100	100	0.00	-0.24	-0.21	-0.30	-0.30	-0.52	-4.59	0.00	0.21	0.27	0.20	0.25	0.04	-3.52
Baton Rouge, LA	x	-	100	-	0.00	-0.77	-0.87	-1.04	-1.15	-1.43	-4.20	0.00	-1.82	-1.99	-2.23	-2.37	-2.77	-4.92
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1.46	-1.67	-1.99	-2.20	-2.69	-6.72	0.00	-3.75	-4.11	-4.57	-4.86	-5.59	-8.56
Birmingham, AL	-	x	-	100	0.00	-0.08	-0.07	-0.10	-0.10	-0.18	-1.57	0.00	0.07	0.09	0.07	0.08	0.01	-1.21
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-0.33	-0.30	-0.43	-0.42	-0.73	-6.50	0.00	0.30	0.39	0.29	0.35	0.05	-4.99
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.05	-0.05	-0.07	-0.06	-0.11	-0.99	0.00	0.05	0.06	0.04	0.05	0.01	-0.76
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-0.08	-0.07	-0.10	-0.10	-0.17	-1.50	0.00	0.07	0.09	0.07	0.08	0.01	-1.15
Canton-Massillon, OH	-	x	-	100	0.00	-0.12	-0.13	-0.16	-0.17	-0.22	-0.83	0.00	-0.23	-0.24	-0.28	-0.29	-0.36	-0.86
Charleston, WV	-	x	-	100	0.00	-0.02	-0.02	-0.02	-0.02	-0.04	-0.37	0.00	0.02	0.02	0.02	0.02	0.00	-0.29
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-0.20	-0.19	-0.26	-0.26	-0.45	-3.98	0.00	0.18	0.24	0.18	0.21	0.03	-3.06
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.04	-0.04	-0.05	-0.05	-0.09	-0.77	0.00	0.04	0.05	0.03	0.04	0.01	-0.59
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-1.65	-1.75	-2.20	-2.34	-3.24	-16.32	0.00	-2.19	-2.30	-2.80	-2.91	-3.96	-14.99
Chico, CA	x	-	100	-	0.00	-0.02	-0.01	-0.02	-0.02	-0.03	-0.30	0.00	0.01	0.02	0.01	0.02	0.00	-0.23
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-0.15	-0.14	-0.20	-0.20	-0.34	-3.00	0.00	0.14	0.18	0.13	0.16	0.02	-2.30
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.22	0.00	0.01	0.01	0.01	0.01	0.00	-0.17
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-0.18	-0.17	-0.24	-0.23	-0.40	-3.54	0.00	0.16	0.21	0.16	0.19	0.03	-2.72
Columbus, OH	x	x	100	100	0.00	-0.16	-0.14	-0.20	-0.20	-0.35	-3.08	0.00	0.14	0.18	0.14	0.17	0.02	-2.37
Dallas-Fort Worth, TX	x	-	100	-	0.00	-0.78	-0.72	-1.01	-1.00	-1.73	-15.28	0.00	0.70	0.91	0.68	0.82	0.12	-11.72
Dayton-Springfield, OH	-	x	-	100	0.00	-0.06	-0.05	-0.07	-0.07	-0.12	-1.08	0.00	0.05	0.06	0.05	0.06	0.01	-0.83
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.44	-0.43	-0.57	-0.58	-0.92	-6.67	0.00	-0.03	0.02	-0.11	-0.08	-0.42	-5.40
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.48	-0.47	-0.63	-0.64	-1.02	-7.47	0.00	-0.02	0.04	-0.10	-0.06	-0.44	-6.03
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	-0.03
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	-0.03	-0.02	-0.03	-0.03	-0.06	-0.52	0.00	0.02	0.03	0.02	0.03	0.00	-0.40
Greater Connecticut, CT	x	-	100	-	0.00	-0.14	-0.13	-0.18	-0.18	-0.30	-2.69	0.00	0.12	0.16	0.12	0.14	0.02	-2.07
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	-0.04
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-0.06	-0.06	-0.08	-0.08	-0.14	-1.23	0.00	0.06	0.07	0.05	0.07	0.01	-0.94
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-0.05	-0.05	-0.07	-0.07	-0.12	-1.05	0.00	0.05	0.06	0.05	0.06	0.01	-0.81

Table B2-16
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Hickory, NC	-	x	-	100	0.00	-0.02	-0.01	-0.02	-0.02	-0.04	-0.31	0.00	0.01	0.02	0.01	0.02	0.00	-0.24
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-3.39	-3.79	-4.58	-5.00	-6.39	-21.56	0.00	-7.32	-7.95	-9.00	-9.54	-11.38	-23.52
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.31	-0.35	-0.42	-0.46	-0.58	-1.81	0.00	-0.72	-0.78	-0.88	-0.93	-1.10	-2.06
Imperial Co., CA	x	-	100	-	0.00	-0.03	-0.02	-0.03	-0.03	-0.06	-0.51	0.00	0.02	0.03	0.02	0.03	0.00	-0.39
Indianapolis, IN	-	x	-	100	0.00	-0.15	-0.13	-0.19	-0.19	-0.32	-2.88	0.00	0.13	0.17	0.13	0.15	0.02	-2.21
Jamestown, NY	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.20	0.00	0.01	0.01	0.01	0.01	0.00	-0.15
Jefferson Co., NY	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.24	0.00	0.01	0.01	0.01	0.01	0.00	-0.19
Johnstown, PA	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.15	0.00	0.01	0.01	0.01	0.01	0.00	-0.11
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.26	0.00	0.01	0.02	0.01	0.01	0.00	-0.20
Knoxville, TN	x	x	100	100	0.00	-0.09	-0.08	-0.12	-0.12	-0.20	-1.77	0.00	0.08	0.11	0.08	0.09	0.01	-1.36
Lancaster, PA	-	x	-	100	0.00	-0.03	-0.03	-0.04	-0.04	-0.07	-0.63	0.00	0.03	0.04	0.03	0.03	0.01	-0.48
Las Vegas, NV	x	-	100	-	0.00	-0.19	-0.17	-0.25	-0.24	-0.42	-3.72	0.00	0.17	0.22	0.17	0.20	0.03	-2.86
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-3.00	-3.11	-3.99	-4.19	-6.03	-34.53	0.00	-2.89	-2.92	-3.82	-3.91	-5.94	-30.25
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-0.07	-0.07	-0.10	-0.09	-0.16	-1.45	0.00	0.07	0.09	0.06	0.08	0.01	-1.11
Louisville, KY-IN	-	x	-	100	0.00	-0.08	-0.07	-0.10	-0.10	-0.17	-1.52	0.00	0.07	0.09	0.07	0.08	0.01	-1.17
Macon, GA	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.29	0.00	0.01	0.02	0.01	0.02	0.00	-0.22
Manitowoc Co., WI	x	-		-	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.14	0.00	0.01	0.01	0.01	0.01	0.00	-0.11
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.23	0.00	0.01	0.01	0.01	0.01	0.00	-0.18
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.05	-0.05	-0.07	-0.06	-0.11	-1.00	0.00	0.05	0.06	0.04	0.05	0.01	-0.76
Memphis, TN-AR	x	-	100	-	0.00	-0.30	-0.33	-0.40	-0.43	-0.57	-2.35	0.00	-0.54	-0.58	-0.67	-0.71	-0.88	-2.35
Milwaukee-Racine, WI	x	-	100	-	0.00	-0.13	-0.12	-0.16	-0.16	-0.28	-2.48	0.00	0.11	0.15	0.11	0.13	0.02	-1.90
Nevada (Western Part), CA	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.17	0.00	0.01	0.01	0.01	0.01	0.00	-0.13
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-1.46	-1.43	-1.91	-1.95	-3.06	-22.28	0.00	-0.13	0.05	-0.38	-0.28	-1.42	-18.06
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.20	0.00	0.01	0.01	0.01	0.01	0.00	-0.15
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-2.08	-2.25	-2.79	-3.00	-4.02	-17.58	0.00	-3.47	-3.71	-4.34	-4.56	-5.80	-17.07
Phoenix-Mesa, AZ	x	-	100	-	0.00	-0.49	-0.45	-0.63	-0.62	-1.08	-9.52	0.00	0.43	0.56	0.42	0.51	0.08	-7.30
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-0.12	-0.11	-0.16	-0.16	-0.27	-2.42	0.00	0.11	0.14	0.11	0.13	0.02	-1.85
Poughkeepsie, NY	x	x	100	100	0.00	-0.11	-0.10	-0.14	-0.14	-0.24	-2.13	0.00	0.10	0.13	0.09	0.11	0.02	-1.63

Table B2-16
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-0.07	-0.06	-0.08	-0.08	-0.14	-1.28	0.00	0.06	0.08	0.06	0.07	0.01	-0.98
Reading, PA	-	x	-	100	0.00	-0.03	-0.03	-0.04	-0.04	-0.07	-0.63	0.00	0.03	0.04	0.03	0.03	0.01	-0.48
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-0.13	-0.12	-0.17	-0.17	-0.29	-2.55	0.00	0.12	0.15	0.11	0.14	0.02	-1.95
Rochester, NY	x	-	100	-	0.00	-0.10	-0.09	-0.12	-0.12	-0.21	-1.85	0.00	0.08	0.11	0.08	0.10	0.01	-1.42
Rome, GA	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.16	0.00	0.01	0.01	0.01	0.01	0.00	-0.12
Sacramento Metro, CA	x	-	50	-	0.00	-0.22	-0.20	-0.28	-0.28	-0.48	-4.24	0.00	0.19	0.25	0.19	0.23	0.03	-3.25
San Diego, CA	x	-	100	-	0.00	-0.21	-0.19	-0.28	-0.27	-0.47	-4.15	0.00	0.19	0.25	0.18	0.22	0.03	-3.18
San Francisco Bay Area, CA	x	-	100	-	0.00	-1.34	-1.42	-1.78	-1.90	-2.63	-13.23	0.00	-1.78	-1.87	-2.28	-2.37	-3.22	-12.16
San Joaquin Valley, CA	x	x	50	100	0.00	-0.65	-0.62	-0.84	-0.85	-1.37	-10.44	0.00	0.08	0.17	-0.01	0.04	-0.47	-8.34
Sheboygan, WI	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.18	0.00	0.01	0.01	0.01	0.01	0.00	-0.13
Springfield (Western MA), MA	x	-	100	-	0.00	-0.07	-0.06	-0.09	-0.09	-0.16	-1.37	0.00	0.06	0.08	0.06	0.07	0.01	-1.05
St. Louis, MO-IL	x	x	100	100	0.00	-0.62	-0.66	-0.83	-0.88	-1.22	-6.13	0.00	-0.82	-0.86	-1.05	-1.09	-1.49	-5.63
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.03	-0.04	-0.04	-0.05	-0.06	-0.24	0.00	-0.06	-0.07	-0.08	-0.08	-0.10	-0.24
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-0.05	-0.05	-0.06	-0.06	-0.11	-0.92	0.00	0.03	0.04	0.03	0.04	-0.01	-0.72
Washington, DC-MD-VA	x	x	100	100	0.00	-0.45	-0.41	-0.58	-0.57	-1.00	-8.81	0.00	0.40	0.52	0.39	0.47	0.07	-6.76
Wheeling, WV-OH	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.21	0.00	0.01	0.01	0.01	0.01	0.00	-0.16
York, PA	-	x	-	100	0.00	-0.04	-0.03	-0.05	-0.05	-0.08	-0.73	0.00	0.03	0.04	0.03	0.04	0.01	-0.56

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-17
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	48.00	66.26	-52.07	-65.35	-205.04	-2,816.53	0.00	48.00	66.26	-52.07	-65.35	-205.05	-2,816.54
Allegan Co., MI	x	-	100	-	0.00	5.25	7.25	-5.70	-7.15	-22.43	-308.09	0.00	5.25	7.25	-5.70	-7.15	-22.43	-308.09
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	4.77	6.59	-5.18	-6.50	-20.39	-280.04	0.00	4.77	6.59	-5.18	-6.50	-20.39	-280.04
Atlanta, GA	x	x	100	100	0.00	255.33	352.44	-276.94	-347.57	-1,090.59	-14,980.69	0.00	255.32	352.43	-276.95	-347.59	-1,090.61	-14,980.71
Baltimore, MD	x	x	100	100	0.00	106.09	146.44	-115.08	-144.43	-453.17	-6,224.87	0.00	106.09	146.44	-115.09	-144.44	-453.18	-6,224.88
Baton Rouge, LA	x	-	100	-	0.00	12.69	20.71	-43.21	-51.68	-128.35	-1,569.39	0.00	12.62	20.64	-43.28	-51.75	-128.42	-1,569.47
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-8.86	-5.79	-49.69	-57.23	-111.49	-1,141.57	0.00	-8.98	-5.93	-49.82	-57.37	-111.64	-1,141.71
Birmingham, AL	-	x	-	100	0.00	38.81	53.57	-42.09	-52.83	-165.78	-2,277.15	0.00	38.81	53.57	-42.10	-52.83	-165.78	-2,277.15
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	172.63	238.28	-187.24	-235.00	-737.36	-10,128.51	0.00	172.62	238.27	-187.25	-235.01	-737.37	-10,128.52
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	23.36	32.25	-25.32	-31.78	-99.74	-1,370.22	0.00	23.36	32.25	-25.32	-31.78	-99.74	-1,370.22
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	41.51	57.29	-45.02	-56.50	-177.30	-2,435.39	0.00	41.51	57.29	-45.02	-56.51	-177.30	-2,435.39
Canton-Massillon, OH	-	x	-	100	0.00	10.26	14.58	-14.98	-18.47	-53.53	-709.96	0.00	10.26	14.58	-14.99	-18.48	-53.54	-709.97
Charleston, WV	-	x	-	100	0.00	11.12	15.34	-12.06	-15.13	-47.48	-652.18	0.00	11.12	15.34	-12.06	-15.13	-47.48	-652.18
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	67.21	92.75	-72.75	-91.32	-286.71	-3,939.21	0.00	67.20	92.75	-72.76	-91.32	-286.71	-3,939.21
Chattanooga, AL-TN-GA	-	x	-	100	0.00	19.89	27.45	-21.56	-27.06	-84.92	-1,166.53	0.00	19.88	27.45	-21.56	-27.06	-84.92	-1,166.53
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	245.14	343.02	-308.73	-383.76	-1,154.97	-15,583.14	0.00	245.03	342.91	-308.84	-383.88	-1,155.09	-15,583.26
Chico, CA	x	-	100	-	0.00	7.18	9.91	-7.79	-9.77	-30.66	-421.18	0.00	7.18	9.91	-7.79	-9.77	-30.66	-421.18
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	68.76	94.91	-74.56	-93.57	-293.64	-4,033.60	0.00	68.75	94.90	-74.56	-93.58	-293.64	-4,033.60
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	6.50	8.97	-7.05	-8.85	-27.77	-381.40	0.00	6.50	8.97	-7.05	-8.85	-27.77	-381.40
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	99.04	136.70	-107.42	-134.82	-423.02	-5,810.71	0.00	99.03	136.70	-107.43	-134.82	-423.03	-5,810.72
Columbus, OH	x	x	100	100	0.00	64.02	88.37	-69.44	-87.15	-273.47	-3,756.41	0.00	64.02	88.37	-69.45	-87.16	-273.47	-3,756.41
Dallas-Fort Worth, TX	x	-	100	-	0.00	259.40	358.06	-281.36	-353.12	-1,108.00	-15,219.68	0.00	259.39	358.04	-281.37	-353.13	-1,108.01	-15,219.70
Dayton-Springfield, OH	-	x	-	100	0.00	30.03	41.46	-32.58	-40.88	-128.29	-1,762.16	0.00	30.03	41.45	-32.58	-40.89	-128.29	-1,762.16
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	118.14	163.60	-133.08	-166.60	-517.06	-7,069.95	0.00	118.12	163.58	-133.10	-166.62	-517.08	-7,069.97
Detroit-Ann Arbor, MI	x	x	100	100	0.00	178.70	247.24	-199.10	-249.42	-776.57	-10,632.45	0.00	178.68	247.22	-199.12	-249.44	-776.59	-10,632.48
Door Co., WI	x	-	100	-	0.00	1.22	1.68	-1.32	-1.66	-5.21	-71.52	0.00	1.22	1.68	-1.32	-1.66	-5.21	-71.52
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.05	0.07	-0.06	-0.07	-0.22	-3.01	0.00	0.05	0.07	-0.06	-0.07	-0.22	-3.01
Evansville, IN	-	x	-	100	0.00	12.88	17.78	-13.95	-17.51	-54.96	-755.06	0.00	12.88	17.77	-13.95	-17.51	-54.96	-755.06
Greater Connecticut, CT	x	-	100	-	0.00	65.67	90.65	-71.23	-89.40	-280.51	-3,853.15	0.00	65.67	90.64	-71.24	-89.41	-280.52	-3,853.15
Greene Co., PA	x	-	100	-	0.00	1.51	2.08	-1.64	-2.05	-6.44	-88.48	0.00	1.51	2.08	-1.64	-2.05	-6.44	-88.48
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	29.70	41.00	-32.22	-40.43	-126.87	-1,742.66	0.00	29.70	41.00	-32.22	-40.43	-126.87	-1,742.66
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	26.91	37.14	-29.18	-36.63	-114.93	-1,578.64	0.00	26.90	37.14	-29.19	-36.63	-114.93	-1,578.64

Table B2-17
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.19	0.26	-0.20	-0.25	-0.79	-10.86	0.00	0.19	0.26	-0.20	-0.25	-0.79	-10.86
Hickory, NC	-	x	-	100	0.00	6.98	9.63	-7.57	-9.50	-29.80	-409.32	0.00	6.98	9.63	-7.57	-9.50	-29.80	-409.32
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	141.74	208.80	-275.10	-334.76	-911.05	-11,716.28	0.00	141.46	208.53	-275.39	-335.06	-911.36	-11,716.58
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	11.56	17.22	-24.15	-29.31	-78.63	-1,003.73	0.00	11.54	17.19	-24.18	-29.34	-78.66	-1,003.76
Imperial Co., CA	x	-	100	-	0.00	8.28	11.43	-8.98	-11.27	-35.37	-485.89	0.00	8.28	11.43	-8.98	-11.27	-35.37	-485.89
Indianapolis, IN	-	x	-	100	0.00	59.77	82.50	-64.83	-81.36	-255.29	-3,506.70	0.00	59.76	82.50	-64.83	-81.36	-255.29	-3,506.71
Jamestown, NY	x	-	100	-	0.00	5.53	7.63	-5.99	-7.52	-23.61	-324.25	0.00	5.53	7.63	-5.99	-7.52	-23.61	-324.25
Jefferson Co., NY	x	-	100	-	0.00	5.13	7.08	-5.57	-6.99	-21.92	-301.08	0.00	5.13	7.08	-5.57	-6.99	-21.92	-301.08
Johnstown, PA	-	x	-	100	0.00	4.53	6.26	-4.92	-6.17	-19.36	-265.93	0.00	4.53	6.26	-4.92	-6.17	-19.36	-265.93
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	4.34	5.99	-4.72	-5.92	-18.57	-254.97	0.00	4.34	5.99	-4.72	-5.92	-18.57	-254.97
Knoxville, TN	x	x	100	100	0.00	40.61	56.06	-44.05	-55.28	-173.46	-2,382.71	0.00	40.61	56.05	-44.05	-55.28	-173.46	-2,382.71
Lancaster, PA	-	x	-	100	0.00	15.87	21.91	-17.22	-21.61	-67.79	-931.24	0.00	15.87	21.91	-17.22	-21.61	-67.80	-931.24
Las Vegas, NV	x	-	100	-	0.00	52.58	72.58	-57.03	-71.57	-224.58	-3,084.91	0.00	52.58	72.58	-57.03	-71.58	-224.58	-3,084.91
Libby, MT	-	x	-	100	0.00	0.26	0.36	-0.28	-0.35	-1.11	-15.29	0.00	0.26	0.36	-0.28	-0.35	-1.11	-15.29
Liberty-Clairton, PA	-	x	-	100	0.00	0.51	0.71	-0.55	-0.70	-2.18	-30.00	0.00	0.51	0.71	-0.55	-0.70	-2.18	-30.00
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	523.17	729.23	-632.77	-788.51	-2,399.14	-32,525.58	0.00	522.99	729.05	-632.96	-788.70	-2,399.34	-32,525.77
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	27.11	37.42	-29.40	-36.90	-115.79	-1,590.49	0.00	27.10	37.41	-29.41	-36.91	-115.79	-1,590.49
Louisville, KY-IN	-	x	-	100	0.00	41.71	57.58	-45.22	-56.76	-178.11	-2,446.77	0.00	41.71	57.57	-45.22	-56.76	-178.12	-2,446.77
Macon, GA	-	x	-	100	0.00	7.77	10.73	-8.43	-10.58	-33.19	-455.98	0.00	7.77	10.73	-8.43	-10.58	-33.19	-455.98
Manitowoc Co., WI	x	-		-	0.00	3.98	5.49	-4.32	-5.42	-17.00	-233.57	0.00	3.98	5.49	-4.32	-5.42	-17.00	-233.57
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	3.89	5.37	-4.22	-5.29	-16.61	-228.12	0.00	3.89	5.37	-4.22	-5.29	-16.61	-228.12
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	15.22	21.00	-16.51	-20.71	-65.00	-892.82	0.00	15.22	21.00	-16.51	-20.72	-65.00	-892.82
Memphis, TN-AR	x	-	100	-	0.00	33.05	46.65	-45.33	-56.07	-165.04	-2,204.65	0.00	33.03	46.62	-45.35	-56.09	-165.06	-2,204.68
Milwaukee-Racine, WI	x	-	100	-	0.00	65.40	90.27	-70.94	-89.03	-279.35	-3,837.14	0.00	65.39	90.27	-70.94	-89.03	-279.35	-3,837.14
Nevada (Western Part), CA	x	-	100	-	0.00	3.70	5.10	-4.01	-5.03	-15.80	-216.99	0.00	3.70	5.10	-4.01	-5.03	-15.80	-216.99
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	531.64	735.66	-593.40	-743.29	-2,313.03	-31,662.10	0.00	531.57	735.59	-593.47	-743.37	-2,313.11	-31,662.18
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	5.89	8.13	-6.39	-8.02	-25.16	-345.66	0.00	5.89	8.13	-6.39	-8.02	-25.16	-345.66
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	231.69	326.58	-313.75	-388.37	-1,146.90	-15,343.34	0.00	231.54	326.43	-313.91	-388.53	-1,147.07	-15,343.51
Phoenix-Mesa, AZ	x	-	100	-	0.00	146.16	201.75	-158.47	-198.89	-624.15	-8,573.90	0.00	146.16	201.74	-158.48	-198.90	-624.16	-8,573.91
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	73.12	100.92	-79.30	-99.53	-312.29	-4,289.76	0.00	73.11	100.92	-79.31	-99.53	-312.30	-4,289.77
Poughkeepsie, NY	x	x	100	100	0.00	47.39	65.42	-51.40	-64.51	-202.42	-2,780.52	0.00	47.39	65.41	-51.40	-64.52	-202.43	-2,780.52

Table B2-17
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	34.28	47.32	-37.18	-46.67	-146.43	-2,011.46	0.00	34.28	47.32	-37.19	-46.67	-146.44	-2,011.46
Reading, PA	-	x	-	100	0.00	13.93	19.22	-15.10	-18.96	-59.48	-817.03	0.00	13.92	19.22	-15.10	-18.96	-59.48	-817.03
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	27.64	38.15	-29.98	-37.63	-118.07	-1,621.85	0.00	27.64	38.15	-29.99	-37.63	-118.07	-1,621.85
Rochester, NY	x	-	100	-	0.00	48.02	66.29	-52.09	-65.37	-205.12	-2,817.60	0.00	48.02	66.28	-52.09	-65.38	-205.13	-2,817.61
Rome, GA	-	x	-	100	0.00	4.20	5.80	-4.55	-5.72	-17.93	-246.34	0.00	4.20	5.80	-4.55	-5.72	-17.93	-246.34
Sacramento Metro, CA	x	-	50	-	0.00	80.67	111.36	-87.50	-109.82	-344.58	-4,733.26	0.00	80.67	111.35	-87.51	-109.82	-344.59	-4,733.27
San Diego, CA	x	-	100	-	0.00	112.93	155.88	-122.49	-153.73	-482.37	-6,625.91	0.00	112.92	155.88	-122.50	-153.74	-482.38	-6,625.92
San Francisco Bay Area, CA	x	-	100	-	0.00	233.65	326.27	-288.04	-358.51	-1,085.18	-14,678.59	0.00	233.56	326.18	-288.14	-358.61	-1,085.28	-14,678.69
San Joaquin Valley, CA	x	x	50	100	0.00	162.20	224.52	-181.76	-227.61	-707.50	-9,679.96	0.00	162.17	224.50	-181.79	-227.64	-707.52	-9,679.99
Sheboygan, WI	x	-	100	-	0.00	4.46	6.15	-4.83	-6.07	-19.03	-261.43	0.00	4.46	6.15	-4.83	-6.07	-19.03	-261.43
Springfield (Western MA), MA	x	-	100	-	0.00	34.47	47.58	-37.39	-46.92	-147.23	-2,022.42	0.00	34.47	47.58	-37.39	-46.93	-147.24	-2,022.42
St. Louis, MO-IL	x	x	100	100	0.00	107.47	150.10	-132.71	-165.16	-499.71	-6,757.98	0.00	107.43	150.06	-132.76	-165.21	-499.76	-6,758.02
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	3.57	5.05	-4.93	-6.10	-17.92	-239.24	0.00	3.57	5.05	-4.93	-6.10	-17.92	-239.25
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Ventura Co., CA	x	-	100	-	0.00	23.62	32.63	-25.77	-32.33	-101.28	-1,390.21	0.00	23.62	32.62	-25.77	-32.33	-101.28	-1,390.21
Washington, DC-MD-VA	x	x	100	100	0.00	181.47	250.49	-196.85	-247.06	-775.18	-10,647.94	0.00	181.46	250.48	-196.86	-247.07	-775.20	-10,647.95
Wheeling, WV-OH	-	x	-	100	0.00	6.32	8.73	-6.86	-8.61	-27.01	-370.96	0.00	6.32	8.73	-6.86	-8.61	-27.01	-370.96
York, PA	-	x	-	100	0.00	14.72	20.31	-15.96	-20.03	-62.86	-863.41	0.00	14.71	20.31	-15.96	-20.03	-62.86	-863.41

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-18
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	114.89	188.42	-301.49	-360.77	-715.95	-11,215.20	0.00	219.17	300.56	-219.36	-278.26	-638.57	-11,024.61
Allegan Co., MI	x	-	100	-	0.00	12.56	20.60	-32.97	-39.45	-78.29	-1,226.41	0.00	23.97	32.87	-23.99	-30.43	-69.83	-1,205.57
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	12.16	19.95	-31.92	-38.19	-75.79	-1,187.29	0.00	23.20	31.82	-23.22	-29.46	-67.60	-1,167.12
Atlanta, GA	x	x	100	100	0.00	666.01	1,092.24	-1,747.70	-2,091.35	-4,150.29	-65,013.07	0.00	1,270.49	1,742.33	-1,271.60	-1,613.04	-3,701.67	-63,908.28
Baltimore, MD	x	x	100	100	0.00	252.61	414.28	-662.92	-793.27	-1,574.23	-24,659.69	0.00	481.88	660.85	-482.34	-611.86	-1,404.08	-24,240.66
Baton Rouge, LA	x	-	100	-	0.00	23.78	58.21	-203.27	-239.87	-434.06	-6,122.28	0.00	30.03	67.32	-212.14	-250.39	-448.57	-6,076.07
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-36.56	-21.28	-187.68	-217.80	-347.74	-4,083.86	0.00	-100.63	-85.37	-265.91	-299.63	-433.82	-4,130.90
Birmingham, AL	-	x	-	100	0.00	90.24	147.98	-236.78	-283.34	-562.28	-8,808.07	0.00	172.14	236.06	-172.27	-218.53	-501.50	-8,658.39
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	395.96	649.37	-1,039.08	-1,243.40	-2,467.51	-38,652.68	0.00	755.33	1,035.86	-756.03	-959.04	-2,200.81	-37,995.86
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	55.41	90.86	-145.31	-173.88	-345.10	-5,406.31	0.00	105.71	144.95	-105.68	-134.07	-307.76	-5,314.41
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	94.63	155.20	-248.34	-297.18	-589.74	-9,238.12	0.00	180.53	247.57	-180.69	-229.21	-526.00	-9,081.14
Canton-Massillon, OH	-	x	-	100	0.00	22.40	39.24	-77.18	-91.91	-176.92	-2,682.98	0.00	40.73	59.27	-64.54	-79.43	-165.82	-2,644.94
Charleston, WV	-	x	-	100	0.00	24.84	40.73	-65.18	-77.99	-154.78	-2,424.59	0.00	47.38	64.98	-47.42	-60.16	-138.05	-2,383.39
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	172.51	282.83	-452.08	-540.98	-1,073.77	-16,823.19	0.00	329.15	451.28	-328.64	-416.97	-957.43	-16,537.06
Chattanooga, AL-TN-GA	-	x	-	100	0.00	45.91	75.30	-120.48	-144.17	-286.11	-4,481.83	0.00	87.59	120.12	-87.66	-111.20	-255.18	-4,405.66
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	571.70	965.50	-1,704.96	-2,035.30	-3,978.07	-61,331.25	0.00	1,068.30	1,503.04	-1,333.87	-1,664.83	-3,637.34	-60,373.07
Chico, CA	x	-	100	-	0.00	17.04	27.95	-44.72	-53.51	-106.19	-1,663.47	0.00	32.51	44.58	-32.54	-41.27	-94.71	-1,635.20
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	161.07	264.14	-422.59	-505.68	-1,003.56	-15,720.82	0.00	307.27	421.37	-307.43	-389.99	-895.04	-15,453.64
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	14.52	23.81	-38.10	-45.59	-90.47	-1,417.23	0.00	27.70	37.98	-27.72	-35.16	-80.69	-1,393.15
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	224.89	368.82	-590.17	-706.21	-1,401.47	-21,953.61	0.00	429.01	588.34	-429.40	-544.70	-1,249.99	-21,580.55
Columbus, OH	x	x	100	100	0.00	155.47	254.98	-407.99	-488.21	-968.86	-15,176.88	0.00	296.59	406.73	-296.85	-376.56	-864.13	-14,918.97
Dallas-Fort Worth, TX	x	-	100	-	0.00	660.12	1,082.59	-1,732.28	-2,072.90	-4,113.66	-64,439.23	0.00	1,259.27	1,726.94	-1,260.38	-1,598.82	-3,669.02	-63,344.21
Dayton-Springfield, OH	-	x	-	100	0.00	68.40	112.18	-179.50	-214.80	-426.26	-6,677.26	0.00	130.49	178.95	-130.60	-165.67	-380.19	-6,563.79
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	290.02	478.86	-784.74	-938.48	-1,855.35	-28,949.69	0.00	550.67	759.57	-581.77	-734.83	-1,665.13	-28,467.47
Detroit-Ann Arbor, MI	x	x	100	100	0.00	410.89	677.29	-1,103.45	-1,319.82	-2,611.67	-40,789.80	0.00	781.07	1,075.83	-814.35	-1,029.67	-2,340.36	-40,107.00
Door Co., WI	x	-	100	-	0.00	2.77	4.55	-7.28	-8.71	-17.29	-270.79	0.00	5.29	7.26	-5.30	-6.72	-15.42	-266.19
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.12	0.19	-0.31	-0.37	-0.74	-11.57	0.00	0.23	0.31	-0.23	-0.29	-0.66	-11.38
Evansville, IN	-	x	-	100	0.00	30.11	49.37	-78.93	-94.45	-187.46	-2,936.90	0.00	57.45	78.77	-57.38	-72.80	-167.15	-2,886.96
Greater Connecticut, CT	x	-	100	-	0.00	154.48	253.34	-405.41	-485.12	-962.71	-15,080.40	0.00	294.68	404.12	-294.98	-374.19	-858.67	-14,824.15
Greene Co., PA	x	-	100	-	0.00	3.31	5.43	-8.69	-10.39	-20.63	-323.10	0.00	6.31	8.66	-6.32	-8.02	-18.40	-317.61
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	70.04	114.87	-183.80	-219.94	-436.47	-6,837.17	0.00	133.61	183.23	-133.73	-169.64	-389.29	-6,720.99
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	62.52	102.53	-164.06	-196.32	-389.59	-6,102.80	0.00	119.26	163.55	-119.37	-151.42	-347.48	-5,999.10

Table B2-18
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.43	0.71	-1.14	-1.36	-2.71	-42.39	0.00	0.83	1.14	-0.83	-1.05	-2.41	-41.67
Hickory, NC	-	x	-	100	0.00	16.75	27.47	-43.96	-52.61	-104.40	-1,635.31	0.00	31.96	43.82	-31.99	-40.58	-93.11	-1,607.52
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	311.31	589.71	-1,397.50	-1,658.39	-3,118.13	-46,053.85	0.00	530.64	835.44	-1,281.59	-1,548.57	-3,034.25	-45,509.57
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	23.11	45.48	-116.20	-137.72	-256.75	-3,754.89	0.00	38.04	62.47	-109.88	-132.00	-253.22	-3,713.89
Imperial Co., CA	x	-	100	-	0.00	21.57	35.38	-56.61	-67.74	-134.42	-2,105.69	0.00	41.15	56.43	-41.19	-52.24	-119.89	-2,069.90
Indianapolis, IN	-	x	-	100	0.00	144.79	237.46	-379.96	-454.67	-902.29	-14,134.04	0.00	276.21	378.79	-276.45	-350.68	-804.76	-13,893.86
Jamestown, NY	x	-	100	-	0.00	12.57	20.62	-32.99	-39.48	-78.35	-1,227.35	0.00	23.98	32.89	-24.01	-30.45	-69.88	-1,206.49
Jefferson Co., NY	x	-	100	-	0.00	12.52	20.54	-32.87	-39.33	-78.05	-1,222.67	0.00	23.89	32.77	-23.92	-30.34	-69.62	-1,201.89
Johnstown, PA	-	x	-	100	0.00	10.05	16.49	-26.38	-31.57	-62.66	-981.47	0.00	19.18	26.30	-19.20	-24.35	-55.88	-964.79
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	11.24	18.45	-29.57	-35.39	-70.20	-1,099.37	0.00	21.44	29.42	-21.55	-27.32	-62.64	-1,080.71
Knoxville, TN	x	x	100	100	0.00	96.90	158.91	-254.27	-304.27	-603.82	-9,458.70	0.00	184.85	253.49	-185.00	-234.68	-538.55	-9,297.97
Lancaster, PA	-	x	-	100	0.00	37.01	60.70	-97.12	-116.22	-230.64	-3,612.94	0.00	70.60	96.82	-70.67	-89.64	-205.71	-3,551.55
Las Vegas, NV	x	-	100	-	0.00	141.83	232.60	-372.15	-445.33	-883.77	-13,844.12	0.00	270.56	371.04	-270.76	-343.47	-788.23	-13,608.85
Libby, MT	-	x	-	100	0.00	0.61	1.00	-1.60	-1.92	-3.81	-59.61	0.00	1.16	1.60	-1.17	-1.48	-3.39	-58.59
Liberty-Clairton, PA	-	x	-	100	0.00	1.08	1.78	-2.85	-3.41	-6.77	-105.97	0.00	2.07	2.84	-2.07	-2.63	-6.04	-104.17
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	1,266.12	2,119.03	-3,634.99	-4,342.26	-8,524.13	- 132,025.74	0.00	2,381.26	3,323.60	-2,787.28	-3,494.19	-7,739.00	- 129,910.47
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	67.97	111.47	-178.39	-213.47	-423.62	-6,635.63	0.00	129.65	177.81	-129.81	-164.67	-377.84	-6,522.89
Louisville, KY-IN	-	x	-	100	0.00	95.26	156.22	-249.89	-299.02	-593.44	-9,296.59	0.00	181.74	249.21	-181.77	-230.59	-529.26	-9,138.57
Macon, GA	-	x	-	100	0.00	17.82	29.22	-46.74	-55.93	-111.01	-1,739.02	0.00	34.00	46.62	-34.00	-43.13	-99.00	-1,709.46
Manitowoc Co., WI	x	-		-	0.00	9.06	14.86	-23.77	-28.45	-56.45	-884.31	0.00	17.28	23.70	-17.30	-21.94	-50.35	-869.28
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	10.06	16.49	-26.39	-31.58	-62.67	-981.73	0.00	19.18	26.31	-19.20	-24.36	-55.90	-965.05
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	40.10	65.76	-105.23	-125.92	-249.90	-3,914.53	0.00	76.50	104.91	-76.57	-97.12	-222.88	-3,848.01
Memphis, TN-AR	x	-	100	-	0.00	73.24	126.30	-237.56	-283.18	-548.46	-8,373.45	0.00	134.78	193.25	-193.53	-239.47	-508.96	-8,249.78
Milwaukee-Racine, WI	x	-	100	-	0.00	150.68	247.11	-395.41	-473.16	-938.99	-14,708.89	0.00	287.43	394.18	-287.70	-364.95	-837.50	-14,458.94
Nevada (Western Part), CA	x	-	100	-	0.00	9.01	14.78	-23.65	-28.30	-56.17	-879.86	0.00	17.19	23.58	-17.21	-21.83	-50.10	-864.91
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	1,223.33	2,017.19	-3,290.44	-3,935.52	-7,786.14	- 121,581.88	0.00	2,324.92	3,203.24	-2,430.66	-3,072.68	-6,979.50	- 119,548.74
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	13.21	21.67	-34.66	-41.48	-82.32	-1,289.50	0.00	25.20	34.56	-25.22	-31.99	-73.42	-1,267.58
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	535.60	919.11	-1,704.25	-2,032.21	-3,943.92	-60,344.20	0.00	989.19	1,411.99	-1,376.24	-1,706.09	-3,647.88	-59,441.40
Phoenix-Mesa, AZ	x	-	100	-	0.00	386.13	633.21	-1,012.94	-1,212.12	-2,405.55	-37,683.90	0.00	736.64	1,010.15	-736.84	-934.74	-2,145.38	-37,043.39
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	162.76	266.92	-427.09	-511.07	-1,014.22	-15,887.42	0.00	310.48	425.78	-310.74	-394.18	-904.58	-15,617.44
Poughkeepsie, NY	x	x	100	100	0.00	114.06	187.05	-299.31	-358.16	-710.77	-11,133.98	0.00	217.58	298.38	-217.77	-276.25	-633.94	-10,944.78

Table B2-18
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	78.77	129.19	-206.72	-247.37	-490.90	-7,689.76	0.00	150.27	206.08	-150.41	-190.79	-437.84	-7,559.09
Reading, PA	-	x	-	100	0.00	33.56	55.05	-88.08	-105.40	-209.16	-3,276.45	0.00	64.03	87.81	-64.09	-81.29	-186.55	-3,220.78
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	79.62	130.58	-208.97	-250.06	-496.23	-7,773.11	0.00	151.88	208.30	-152.05	-192.88	-442.60	-7,641.03
Rochester, NY	x	-	100	-	0.00	111.19	182.35	-291.79	-349.16	-692.91	-10,854.25	0.00	212.11	290.89	-212.30	-269.31	-618.02	-10,669.80
Rome, GA	-	x	-	100	0.00	9.63	15.79	-25.26	-30.23	-59.98	-939.59	0.00	18.36	25.18	-18.38	-23.31	-53.50	-923.63
Sacramento Metro, CA	x	-	50	-	0.00	200.68	329.11	-526.62	-630.17	-1,250.56	-19,589.66	0.00	382.82	524.99	-383.16	-486.04	-1,115.39	-19,256.77
San Diego, CA	x	-	100	-	0.00	258.55	424.01	-678.47	-811.88	-1,611.17	-25,238.53	0.00	493.21	676.38	-493.65	-626.20	-1,437.02	-24,809.65
San Francisco Bay Area, CA	x	-	100	-	0.00	532.32	895.59	-1,562.58	-1,865.86	-3,653.45	-56,433.80	0.00	997.43	1,398.60	-1,212.47	-1,516.02	-3,330.78	-55,542.82
San Joaquin Valley, CA	x	x	50	100	0.00	417.51	688.51	-1,123.49	-1,343.73	-2,658.33	-41,507.88	0.00	793.41	1,093.24	-830.15	-1,049.35	-2,383.14	-40,813.97
Sheboygan, WI	x	-	100	-	0.00	10.38	17.03	-27.25	-32.61	-64.71	-1,013.65	0.00	19.81	27.16	-19.83	-25.15	-57.72	-996.42
Springfield (Western MA), MA	x	-	100	-	0.00	80.53	132.07	-211.33	-252.89	-501.85	-7,861.36	0.00	153.63	210.68	-153.76	-195.05	-447.61	-7,727.77
St. Louis, MO-IL	x	x	100	100	0.00	244.33	411.23	-718.38	-857.79	-1,679.28	-25,934.17	0.00	457.68	641.98	-557.90	-697.45	-1,531.43	-25,525.16
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	7.54	13.06	-24.83	-29.60	-57.23	-872.34	0.00	13.84	19.92	-20.37	-25.17	-53.25	-859.58
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	-0.05
Ventura Co., CA	x	-	100	-	0.00	54.59	89.63	-143.96	-172.26	-341.63	-5,348.14	0.00	104.06	142.84	-105.07	-133.19	-305.01	-5,257.55
Washington, DC-MD-VA	x	x	100	100	0.00	437.59	717.65	-1,148.42	-1,374.23	-2,727.12	-42,718.94	0.00	834.74	1,144.77	-835.62	-1,059.99	-2,432.39	-41,993.05
Wheeling, WV-OH	-	x	-	100	0.00	14.13	23.18	-37.08	-44.38	-88.06	-1,379.49	0.00	26.96	36.97	-26.98	-34.23	-78.54	-1,356.05
York, PA	-	x	-	100	0.00	36.32	59.57	-95.32	-114.06	-226.35	-3,545.62	0.00	69.29	95.02	-69.35	-87.97	-201.88	-3,485.37

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-19
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	181.01	316.27	-608.06	-721.33	-1,289.99	-20,998.63	0.00	589.49	755.24	-284.18	-396.04	-989.32	-20,256.06
Allegan Co., MI	x	-	100	-	0.00	19.77	34.55	-66.43	-78.80	-140.92	-2,293.99	0.00	64.40	82.51	-31.05	-43.27	-108.08	-2,212.87
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	20.40	35.65	-68.53	-81.30	-145.39	-2,366.73	0.00	66.44	85.12	-32.03	-44.64	-111.51	-2,283.03
Atlanta, GA	x	x	100	100	0.00	1,155.97	2,019.74	-3,883.11	-4,606.51	-8,238.03	-134,099.91	0.00	3,764.57	4,823.13	-1,814.78	-2,529.15	-6,317.87	-129,357.75
Baltimore, MD	x	x	100	100	0.00	396.07	692.03	-1,330.53	-1,578.39	-2,822.70	-45,948.05	0.00	1,289.84	1,652.54	-621.87	-866.64	-2,164.81	-44,323.23
Baton Rouge, LA	x	-	100	-	0.00	39.17	104.66	-392.43	-461.44	-774.57	-11,503.42	0.00	125.01	203.36	-360.85	-434.01	-763.59	-11,252.13
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-58.42	-29.14	-328.94	-381.97	-581.14	-7,234.75	0.00	-195.41	-163.38	-511.00	-573.47	-787.08	-7,292.01
Birmingham, AL	-	x	-	100	0.00	138.83	242.57	-466.34	-553.22	-989.36	-16,104.98	0.00	452.13	579.26	-217.93	-303.72	-758.74	-15,535.45
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	599.49	1,047.45	-2,013.84	-2,389.01	-4,272.36	-69,545.87	0.00	1,952.31	2,501.29	-941.21	-1,311.69	-3,276.57	-67,086.56
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	86.44	151.00	-290.20	-344.27	-615.70	-10,023.19	0.00	281.50	360.63	-135.52	-188.91	-472.09	-9,668.65
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	141.94	248.01	-476.83	-565.66	-1,011.59	-16,466.79	0.00	462.26	592.24	-222.86	-310.58	-775.81	-15,884.49
Canton-Massillon, OH	-	x	-	100	0.00	33.45	63.18	-146.43	-173.18	-303.09	-4,789.42	0.00	108.60	144.79	-91.61	-118.68	-254.59	-4,640.36
Charleston, WV	-	x	-	100	0.00	36.55	63.87	-122.79	-145.67	-260.50	-4,240.50	0.00	119.04	152.52	-57.39	-79.98	-199.78	-4,090.55
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	292.27	510.53	-980.79	-1,163.52	-2,080.98	-33,878.72	0.00	951.84	1,219.32	-457.69	-638.12	-1,595.28	-32,680.07
Chattanooga, AL-TN-GA	-	x	-	100	0.00	69.89	122.12	-234.82	-278.56	-498.16	-8,108.91	0.00	227.61	291.62	-109.77	-152.97	-382.07	-7,822.18
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	902.42	1,629.29	-3,409.89	-4,039.19	-7,149.98	-114,784.83	0.00	2,935.14	3,823.15	-1,851.10	-2,479.82	-5,729.47	-110,951.35
Chico, CA	x	-	100	-	0.00	26.61	46.50	-89.40	-106.05	-189.65	-3,087.19	0.00	86.67	111.04	-41.78	-58.23	-145.45	-2,978.02
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	251.73	439.80	-845.44	-1,002.94	-1,793.64	-29,197.80	0.00	819.78	1,050.27	-395.01	-550.55	-1,375.47	-28,165.19
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	21.33	37.27	-71.66	-85.00	-152.02	-2,474.56	0.00	69.47	89.00	-33.49	-46.67	-116.59	-2,387.05
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	336.29	587.58	-1,129.69	-1,340.15	-2,396.64	-39,012.85	0.00	1,095.18	1,403.14	-527.98	-735.81	-1,838.04	-37,633.25
Columbus, OH	x	x	100	100	0.00	249.74	436.35	-838.92	-995.21	-1,779.78	-28,971.46	0.00	813.31	1,042.00	-392.08	-546.41	-1,364.94	-27,946.95
Dallas-Fort Worth, TX	x	-	100	-	0.00	1,113.98	1,946.37	-3,742.08	-4,439.21	-7,938.83	-129,229.43	0.00	3,627.81	4,647.92	-1,748.90	-2,437.32	-6,088.43	-124,659.52
Dayton-Springfield, OH	-	x	-	100	0.00	102.50	179.08	-344.31	-408.45	-730.45	-11,890.33	0.00	333.79	427.65	-160.92	-224.26	-560.19	-11,469.86
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	473.48	833.37	-1,634.36	-1,938.14	-3,457.56	-56,096.85	0.00	1,541.53	1,982.25	-793.65	-1,094.49	-2,680.16	-54,139.24
Detroit-Ann Arbor, MI	x	x	100	100	0.00	624.43	1,097.50	-2,144.26	-2,542.99	-4,538.68	-73,683.58	0.00	2,033.08	2,612.49	-1,033.89	-1,428.54	-3,511.14	-71,105.75
Door Co., WI	x	-	100	-	0.00	4.15	7.26	-13.95	-16.55	-29.60	-481.80	0.00	13.53	17.33	-6.52	-9.09	-22.70	-464.76
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.18	0.32	-0.61	-0.72	-1.29	-20.94	0.00	0.59	0.75	-0.28	-0.39	-0.99	-20.20
Evansville, IN	-	x	-	100	0.00	46.35	80.96	-155.53	-184.51	-329.99	-5,372.30	0.00	150.93	193.35	-72.58	-101.19	-252.97	-5,182.22
Greater Connecticut, CT	x	-	100	-	0.00	239.10	417.76	-803.23	-952.87	-1,704.04	-27,738.40	0.00	778.65	997.60	-375.44	-523.21	-1,306.90	-26,757.53
Greene Co., PA	x	-	100	-	0.00	4.78	8.35	-16.05	-19.04	-34.06	-554.41	0.00	15.56	19.94	-7.50	-10.46	-26.12	-534.80

Table B2-19
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	108.67	189.87	-365.04	-433.04	-774.43	-12,606.22	0.00	353.89	453.40	-170.60	-237.76	-593.92	-12,160.43
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	95.60	167.03	-321.13	-380.95	-681.27	-11,089.77	0.00	311.32	398.86	-150.08	-209.16	-522.48	-10,697.60
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.67	1.17	-2.26	-2.68	-4.79	-77.94	0.00	2.19	2.80	-1.05	-1.47	-3.67	-75.18
Hickory, NC	-	x	-	100	0.00	26.46	46.24	-88.90	-105.46	-188.60	-3,069.98	0.00	86.18	110.41	-41.55	-57.90	-144.64	-2,961.42
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	501.10	1,024.80	-2,758.31	-3,255.29	-5,612.86	-86,812.21	0.00	1,621.32	2,255.27	-2,020.44	-2,531.88	-5,003.43	-84,383.19
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	33.94	73.59	-216.91	-255.70	-437.30	-6,682.50	0.00	109.52	157.35	-171.37	-211.66	-402.26	-6,507.53
Imperial Co., CA	x	-	100	-	0.00	36.96	64.58	-124.17	-147.30	-263.42	-4,287.93	0.00	120.37	154.22	-58.03	-80.87	-202.02	-4,136.29
Indianapolis, IN	-	x	-	100	0.00	232.39	406.05	-780.66	-926.09	-1,656.17	-26,959.39	0.00	756.82	969.63	-364.85	-508.47	-1,270.15	-26,006.03
Jamestown, NY	x	-	100	-	0.00	18.82	32.88	-63.21	-74.99	-134.11	-2,183.03	0.00	61.28	78.52	-29.54	-41.17	-102.85	-2,105.83
Jefferson Co., NY	x	-	100	-	0.00	20.11	35.14	-67.56	-80.15	-143.33	-2,333.08	0.00	65.49	83.91	-31.58	-44.00	-109.92	-2,250.58
Johnstown, PA	-	x	-	100	0.00	14.67	25.63	-49.29	-58.47	-104.57	-1,702.12	0.00	47.78	61.22	-23.04	-32.11	-80.20	-1,641.93
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	19.16	33.50	-64.54	-76.56	-136.88	-2,227.38	0.00	62.38	79.96	-30.29	-42.17	-105.10	-2,148.73
Knoxville, TN	x	x	100	100	0.00	152.25	266.01	-511.41	-606.69	-1,084.97	-17,661.27	0.00	495.81	635.22	-239.01	-333.09	-832.07	-17,036.71
Lancaster, PA	-	x	-	100	0.00	56.78	99.20	-190.73	-226.26	-404.63	-6,586.56	0.00	184.90	236.89	-89.14	-124.23	-310.32	-6,353.64
Las Vegas, NV	x	-	100	-	0.00	251.67	439.72	-845.33	-1,002.81	-1,793.39	-29,193.45	0.00	819.61	1,050.06	-395.01	-550.52	-1,375.32	-28,161.03
Libby, MT	-	x	-	100	0.00	0.94	1.64	-3.16	-3.75	-6.71	-109.19	0.00	3.07	3.93	-1.48	-2.06	-5.14	-105.33
Liberty-Clairton, PA	-	x	-	100	0.00	1.51	2.65	-5.09	-6.04	-10.81	-175.86	0.00	4.93	6.32	-2.38	-3.32	-8.29	-169.65
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	2,060.05	3,679.70	-7,498.61	-8,886.47	-15,779.77	- 254,414.24	0.00	6,703.13	8,683.80	-3,898.08	-5,279.74	-12,477.83	- 245,762.33
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	112.36	196.34	-377.57	-447.90	-800.98	-13,038.02	0.00	365.92	468.83	-176.54	-246.00	-614.37	-12,577.03
Louisville, KY-IN	-	x	-	100	0.00	143.21	250.20	-480.90	-570.49	-1,020.27	-16,608.81	0.00	466.39	597.50	-224.63	-313.10	-782.35	-16,021.37
Macon, GA	-	x	-	100	0.00	26.88	46.95	-90.24	-107.05	-191.45	-3,116.63	0.00	87.52	112.13	-42.14	-58.75	-146.80	-3,006.39
Manitowoc Co., WI	x	-		-	0.00	13.56	23.69	-45.56	-54.04	-96.65	-1,573.24	0.00	44.16	56.58	-21.30	-29.68	-74.13	-1,517.61
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	17.13	29.93	-57.55	-68.27	-122.09	-1,987.33	0.00	55.79	71.48	-26.90	-37.48	-93.63	-1,917.05
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	69.69	121.76	-234.10	-277.71	-496.64	-8,084.42	0.00	226.95	290.77	-109.41	-152.48	-380.88	-7,798.53
Memphis, TN-AR	x	-	100	-	0.00	110.05	203.95	-453.69	-536.89	-943.83	-15,007.97	0.00	357.58	472.04	-269.17	-352.95	-778.44	-14,527.32
Milwaukee-Racine, WI	x	-	100	-	0.00	228.65	399.50	-768.09	-911.18	-1,629.49	-26,525.05	0.00	744.62	954.00	-358.98	-500.29	-1,249.70	-25,587.06
Nevada (Western Part), CA	x	-	100	-	0.00	14.45	25.25	-48.55	-57.59	-102.99	-1,676.46	0.00	47.06	60.29	-22.69	-31.62	-78.99	-1,617.17
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	1,858.79	3,268.35	-6,392.56	-7,581.12	-13,528.82	- 219,594.84	0.00	6,051.93	7,778.28	-3,088.64	-4,265.22	-10,472.03	- 211,917.89
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	19.49	34.05	-65.45	-77.65	-138.86	-2,260.49	0.00	63.46	81.31	-30.58	-42.63	-106.49	-2,180.55
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	839.87	1,544.25	-3,374.46	-3,994.41	-7,035.98	- 112,188.96	0.00	2,729.70	3,588.88	-1,953.40	-2,576.25	-5,755.61	- 108,551.44

Table B2-19
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Emission Changes a/ by Nonattainment Area

CO 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Phoenix-Mesa, AZ	x	-	100	-	0.00	671.04	1,172.36	-2,253.45	-2,673.27	-4,780.86	-77,826.48	0.00	2,185.33	2,799.71	-1,052.69	-1,467.25	-3,666.07	-75,073.90
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	238.58	416.84	-801.40	-950.70	-1,700.18	-27,675.79	0.00	776.95	995.42	-374.52	-521.96	-1,303.88	-26,697.08
Poughkeepsie, NY	x	x	100	100	0.00	180.63	315.60	-606.77	-719.80	-1,287.26	-20,954.12	0.00	588.24	753.64	-283.58	-395.21	-987.22	-20,213.12
Providence (All RI), RI	x	-	100	-	0.00	119.10	208.10	-400.09	-474.62	-848.79	-13,816.72	0.00	387.87	496.94	-186.99	-260.59	-650.96	-13,328.12
Reading, PA	-	x	-	100	0.00	53.22	92.99	-178.78	-212.09	-379.28	-6,173.99	0.00	173.32	222.06	-83.55	-116.44	-290.88	-5,955.66
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	150.88	263.64	-506.93	-601.36	-1,075.43	-17,505.62	0.00	491.37	629.55	-236.97	-330.23	-824.82	-16,886.62
Rochester, NY	x	-	100	-	0.00	169.45	296.07	-569.22	-675.26	-1,207.59	-19,657.31	0.00	551.83	707.00	-266.03	-370.75	-926.12	-18,962.18
Rome, GA	-	x	-	100	0.00	14.52	25.36	-48.76	-57.85	-103.45	-1,684.01	0.00	47.27	60.57	-22.79	-31.76	-79.34	-1,624.46
Sacramento Metro, CA	x	-	50	-	0.00	329.80	576.24	-1,107.88	-1,314.27	-2,350.37	-38,259.60	0.00	1,074.04	1,376.05	-517.79	-721.61	-1,802.55	-36,906.65
San Diego, CA	x	-	100	-	0.00	389.40	680.37	-1,308.07	-1,551.76	-2,775.08	-45,173.10	0.00	1,268.13	1,624.72	-611.34	-851.98	-2,128.26	-43,575.65
San Francisco Bay Area, CA	x	-	100	-	0.00	811.03	1,459.67	-3,031.32	-3,591.22	-6,362.75	-102,273.53	0.00	2,638.22	3,430.89	-1,625.49	-2,184.30	-5,079.21	-98,839.82
San Joaquin Valley, CA	x	x	50	100	0.00	710.56	1,248.67	-2,438.46	-2,891.92	-5,161.74	-83,805.24	0.00	2,313.54	2,972.62	-1,174.68	-1,623.47	-3,992.12	-80,872.37
Sheboygan, WI	x	-	100	-	0.00	15.92	27.81	-53.48	-63.44	-113.45	-1,846.76	0.00	51.84	66.42	-25.00	-34.83	-87.01	-1,781.46
Springfield (Western MA), MA	x	-	100	-	0.00	123.79	216.29	-415.83	-493.30	-882.19	-14,360.44	0.00	403.14	516.49	-194.34	-270.84	-676.57	-13,852.62
St. Louis, MO-IL	x	x	100	100	0.00	372.56	670.79	-1,394.47	-1,652.01	-2,926.60	-47,033.81	0.00	1,211.87	1,576.32	-748.98	-1,006.05	-2,337.40	-45,455.81
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	10.79	20.15	-45.58	-53.93	-94.63	-1,500.92	0.00	35.05	46.46	-27.65	-36.07	-78.64	-1,453.41
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.08	0.00	0.00	0.00	0.00	0.00	0.00	-0.08
Ventura Co., CA	x	-	100	-	0.00	83.05	145.28	-280.27	-332.47	-594.31	-9,668.72	0.00	270.44	346.70	-131.88	-183.44	-456.64	-9,327.59
Washington, DC-MD-VA	x	x	100	100	0.00	702.28	1,227.07	-2,359.32	-2,798.84	-5,005.24	-81,475.17	0.00	2,287.06	2,930.20	-1,102.79	-1,536.83	-3,838.75	-78,594.11
Wheeling, WV-OH	-	x	-	100	0.00	20.78	36.31	-69.82	-82.82	-148.11	-2,411.03	0.00	67.68	86.72	-32.63	-45.47	-113.59	-2,325.77
York, PA	-	x	-	100	0.00	58.98	103.05	-198.12	-235.02	-420.30	-6,841.73	0.00	192.06	246.07	-92.59	-129.04	-322.34	-6,599.79

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-20
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	250.62	467.86	-1,064.40	-1,248.99	-1,971.55	-32,784.70	0.00	1,261.39	1,553.76	-260.69	-441.95	-1,231.19	-30,957.84
Allegan Co., MI	x	-	100	-	0.00	27.27	50.91	-115.82	-135.90	-214.53	-3,567.35	0.00	137.25	169.07	-28.37	-48.09	-133.97	-3,368.57
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	32.01	59.75	-135.94	-159.52	-251.80	-4,187.12	0.00	161.10	198.44	-33.30	-56.45	-157.24	-3,953.80
Atlanta, GA	x	x	100	100	0.00	1,994.45	3,723.30	-8,470.66	-9,939.64	-15,689.92	- 260,906.01	0.00	10,038.40	12,365.14	-2,074.59	-3,517.08	-9,797.97	- 246,367.51
Baltimore, MD	x	x	100	100	0.00	543.54	1,014.72	-2,308.59	-2,708.95	-4,276.12	-71,106.69	0.00	2,735.76	3,369.88	-565.49	-958.62	-2,670.41	-67,144.47
Baton Rouge, LA	x	-	100	-	0.00	59.34	170.66	-685.78	-800.82	-1,215.97	-18,626.46	0.00	374.33	521.05	-502.62	-624.90	-1,083.13	-17,880.68
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-86.46	-40.83	-506.17	-586.12	-828.29	-10,564.43	0.00	-282.78	-227.61	-797.79	-895.05	-1,169.17	-10,563.97
Birmingham, AL	-	x	-	100	0.00	186.62	348.38	-792.54	-929.99	-1,468.01	-24,411.50	0.00	939.27	1,156.97	-194.08	-329.04	-916.71	-23,051.19
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	770.66	1,438.70	-3,273.15	-3,840.78	-6,062.74	- 100,816.33	0.00	3,878.87	4,777.94	-801.69	-1,359.09	-3,786.08	-95,198.57
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	117.10	218.58	-497.12	-583.33	-920.82	-15,313.04	0.00	589.35	725.92	-121.58	-206.23	-574.86	-14,459.60
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	177.77	331.88	-755.05	-885.99	-1,398.55	-23,256.24	0.00	894.77	1,102.17	-184.94	-313.51	-873.37	-21,960.34
Canton-Massillon, OH	-	x	-	100	0.00	41.23	84.79	-231.75	-271.44	-422.18	-6,812.25	0.00	217.40	275.62	-100.46	-140.65	-305.93	-6,470.81
Charleston, WV	-	x	-	100	0.00	44.24	82.58	-187.88	-220.46	-348.01	-5,786.95	0.00	222.65	274.26	-46.02	-78.01	-217.32	-5,464.48
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	472.12	881.20	-2,003.96	-2,351.49	-3,712.01	-61,730.98	0.00	2,376.05	2,926.61	-489.88	-831.13	-2,317.17	-58,290.34
Chattanooga, AL-TN-GA	-	x	-	100	0.00	90.80	169.54	-385.84	-452.75	-714.66	-11,883.19	0.00	457.04	563.01	-94.66	-160.37	-446.44	-11,221.16
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	1,295.14	2,504.29	-6,126.95	-7,183.88	-11,270.39	- 185,112.76	0.00	6,627.96	8,250.77	-1,983.81	-3,035.12	-7,505.60	- 175,219.54
Chico, CA	x	-	100	-	0.00	36.13	67.44	-153.44	-180.05	-284.21	-4,726.10	0.00	181.84	223.98	-37.58	-63.71	-177.48	-4,462.75
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	355.69	663.98	-1,510.42	-1,772.36	-2,797.73	-46,524.05	0.00	1,790.22	2,205.13	-369.73	-626.94	-1,746.93	-43,931.42
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	25.63	47.85	-108.86	-127.74	-201.65	-3,353.14	0.00	129.01	158.91	-26.66	-45.20	-125.92	-3,166.30
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	419.86	783.81	-1,783.23	-2,092.47	-3,303.01	-54,925.28	0.00	2,113.24	2,603.05	-436.76	-740.43	-2,062.67	-51,864.70
Columbus, OH	x	x	100	100	0.00	365.42	682.18	-1,551.98	-1,821.13	-2,874.69	-47,802.83	0.00	1,839.22	2,265.52	-380.10	-644.40	-1,795.17	-45,139.11
Dallas-Fort Worth, TX	x	-	100	-	0.00	1,811.02	3,380.89	-7,691.67	-9,025.56	-14,247.02	- 236,912.04	0.00	9,115.20	11,227.95	-1,883.83	-3,193.67	-8,896.95	- 223,710.59
Dayton-Springfield, OH	-	x	-	100	0.00	128.14	239.22	-544.25	-638.63	-1,008.09	-16,763.40	0.00	644.97	794.47	-133.30	-225.98	-629.53	-15,829.30
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	716.97	1,348.51	-3,117.90	-3,657.95	-5,766.06	-95,615.47	0.00	3,621.32	4,470.75	-819.83	-1,351.71	-3,655.15	-90,336.55
Detroit-Ann Arbor, MI	x	x	100	100	0.00	806.42	1,516.17	-3,502.59	-4,109.31	-6,478.01	- 107,436.94	0.00	4,072.39	5,027.03	-917.73	-1,515.18	-4,103.31	- 101,502.50
Door Co., WI	x	-	100	-	0.00	5.18	9.67	-22.01	-25.83	-40.77	-677.91	0.00	26.08	32.13	-5.39	-9.14	-25.46	-640.14
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.23	0.44	-0.99	-1.16	-1.83	-30.48	0.00	1.17	1.45	-0.24	-0.41	-1.14	-28.78
Evansville, IN	-	x	-	100	0.00	61.28	114.37	-260.04	-305.14	-481.69	-8,010.75	0.00	308.39	379.84	-63.52	-107.80	-300.64	-7,564.21
Greater Connecticut, CT	x	-	100	-	0.00	319.01	595.55	-1,354.97	-1,589.94	-2,509.75	-41,733.98	0.00	1,605.65	1,977.82	-331.93	-562.67	-1,567.35	-39,408.50
Greene Co., PA	x	-	100	-	0.00	5.55	10.35	-23.56	-27.64	-43.63	-725.54	0.00	27.92	34.39	-5.77	-9.78	-27.25	-685.11

Table B2-20
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	145.65	271.91	-618.60	-725.88	-1,145.82	-19,053.67	0.00	733.09	903.01	-151.51	-256.85	-715.54	-17,991.95
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	124.55	232.51	-528.97	-620.70	-979.79	-16,292.88	0.00	626.87	772.16	-129.56	-219.64	-611.86	-15,384.99
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.90	1.69	-3.83	-4.50	-7.10	-118.07	0.00	4.55	5.60	-0.93	-1.59	-4.43	-111.48
Hickory, NC	-	x	-	100	0.00	36.76	68.63	-156.13	-183.21	-289.19	-4,808.92	0.00	185.02	227.90	-38.24	-64.83	-180.60	-4,540.96
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	748.58	1,644.28	-4,967.07	-5,812.45	-8,976.67	- 142,703.19	0.00	4,079.65	5,272.33	-2,595.82	-3,464.33	-6,940.19	- 135,955.41
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	40.03	98.38	-341.26	-398.91	-610.69	-9,525.86	0.00	231.37	308.67	-215.69	-275.98	-509.18	-9,110.38
Imperial Co., CA	x	-	100	-	0.00	60.41	112.78	-256.58	-301.08	-475.26	-7,903.08	0.00	304.07	374.55	-62.84	-106.54	-296.79	-7,462.70
Indianapolis, IN	-	x	-	100	0.00	340.77	636.17	-1,447.31	-1,698.30	-2,680.80	-44,578.70	0.00	1,715.17	2,112.72	-354.47	-600.94	-1,674.10	-42,094.65
Jamestown, NY	x	-	100	-	0.00	23.46	43.81	-99.66	-116.94	-184.60	-3,069.61	0.00	118.10	145.48	-24.41	-41.38	-115.28	-2,898.56
Jefferson Co., NY	x	-	100	-	0.00	28.86	53.88	-122.59	-143.85	-227.07	-3,775.85	0.00	145.27	178.95	-30.03	-50.90	-141.80	-3,565.45
Johnstown, PA	-	x	-	100	0.00	17.39	32.47	-73.88	-86.69	-136.84	-2,275.44	0.00	87.54	107.83	-18.10	-30.68	-85.46	-2,148.66
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	30.96	57.87	-132.05	-154.94	-244.52	-4,063.96	0.00	155.91	192.12	-32.79	-55.28	-153.13	-3,837.89
Knoxville, TN	x	x	100	100	0.00	209.85	391.75	-891.24	-1,045.80	-1,650.82	-27,451.42	0.00	1,056.21	1,301.02	-218.27	-370.04	-1,030.89	-25,921.73
Lancaster, PA	-	x	-	100	0.00	74.38	138.85	-315.89	-370.67	-585.10	-9,729.63	0.00	374.35	461.11	-77.37	-131.16	-365.39	-9,187.47
Las Vegas, NV	x	-	100	-	0.00	441.13	823.47	-1,873.21	-2,198.07	-3,469.73	-57,698.85	0.00	2,220.21	2,734.78	-458.54	-777.54	-2,166.54	-54,483.49
Libby, MT	-	x	-	100	0.00	1.25	2.32	-5.29	-6.20	-9.79	-162.87	0.00	6.27	7.72	-1.29	-2.20	-6.12	-153.79
Liberty-Clairton, PA	-	x	-	100	0.00	1.64	3.07	-6.99	-8.20	-12.95	-215.28	0.00	8.27	10.19	-1.72	-2.91	-8.10	-203.29
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	3,119.31	5,955.99	-14,209.69	-16,665.32	-26,199.82	- 432,140.70	0.00	15,867.78	19,678.58	-4,222.08	-6,654.07	-17,078.95	- 408,708.14
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	172.04	321.24	-731.13	-857.92	-1,354.20	-22,517.20	0.00	866.00	1,066.78	-179.41	-303.93	-846.00	-21,262.77
Louisville, KY-IN	-	x	-	100	0.00	180.52	336.97	-766.45	-899.38	-1,419.71	-23,609.11	0.00	908.56	1,119.12	-187.52	-318.04	-886.39	-22,293.37
Macon, GA	-	x	-	100	0.00	34.03	63.52	-144.47	-169.52	-267.60	-4,450.11	0.00	171.27	210.96	-35.33	-59.93	-167.06	-4,202.09
Manitowoc Co., WI	x	-		-	0.00	16.92	31.58	-71.86	-84.32	-133.10	-2,213.19	0.00	85.15	104.88	-17.61	-29.84	-83.12	-2,089.87
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	27.75	51.80	-117.85	-138.29	-218.30	-3,630.00	0.00	139.66	172.03	-28.87	-48.94	-136.32	-3,427.73
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	118.04	220.36	-501.32	-588.26	-928.58	-15,441.23	0.00	594.10	731.81	-122.78	-208.15	-579.88	-14,580.80
Memphis, TN-AR	x	-	100	-	0.00	137.66	276.27	-724.33	-848.69	-1,324.17	-21,506.33	0.00	717.23	902.77	-285.16	-410.28	-931.18	-20,402.00
Milwaukee-Racine, WI	x	-	100	-	0.00	294.12	549.08	-1,249.19	-1,465.83	-2,313.84	-38,476.46	0.00	1,480.36	1,823.49	-305.97	-518.70	-1,444.96	-36,332.45
Nevada (Western Part), CA	x	-	100	-	0.00	20.68	38.60	-87.83	-103.06	-162.68	-2,705.16	0.00	104.08	128.20	-21.51	-36.47	-101.59	-2,554.43
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	2,391.02	4,497.73	-10,401.90	-12,203.59	-19,236.20	- 318,969.20	0.00	12,077.48	14,910.98	-2,738.12	-4,512.62	-12,196.89	- 301,361.59
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	23.61	44.07	-100.25	-117.64	-185.69	-3,087.87	0.00	118.82	146.35	-24.54	-41.61	-115.95	-2,915.80
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	1,153.31	2,280.04	-5,818.18	-6,818.93	-10,661.73	- 173,912.58	0.00	5,965.32	7,475.12	-2,134.71	-3,137.16	-7,344.68	- 164,841.22

Table B2-20
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Phoenix-Mesa, AZ	x	-	100	-	0.00	1,128.10	2,105.79	-4,789.83	-5,620.50	-8,872.22	-147,540.10	0.00	5,677.68	6,993.49	-1,172.07	-1,987.73	-5,539.49	-139,317.81
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	286.21	534.30	-1,215.54	-1,426.33	-2,251.50	-37,440.06	0.00	1,440.53	1,774.42	-297.68	-504.68	-1,405.99	-35,353.77
Poughkeepsie, NY	x	x	100	100	0.00	252.33	471.07	-1,071.70	-1,257.55	-1,985.07	-33,009.46	0.00	1,270.04	1,564.41	-262.48	-444.98	-1,239.63	-31,170.08
Providence (All RI), RI	x	-	100	-	0.00	151.65	283.10	-644.07	-755.76	-1,192.98	-19,837.96	0.00	763.26	940.17	-157.75	-267.43	-745.00	-18,732.53
Reading, PA	-	x	-	100	0.00	74.48	139.05	-316.35	-371.21	-585.96	-9,743.88	0.00	374.90	461.79	-77.48	-131.35	-365.92	-9,200.92
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	301.61	563.09	-1,281.26	-1,503.45	-2,373.20	-39,462.54	0.00	1,518.10	1,870.01	-314.03	-532.22	-1,482.22	-37,263.77
Rochester, NY	x	-	100	-	0.00	219.38	409.55	-931.76	-1,093.34	-1,725.86	-28,699.17	0.00	1,104.20	1,360.13	-228.21	-386.88	-1,077.77	-27,099.96
Rome, GA	-	x	-	100	0.00	18.38	34.31	-78.06	-91.60	-144.59	-2,404.36	0.00	92.51	113.95	-19.12	-32.41	-90.29	-2,270.38
Sacramento Metro, CA	x	-	50	-	0.00	502.62	938.32	-2,134.79	-2,505.00	-3,954.18	-65,753.24	0.00	2,529.78	3,116.16	-522.92	-886.47	-2,469.37	-62,089.34
San Diego, CA	x	-	100	-	0.00	491.69	917.90	-2,088.27	-2,450.42	-3,868.03	-64,321.07	0.00	2,474.76	3,048.37	-511.45	-867.07	-2,415.50	-60,736.91
San Francisco Bay Area, CA	x	-	100	-	0.00	1,048.40	2,027.72	-4,963.55	-5,819.75	-9,129.90	-149,943.04	0.00	5,365.92	6,680.26	-1,609.79	-2,461.52	-6,082.73	-141,931.81
San Joaquin Valley, CA	x	x	50	100	0.00	1,149.77	2,158.20	-4,968.50	-5,829.38	-9,192.32	-152,544.74	0.00	5,801.87	7,158.44	-1,282.67	-2,129.85	-5,804.05	-144,101.92
Sheboygan, WI	x	-	100	-	0.00	20.83	38.88	-88.46	-103.80	-163.85	-2,724.58	0.00	104.82	129.12	-21.67	-36.74	-102.33	-2,572.76
Springfield (Western MA), MA	x	-	100	-	0.00	162.86	304.04	-691.71	-811.66	-1,281.23	-21,305.36	0.00	819.72	1,009.72	-169.41	-287.21	-800.10	-20,118.16
St. Louis, MO-IL	x	x	100	100	0.00	486.70	941.42	-2,304.85	-2,702.42	-4,239.44	-69,623.59	0.00	2,491.14	3,101.41	-747.93	-1,143.44	-2,824.91	-65,904.08
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	12.18	24.88	-67.26	-78.78	-122.64	-1,982.33	0.00	64.02	81.01	-28.45	-40.10	-88.17	-1,882.32
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.11	0.00	0.00	0.01	0.00	0.00	0.00	-0.11
Ventura Co., CA	x	-	100	-	0.00	106.96	199.98	-456.46	-535.59	-845.20	-14,046.83	0.00	538.74	663.91	-113.47	-191.23	-529.43	-13,265.56
Washington, DC-MD-VA	x	x	100	100	0.00	1,043.78	1,948.62	-4,433.45	-5,202.30	-8,211.89	-136,553.10	0.00	5,253.59	6,471.34	-1,086.12	-1,841.12	-5,128.42	-128,944.20
Wheeling, WV-OH	-	x	-	100	0.00	25.04	46.75	-106.35	-124.79	-196.98	-3,275.64	0.00	126.03	155.24	-26.05	-44.16	-123.01	-3,093.11
York, PA	-	x	-	100	0.00	86.55	161.58	-367.61	-431.36	-680.92	-11,322.86	0.00	435.65	536.62	-90.04	-152.64	-425.22	-10,691.92

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-21
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-2.00	-2.25	-2.61	-2.87	-3.23	-10.84	0.00	-2.01	-2.26	-2.62	-2.88	-3.24	-10.85
Allegan Co., MI	x	-	100	-	0.00	-0.22	-0.25	-0.29	-0.31	-0.35	-1.19	0.00	-0.22	-0.25	-0.29	-0.32	-0.35	-1.19
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.20	-0.22	-0.26	-0.29	-0.32	-1.08	0.00	-0.20	-0.22	-0.26	-0.29	-0.32	-1.08
Atlanta, GA	x	x	100	100	0.00	-10.63	-11.95	-13.88	-15.25	-17.18	-57.56	0.00	-10.68	-12.01	-13.94	-15.31	-17.24	-57.62
Baltimore, MD	x	x	100	100	0.00	-4.43	-4.98	-5.78	-6.35	-7.16	-24.05	0.00	-4.45	-5.00	-5.81	-6.38	-7.19	-24.07
Baton Rouge, LA	x	-	100	-	0.00	-1.03	-1.16	-1.35	-1.48	-1.67	-5.59	0.00	-1.04	-1.16	-1.35	-1.49	-1.67	-5.59
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-0.64	-0.72	-0.84	-0.92	-1.04	-3.50	0.00	-0.65	-0.73	-0.84	-0.93	-1.04	-3.50
Birmingham, AL	-	x	-	100	0.00	-1.61	-1.81	-2.10	-2.31	-2.60	-8.70	0.00	-1.62	-1.82	-2.11	-2.32	-2.61	-8.71
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-7.20	-8.09	-9.40	-10.33	-11.63	-39.04	0.00	-7.23	-8.13	-9.44	-10.37	-11.68	-39.08
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.94	-1.06	-1.23	-1.35	-1.51	-4.93	0.00	-0.95	-1.07	-1.23	-1.36	-1.52	-4.94
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-1.73	-1.95	-2.26	-2.48	-2.80	-9.39	0.00	-1.74	-1.96	-2.27	-2.49	-2.81	-9.40
Canton-Massillon, OH	-	x	-	100	0.00	-0.49	-0.55	-0.64	-0.71	-0.80	-2.67	0.00	-0.50	-0.56	-0.65	-0.71	-0.80	-2.68
Charleston, WV	-	x	-	100	0.00	-0.46	-0.52	-0.60	-0.66	-0.75	-2.51	0.00	-0.47	-0.52	-0.61	-0.67	-0.75	-2.51
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-2.59	-2.92	-3.36	-3.69	-4.11	-12.77	0.00	-2.61	-2.93	-3.38	-3.71	-4.12	-12.78
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.82	-0.92	-1.07	-1.17	-1.32	-4.36	0.00	-0.82	-0.92	-1.07	-1.18	-1.32	-4.37
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-10.77	-12.11	-14.04	-15.43	-17.33	-57.26	0.00	-10.82	-12.17	-14.10	-15.49	-17.40	-57.33
Chico, CA	x	-	100	-	0.00	-0.30	-0.34	-0.39	-0.43	-0.48	-1.62	0.00	-0.30	-0.34	-0.39	-0.43	-0.49	-1.62
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-2.84	-3.19	-3.70	-4.07	-4.57	-15.20	0.00	-2.85	-3.21	-3.72	-4.08	-4.59	-15.22
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.27	-0.30	-0.35	-0.39	-0.44	-1.47	0.00	-0.27	-0.31	-0.36	-0.39	-0.44	-1.47
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-4.13	-4.64	-5.39	-5.92	-6.67	-22.38	0.00	-4.15	-4.66	-5.41	-5.95	-6.70	-22.41
Columbus, OH	x	x	100	100	0.00	-2.67	-3.00	-3.48	-3.83	-4.31	-14.44	0.00	-2.68	-3.01	-3.50	-3.84	-4.32	-14.46
Dallas-Fort Worth, TX	x	-	100	-	0.00	-10.80	-12.15	-14.11	-15.50	-17.46	-58.55	0.00	-10.86	-12.21	-14.17	-15.57	-17.53	-58.61
Dayton-Springfield, OH	-	x	-	100	0.00	-1.25	-1.41	-1.63	-1.80	-2.02	-6.78	0.00	-1.26	-1.41	-1.64	-1.80	-2.03	-6.79
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-5.00	-5.63	-6.53	-7.18	-8.09	-27.11	0.00	-5.03	-5.65	-6.56	-7.21	-8.12	-27.13
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-7.53	-8.47	-9.84	-10.81	-12.18	-40.85	0.00	-7.57	-8.51	-9.88	-10.86	-12.22	-40.89
Door Co., WI	x	-	100	-	0.00	-0.05	-0.06	-0.07	-0.07	-0.08	-0.28	0.00	-0.05	-0.06	-0.07	-0.07	-0.08	-0.28
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Evansville, IN	-	x	-	100	0.00	-0.51	-0.57	-0.66	-0.72	-0.81	-2.56	0.00	-0.51	-0.57	-0.66	-0.73	-0.81	-2.56
Greater Connecticut, CT	x	-	100	-	0.00	-2.74	-3.09	-3.59	-3.94	-4.44	-14.94	0.00	-2.76	-3.10	-3.60	-3.96	-4.46	-14.96
Greene Co., PA	x	-	100	-	0.00	-0.06	-0.07	-0.08	-0.09	-0.10	-0.34	0.00	-0.06	-0.07	-0.08	-0.09	-0.10	-0.34
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-1.24	-1.39	-1.62	-1.78	-2.00	-6.70	0.00	-1.24	-1.40	-1.62	-1.78	-2.01	-6.71
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-1.12	-1.26	-1.46	-1.61	-1.81	-6.08	0.00	-1.13	-1.27	-1.47	-1.62	-1.82	-6.08

Table B2-21
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.04	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.04
Hickory, NC	-	x	-	100	0.00	-0.29	-0.33	-0.38	-0.42	-0.47	-1.58	0.00	-0.29	-0.33	-0.38	-0.42	-0.47	-1.58
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-7.97	-8.96	-10.41	-11.44	-12.88	-43.20	0.00	-8.01	-9.01	-10.45	-11.49	-12.93	-43.24
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.56	-0.63	-0.72	-0.79	-0.86	-2.28	0.00	-0.56	-0.63	-0.72	-0.79	-0.86	-2.29
Imperial Co., CA	x	-	100	-	0.00	-0.34	-0.39	-0.45	-0.50	-0.56	-1.87	0.00	-0.35	-0.39	-0.45	-0.50	-0.56	-1.87
Indianapolis, IN	-	x	-	100	0.00	-2.49	-2.80	-3.25	-3.57	-4.02	-13.49	0.00	-2.50	-2.81	-3.26	-3.59	-4.04	-13.50
Jamestown, NY	x	-	100	-	0.00	-0.23	-0.26	-0.30	-0.33	-0.37	-1.25	0.00	-0.23	-0.26	-0.30	-0.33	-0.37	-1.25
Jefferson Co., NY	x	-	100	-	0.00	-0.21	-0.24	-0.28	-0.31	-0.35	-1.16	0.00	-0.22	-0.24	-0.28	-0.31	-0.35	-1.16
Johnstown, PA	-	x	-	100	0.00	-0.19	-0.21	-0.25	-0.27	-0.31	-1.03	0.00	-0.19	-0.21	-0.25	-0.27	-0.31	-1.03
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.19	-0.22	-0.25	-0.28	-0.32	-1.11	0.00	-0.19	-0.22	-0.25	-0.28	-0.32	-1.11
Knoxville, TN	x	x	100	100	0.00	-1.69	-1.90	-2.21	-2.42	-2.73	-9.14	0.00	-1.70	-1.91	-2.22	-2.43	-2.74	-9.15
Lancaster, PA	-	x	-	100	0.00	-0.66	-0.74	-0.86	-0.95	-1.07	-3.58	0.00	-0.66	-0.75	-0.87	-0.95	-1.07	-3.59
Las Vegas, NV	x	-	100	-	0.00	-2.18	-2.46	-2.85	-3.13	-3.53	-11.80	0.00	-2.20	-2.47	-2.86	-3.15	-3.54	-11.81
Libby, MT	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.06	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.06
Liberty-Clairton, PA	-	x	-	100	0.00	-0.02	-0.02	-0.03	-0.03	-0.04	-0.12	0.00	-0.02	-0.02	-0.03	-0.03	-0.04	-0.12
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-22.89	-25.75	-29.90	-32.86	-37.01	-124.04	0.00	-23.01	-25.87	-30.03	-32.99	-37.14	-124.17
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-1.13	-1.28	-1.48	-1.63	-1.84	-6.18	0.00	-1.14	-1.28	-1.49	-1.64	-1.84	-6.19
Louisville, KY-IN	-	x	-	100	0.00	-1.71	-1.92	-2.22	-2.44	-2.75	-9.05	0.00	-1.72	-1.93	-2.23	-2.45	-2.76	-9.06
Macon, GA	-	x	-	100	0.00	-0.32	-0.36	-0.41	-0.45	-0.51	-1.67	0.00	-0.32	-0.36	-0.41	-0.46	-0.51	-1.68
Manitowoc Co., WI	x	-		-	0.00	-0.17	-0.19	-0.22	-0.24	-0.27	-0.91	0.00	-0.17	-0.19	-0.22	-0.24	-0.27	-0.91
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.16	-0.18	-0.21	-0.23	-0.26	-0.88	0.00	-0.16	-0.18	-0.21	-0.23	-0.26	-0.88
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.63	-0.71	-0.83	-0.91	-1.02	-3.43	0.00	-0.64	-0.72	-0.83	-0.91	-1.03	-3.44
Memphis, TN-AR	x	-	100	-	0.00	-1.54	-1.73	-2.01	-2.21	-2.49	-8.34	0.00	-1.55	-1.74	-2.02	-2.22	-2.50	-8.34
Milwaukee-Racine, WI	x	-	100	-	0.00	-2.73	-3.07	-3.56	-3.91	-4.41	-14.80	0.00	-2.74	-3.08	-3.58	-3.93	-4.43	-14.81
Nevada (Western Part), CA	x	-	100	-	0.00	-0.15	-0.17	-0.20	-0.22	-0.25	-0.84	0.00	-0.15	-0.17	-0.20	-0.22	-0.25	-0.84
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-22.45	-25.24	-29.32	-32.22	-36.29	-121.79	0.00	-22.57	-25.36	-29.44	-32.35	-36.43	-121.92
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.24	-0.27	-0.32	-0.35	-0.39	-1.31	0.00	-0.24	-0.28	-0.32	-0.35	-0.39	-1.31
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-10.74	-12.07	-14.02	-15.41	-17.37	-58.34	0.00	-10.79	-12.13	-14.09	-15.48	-17.43	-58.41
Phoenix-Mesa, AZ	x	-	100	-	0.00	-5.99	-6.74	-7.81	-8.59	-9.65	-31.88	0.00	-6.02	-6.77	-7.85	-8.62	-9.68	-31.92
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-3.04	-3.42	-3.97	-4.36	-4.91	-16.45	0.00	-3.06	-3.44	-3.99	-4.38	-4.93	-16.47
Poughkeepsie, NY	x	x	100	100	0.00	-1.97	-2.22	-2.58	-2.83	-3.19	-10.70	0.00	-1.98	-2.23	-2.59	-2.84	-3.20	-10.71

Table B2-21
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-1.43	-1.61	-1.87	-2.05	-2.31	-7.75	0.00	-1.44	-1.61	-1.87	-2.06	-2.32	-7.76
Reading, PA	-	x	-	100	0.00	-0.58	-0.65	-0.76	-0.83	-0.94	-3.14	0.00	-0.58	-0.66	-0.76	-0.84	-0.94	-3.15
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-1.16	-1.30	-1.51	-1.66	-1.87	-6.29	0.00	-1.16	-1.31	-1.52	-1.67	-1.88	-6.29
Rochester, NY	x	-	100	-	0.00	-2.00	-2.25	-2.61	-2.87	-3.23	-10.84	0.00	-2.01	-2.26	-2.62	-2.88	-3.25	-10.86
Rome, GA	-	x	-	100	0.00	-0.17	-0.20	-0.23	-0.25	-0.28	-0.95	0.00	-0.18	-0.20	-0.23	-0.25	-0.28	-0.95
Sacramento Metro, CA	x	-	50	-	0.00	-3.36	-3.78	-4.38	-4.82	-5.43	-18.18	0.00	-3.37	-3.79	-4.40	-4.84	-5.45	-18.20
San Diego, CA	x	-	100	-	0.00	-4.70	-5.29	-6.14	-6.75	-7.60	-25.49	0.00	-4.73	-5.31	-6.17	-6.78	-7.63	-25.52
San Francisco Bay Area, CA	x	-	100	-	0.00	-9.91	-11.15	-12.89	-14.17	-15.85	-51.11	0.00	-9.96	-11.20	-12.95	-14.22	-15.91	-51.17
San Joaquin Valley, CA	x	x	50	100	0.00	-6.84	-7.69	-8.93	-9.81	-11.05	-36.97	0.00	-6.87	-7.73	-8.97	-9.85	-11.09	-37.01
Sheboygan, WI	x	-	100	-	0.00	-0.19	-0.21	-0.24	-0.27	-0.30	-1.02	0.00	-0.19	-0.21	-0.24	-0.27	-0.30	-1.02
Springfield (Western MA), MA	x	-	100	-	0.00	-1.44	-1.61	-1.87	-2.06	-2.32	-7.78	0.00	-1.44	-1.62	-1.88	-2.07	-2.33	-7.79
St. Louis, MO-IL	x	x	100	100	0.00	-4.78	-5.38	-6.25	-6.87	-7.74	-26.12	0.00	-4.81	-5.40	-6.28	-6.90	-7.77	-26.15
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.17	-0.19	-0.22	-0.24	-0.27	-0.90	0.00	-0.17	-0.19	-0.22	-0.24	-0.27	-0.91
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-0.99	-1.11	-1.29	-1.42	-1.59	-5.35	0.00	-0.99	-1.11	-1.29	-1.42	-1.60	-5.35
Washington, DC-MD-VA	x	x	100	100	0.00	-7.59	-8.53	-9.92	-10.90	-12.28	-41.33	0.00	-7.63	-8.58	-9.96	-10.94	-12.33	-41.37
Wheeling, WV-OH	-	x	-	100	0.00	-0.26	-0.30	-0.34	-0.38	-0.43	-1.43	0.00	-0.26	-0.30	-0.35	-0.38	-0.43	-1.43
York, PA	-	x	-	100	0.00	-0.61	-0.69	-0.80	-0.88	-0.99	-3.32	0.00	-0.62	-0.69	-0.80	-0.88	-0.99	-3.33

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-22
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-5.92	-6.59	-7.35	-8.25	-8.84	-27.07	0.00	-13.92	-14.81	-15.85	-17.04	-17.79	-35.00
Allegan Co., MI	x	-	100	-	0.00	-0.65	-0.72	-0.80	-0.90	-0.97	-2.96	0.00	-1.52	-1.62	-1.73	-1.86	-1.95	-3.83
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.63	-0.70	-0.78	-0.87	-0.94	-2.87	0.00	-1.47	-1.57	-1.68	-1.81	-1.89	-3.71
Atlanta, GA	x	x	100	100	0.00	-34.27	-38.19	-42.59	-47.78	-51.20	-156.67	0.00	-80.63	-85.78	-91.83	-98.73	-103.06	-202.66
Baltimore, MD	x	x	100	100	0.00	-13.03	-14.52	-16.20	-18.17	-19.48	-59.74	0.00	-30.66	-32.62	-34.92	-37.55	-39.20	-77.23
Baton Rouge, LA	x	-	100	-	0.00	-3.08	-3.43	-3.82	-4.29	-4.60	-14.08	0.00	-7.24	-7.70	-8.24	-8.86	-9.25	-18.20
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1.85	-2.06	-2.30	-2.58	-2.76	-8.48	0.00	-4.35	-4.62	-4.95	-5.32	-5.56	-10.96
Birmingham, AL	-	x	-	100	0.00	-4.63	-5.16	-5.75	-6.46	-6.91	-21.11	0.00	-10.90	-11.59	-12.41	-13.34	-13.92	-27.32
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-20.40	-22.74	-25.36	-28.45	-30.49	-93.43	0.00	-48.00	-51.07	-54.68	-58.78	-61.37	-120.81
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-2.77	-3.09	-3.43	-3.85	-4.11	-12.24	0.00	-6.52	-6.93	-7.41	-7.97	-8.30	-15.95
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-4.88	-5.43	-6.06	-6.80	-7.29	-22.33	0.00	-11.47	-12.21	-13.07	-14.05	-14.67	-28.88
Canton-Massillon, OH	-	x	-	100	0.00	-1.39	-1.55	-1.73	-1.95	-2.08	-6.38	0.00	-3.28	-3.49	-3.74	-4.02	-4.20	-8.25
Charleston, WV	-	x	-	100	0.00	-1.28	-1.42	-1.59	-1.78	-1.91	-5.85	0.00	-3.01	-3.20	-3.43	-3.68	-3.85	-7.57
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-8.32	-9.28	-10.29	-11.53	-12.25	-35.19	0.00	-19.58	-20.84	-22.24	-23.91	-24.83	-46.31
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-2.36	-2.63	-2.93	-3.29	-3.52	-10.75	0.00	-5.55	-5.90	-6.32	-6.79	-7.09	-13.92
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-31.39	-34.99	-38.94	-43.68	-46.66	-139.83	0.00	-73.87	-78.60	-84.06	-90.36	-94.17	-181.89
Chico, CA	x	-	100	-	0.00	-0.88	-0.98	-1.09	-1.22	-1.31	-4.01	0.00	-2.06	-2.20	-2.35	-2.53	-2.64	-5.19
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-8.21	-9.15	-10.20	-11.44	-12.24	-37.15	0.00	-19.32	-20.56	-22.00	-23.65	-24.67	-48.16
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.75	-0.83	-0.93	-1.04	-1.12	-3.42	0.00	-1.76	-1.87	-2.00	-2.15	-2.25	-4.43
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-11.59	-12.91	-14.40	-16.16	-17.31	-53.03	0.00	-27.26	-29.00	-31.05	-33.38	-34.85	-68.58
Columbus, OH	x	x	100	100	0.00	-8.00	-8.92	-9.94	-11.16	-11.96	-36.59	0.00	-18.83	-20.03	-21.44	-23.05	-24.06	-47.33
Dallas-Fort Worth, TX	x	-	100	-	0.00	-33.98	-37.87	-42.24	-47.39	-50.78	-155.46	0.00	-79.95	-85.07	-91.07	-97.91	-102.21	-201.06
Dayton-Springfield, OH	-	x	-	100	0.00	-3.52	-3.92	-4.38	-4.91	-5.26	-16.11	0.00	-8.29	-8.82	-9.44	-10.15	-10.59	-20.84
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-15.23	-16.97	-18.93	-21.24	-22.76	-69.64	0.00	-35.84	-38.13	-40.82	-43.89	-45.81	-90.08
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-21.49	-23.95	-26.71	-29.97	-32.11	-98.34	0.00	-50.56	-53.79	-57.59	-61.92	-64.64	-127.18
Door Co., WI	x	-	100	-	0.00	-0.14	-0.16	-0.18	-0.20	-0.21	-0.65	0.00	-0.34	-0.36	-0.38	-0.41	-0.43	-0.85
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.03	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.03
Evansville, IN	-	x	-	100	0.00	-1.47	-1.64	-1.81	-2.03	-2.16	-6.28	0.00	-3.45	-3.67	-3.92	-4.22	-4.38	-8.24
Greater Connecticut, CT	x	-	100	-	0.00	-7.98	-8.89	-9.92	-11.13	-11.94	-36.67	0.00	-18.78	-19.98	-21.39	-23.00	-24.02	-47.38
Greene Co., PA	x	-	100	-	0.00	-0.17	-0.19	-0.21	-0.24	-0.25	-0.78	0.00	-0.40	-0.43	-0.46	-0.49	-0.51	-1.01
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-3.61	-4.02	-4.48	-5.03	-5.39	-16.49	0.00	-8.48	-9.03	-9.66	-10.39	-10.84	-21.33
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-3.22	-3.59	-4.00	-4.49	-4.81	-14.73	0.00	-7.57	-8.06	-8.63	-9.28	-9.68	-19.05

Table B2-22
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.02	-0.02	-0.03	-0.03	-0.03	-0.10	0.00	-0.05	-0.05	-0.06	-0.06	-0.06	-0.12
Hickory, NC	-	x	-	100	0.00	-0.86	-0.96	-1.07	-1.21	-1.29	-3.96	0.00	-2.03	-2.16	-2.32	-2.49	-2.60	-5.12
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-23.65	-26.35	-29.39	-32.98	-35.34	-108.19	0.00	-55.64	-59.20	-63.38	-68.14	-71.13	-139.93
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-1.57	-1.76	-1.92	-2.15	-2.24	-5.41	0.00	-3.71	-3.95	-4.19	-4.49	-4.62	-7.49
Imperial Co., CA	x	-	100	-	0.00	-1.11	-1.24	-1.38	-1.55	-1.66	-5.08	0.00	-2.61	-2.78	-2.98	-3.20	-3.34	-6.57
Indianapolis, IN	-	x	-	100	0.00	-7.45	-8.31	-9.26	-10.39	-11.14	-34.10	0.00	-17.54	-18.66	-19.97	-21.48	-22.42	-44.10
Jamestown, NY	x	-	100	-	0.00	-0.65	-0.72	-0.81	-0.90	-0.97	-2.96	0.00	-1.52	-1.62	-1.74	-1.87	-1.95	-3.83
Jefferson Co., NY	x	-	100	-	0.00	-0.65	-0.72	-0.80	-0.90	-0.97	-2.96	0.00	-1.52	-1.62	-1.73	-1.86	-1.94	-3.82
Johnstown, PA	-	x	-	100	0.00	-0.52	-0.58	-0.65	-0.72	-0.78	-2.39	0.00	-1.22	-1.30	-1.39	-1.50	-1.56	-3.08
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.64	-0.71	-0.80	-0.90	-0.98	-3.24	0.00	-1.51	-1.60	-1.72	-1.85	-1.95	-4.10
Knoxville, TN	x	x	100	100	0.00	-4.98	-5.55	-6.19	-6.95	-7.44	-22.76	0.00	-11.72	-12.47	-13.35	-14.35	-14.98	-29.45
Lancaster, PA	-	x	-	100	0.00	-1.91	-2.12	-2.37	-2.66	-2.85	-8.72	0.00	-4.48	-4.77	-5.11	-5.49	-5.73	-11.28
Las Vegas, NV	x	-	100	-	0.00	-7.27	-8.10	-9.03	-10.13	-10.85	-33.10	0.00	-17.11	-18.20	-19.48	-20.94	-21.86	-42.85
Libby, MT	-	x	-	100	0.00	-0.03	-0.04	-0.04	-0.04	-0.05	-0.14	0.00	-0.07	-0.08	-0.08	-0.09	-0.09	-0.19
Liberty-Clairton, PA	-	x	-	100	0.00	-0.06	-0.06	-0.07	-0.08	-0.09	-0.28	0.00	-0.14	-0.15	-0.16	-0.17	-0.18	-0.36
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-69.23	-77.15	-86.04	-96.53	-103.43	-316.44	0.00	-162.88	-173.30	-185.52	-199.46	-208.21	-409.34
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-3.53	-3.94	-4.39	-4.93	-5.29	-16.34	0.00	-8.31	-8.84	-9.47	-10.18	-10.64	-21.08
Louisville, KY-IN	-	x	-	100	0.00	-4.81	-5.37	-5.98	-6.70	-7.16	-21.57	0.00	-11.33	-12.05	-12.89	-13.86	-14.45	-28.02
Macon, GA	-	x	-	100	0.00	-0.90	-1.00	-1.11	-1.25	-1.33	-3.99	0.00	-2.11	-2.24	-2.40	-2.58	-2.69	-5.20
Manitowoc Co., WI	x	-		-	0.00	-0.47	-0.52	-0.58	-0.66	-0.70	-2.17	0.00	-1.10	-1.18	-1.26	-1.35	-1.41	-2.80
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.52	-0.58	-0.64	-0.72	-0.77	-2.37	0.00	-1.22	-1.30	-1.39	-1.49	-1.56	-3.07
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-2.06	-2.30	-2.57	-2.88	-3.08	-9.44	0.00	-4.86	-5.17	-5.53	-5.95	-6.21	-12.21
Memphis, TN-AR	x	-	100	-	0.00	-4.37	-4.87	-5.43	-6.09	-6.52	-19.98	0.00	-10.27	-10.93	-11.70	-12.58	-13.13	-25.83
Milwaukee-Racine, WI	x	-	100	-	0.00	-7.77	-8.65	-9.65	-10.83	-11.61	-35.57	0.00	-18.27	-19.44	-20.81	-22.38	-23.36	-46.00
Nevada (Western Part), CA	x	-	100	-	0.00	-0.46	-0.52	-0.58	-0.65	-0.69	-2.13	0.00	-1.09	-1.16	-1.25	-1.34	-1.40	-2.75
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-64.09	-71.42	-79.66	-89.37	-95.78	-293.48	0.00	-150.78	-160.43	-171.75	-184.66	-192.78	-379.49
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.68	-0.75	-0.84	-0.94	-1.01	-3.07	0.00	-1.59	-1.69	-1.81	-1.95	-2.03	-3.97
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-31.57	-35.18	-39.24	-44.03	-47.19	-144.78	0.00	-74.27	-79.02	-84.60	-90.96	-94.97	-187.15
Phoenix-Mesa, AZ	x	-	100	-	0.00	-19.56	-21.80	-24.28	-27.24	-29.13	-87.88	0.00	-46.03	-48.98	-52.40	-56.33	-58.73	-114.11
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-8.37	-9.32	-10.40	-11.66	-12.50	-38.20	0.00	-19.68	-20.94	-22.42	-24.10	-25.16	-49.43
Poughkeepsie, NY	x	x	100	100	0.00	-5.87	-6.54	-7.30	-8.19	-8.78	-26.87	0.00	-13.82	-14.70	-15.74	-16.92	-17.66	-34.75

Table B2-22
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-4.06	-4.52	-5.04	-5.66	-6.06	-18.57	0.00	-9.55	-10.16	-10.87	-11.69	-12.20	-24.02
Reading, PA	-	x	-	100	0.00	-1.73	-1.93	-2.15	-2.41	-2.58	-7.91	0.00	-4.07	-4.33	-4.63	-4.98	-5.20	-10.23
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-4.12	-4.59	-5.13	-5.75	-6.17	-18.98	0.00	-9.70	-10.32	-11.05	-11.88	-12.41	-24.51
Rochester, NY	x	-	100	-	0.00	-5.73	-6.38	-7.12	-7.98	-8.56	-26.20	0.00	-13.47	-14.33	-15.34	-16.50	-17.22	-33.88
Rome, GA	-	x	-	100	0.00	-0.50	-0.55	-0.62	-0.69	-0.74	-2.27	0.00	-1.17	-1.24	-1.33	-1.43	-1.49	-2.93
Sacramento Metro, CA	x	-	50	-	0.00	-10.33	-11.51	-12.84	-14.41	-15.44	-47.26	0.00	-24.31	-25.86	-27.68	-29.76	-31.07	-61.12
San Diego, CA	x	-	100	-	0.00	-13.31	-14.83	-16.54	-18.56	-19.89	-60.88	0.00	-31.31	-33.32	-35.67	-38.35	-40.03	-78.74
San Francisco Bay Area, CA	x	-	100	-	0.00	-28.40	-31.66	-35.18	-39.46	-42.04	-123.79	0.00	-66.83	-71.12	-75.99	-81.68	-85.01	-161.80
San Joaquin Valley, CA	x	x	50	100	0.00	-21.78	-24.27	-27.06	-30.35	-32.51	-99.17	0.00	-51.23	-54.51	-58.34	-62.73	-65.46	-128.38
Sheboygan, WI	x	-	100	-	0.00	-0.54	-0.60	-0.67	-0.75	-0.80	-2.47	0.00	-1.26	-1.34	-1.44	-1.55	-1.62	-3.19
Springfield (Western MA), MA	x	-	100	-	0.00	-4.15	-4.62	-5.15	-5.78	-6.19	-18.97	0.00	-9.75	-10.38	-11.11	-11.94	-12.47	-24.53
St. Louis, MO-IL	x	x	100	100	0.00	-13.69	-15.25	-17.02	-19.10	-20.48	-63.11	0.00	-32.20	-34.26	-36.69	-39.45	-41.20	-81.49
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.45	-0.51	-0.56	-0.63	-0.68	-2.08	0.00	-1.07	-1.14	-1.22	-1.31	-1.37	-2.69
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-2.82	-3.14	-3.50	-3.93	-4.21	-12.90	0.00	-6.63	-7.06	-7.56	-8.12	-8.48	-16.68
Washington, DC-MD-VA	x	x	100	100	0.00	-22.63	-25.21	-28.13	-31.56	-33.84	-104.01	0.00	-53.23	-56.64	-60.64	-65.20	-68.09	-134.39
Wheeling, WV-OH	-	x	-	100	0.00	-0.73	-0.81	-0.90	-1.01	-1.09	-3.33	0.00	-1.71	-1.82	-1.95	-2.10	-2.19	-4.30
York, PA	-	x	-	100	0.00	-1.87	-2.08	-2.33	-2.61	-2.80	-8.56	0.00	-4.40	-4.68	-5.01	-5.39	-5.63	-11.07

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.

b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.

c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)

EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-23
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-9.16	-10.18	-11.25	-12.68	-13.41	-40.05	0.00	-30.54	-32.12	-33.95	-36.15	-37.28	-60.78
Allegan Co., MI	x	-	100	-	0.00	-1.00	-1.11	-1.23	-1.38	-1.46	-4.38	0.00	-3.34	-3.51	-3.71	-3.95	-4.07	-6.64
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-1.03	-1.15	-1.27	-1.43	-1.51	-4.52	0.00	-3.44	-3.62	-3.83	-4.08	-4.21	-6.86
Atlanta, GA	x	x	100	100	0.00	-58.45	-64.97	-71.81	-80.90	-85.56	-255.47	0.00	-194.92	-204.99	-216.70	-230.72	-237.92	-387.73
Baltimore, MD	x	x	100	100	0.00	-20.08	-22.32	-24.67	-27.79	-29.40	-87.99	0.00	-66.95	-70.41	-74.44	-79.25	-81.74	-133.43
Baton Rouge, LA	x	-	100	-	0.00	-4.83	-5.37	-5.93	-6.68	-7.07	-21.12	0.00	-16.10	-16.93	-17.90	-19.05	-19.65	-32.04
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-2.78	-3.09	-3.41	-3.84	-4.07	-12.18	0.00	-9.26	-9.74	-10.30	-10.96	-11.31	-18.47
Birmingham, AL	-	x	-	100	0.00	-7.00	-7.78	-8.60	-9.69	-10.24	-30.51	0.00	-23.35	-24.55	-25.95	-27.63	-28.49	-46.35
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-30.35	-33.74	-37.29	-42.01	-44.44	-132.85	0.00	-101.22	-106.45	-112.53	-119.81	-123.56	-201.54
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-4.25	-4.73	-5.21	-5.87	-6.18	-17.99	0.00	-14.18	-14.91	-15.75	-16.77	-17.26	-27.59
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-7.19	-7.99	-8.83	-9.95	-10.52	-31.46	0.00	-23.97	-25.21	-26.65	-28.37	-29.26	-47.73
Canton-Massillon, OH	-	x	-	100	0.00	-2.06	-2.29	-2.54	-2.86	-3.02	-9.03	0.00	-6.88	-7.24	-7.65	-8.15	-8.40	-13.70
Charleston, WV	-	x	-	100	0.00	-1.85	-2.06	-2.27	-2.56	-2.71	-8.09	0.00	-6.17	-6.48	-6.86	-7.30	-7.53	-12.27
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-14.01	-15.58	-17.14	-19.30	-20.26	-57.48	0.00	-46.74	-49.17	-51.89	-55.23	-56.78	-89.07
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-3.56	-3.96	-4.38	-4.94	-5.23	-15.73	0.00	-11.88	-12.50	-13.22	-14.07	-14.52	-23.80
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-48.19	-53.59	-59.06	-66.51	-70.04	-202.89	0.00	-160.76	-169.09	-178.55	-190.07	-195.66	-311.71
Chico, CA	x	-	100	-	0.00	-1.35	-1.50	-1.65	-1.86	-1.97	-5.89	0.00	-4.49	-4.72	-4.99	-5.31	-5.48	-8.93
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-12.61	-14.02	-15.48	-17.44	-18.42	-54.53	0.00	-42.05	-44.23	-46.74	-49.76	-51.29	-83.04
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-1.08	-1.20	-1.33	-1.49	-1.58	-4.73	0.00	-3.60	-3.79	-4.00	-4.26	-4.40	-7.17
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-17.02	-18.92	-20.91	-23.56	-24.92	-74.49	0.00	-56.76	-59.70	-63.11	-67.19	-69.29	-113.01
Columbus, OH	x	x	100	100	0.00	-12.63	-14.04	-15.52	-17.48	-18.49	-55.21	0.00	-42.12	-44.29	-46.82	-49.85	-51.41	-83.79
Dallas-Fort Worth, TX	x	-	100	-	0.00	-56.35	-62.64	-69.23	-77.99	-82.50	-246.41	0.00	-187.92	-197.63	-208.92	-222.44	-229.39	-373.93
Dayton-Springfield, OH	-	x	-	100	0.00	-5.19	-5.76	-6.37	-7.18	-7.59	-22.67	0.00	-17.29	-18.18	-19.22	-20.47	-21.11	-34.41
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-24.41	-27.13	-29.99	-33.78	-35.73	-106.63	0.00	-81.40	-85.60	-90.49	-96.34	-99.35	-161.86
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-32.11	-35.69	-39.45	-44.44	-47.00	-140.44	0.00	-107.06	-112.60	-119.03	-126.73	-130.69	-213.09
Door Co., WI	x	-	100	-	0.00	-0.21	-0.23	-0.26	-0.29	-0.31	-0.92	0.00	-0.70	-0.74	-0.78	-0.83	-0.86	-1.40
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.04	0.00	-0.03	-0.03	-0.03	-0.03	-0.04	-0.06
Evansville, IN	-	x	-	100	0.00	-2.22	-2.47	-2.72	-3.06	-3.22	-9.13	0.00	-7.42	-7.80	-8.24	-8.77	-9.01	-14.15
Greater Connecticut, CT	x	-	100	-	0.00	-12.14	-13.49	-14.92	-16.81	-17.79	-53.31	0.00	-40.48	-42.57	-45.01	-47.92	-49.43	-80.78
Greene Co., PA	x	-	100	-	0.00	-0.24	-0.27	-0.30	-0.33	-0.35	-1.06	0.00	-0.81	-0.85	-0.90	-0.95	-0.98	-1.60
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-5.50	-6.11	-6.75	-7.61	-8.05	-24.04	0.00	-18.33	-19.28	-20.38	-21.70	-22.38	-36.48
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-4.84	-5.38	-5.94	-6.70	-7.08	-21.16	0.00	-16.13	-16.96	-17.93	-19.09	-19.69	-32.10

Table B2-23
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.03	-0.04	-0.04	-0.04	-0.05	-0.13	0.00	-0.11	-0.11	-0.12	-0.13	-0.13	-0.21
Hickory, NC	-	x	-	100	0.00	-1.34	-1.49	-1.65	-1.86	-1.96	-5.88	0.00	-4.47	-4.70	-4.97	-5.30	-5.46	-8.92
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-37.07	-41.20	-45.54	-51.30	-54.27	-162.10	0.00	-123.61	-130.00	-137.42	-146.32	-150.89	-245.98
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-2.32	-2.59	-2.80	-3.15	-3.23	-7.58	0.00	-7.76	-8.16	-8.57	-9.11	-9.28	-12.76
Imperial Co., CA	x	-	100	-	0.00	-1.87	-2.08	-2.30	-2.59	-2.74	-8.18	0.00	-6.24	-6.56	-6.93	-7.38	-7.61	-12.41
Indianapolis, IN	-	x	-	100	0.00	-11.76	-13.07	-14.44	-16.27	-17.21	-51.40	0.00	-39.20	-41.23	-43.58	-46.40	-47.85	-78.01
Jamestown, NY	x	-	100	-	0.00	-0.95	-1.06	-1.17	-1.32	-1.39	-4.17	0.00	-3.18	-3.34	-3.53	-3.76	-3.88	-6.32
Jefferson Co., NY	x	-	100	-	0.00	-1.02	-1.13	-1.25	-1.41	-1.49	-4.46	0.00	-3.40	-3.57	-3.78	-4.02	-4.15	-6.77
Johnstown, PA	-	x	-	100	0.00	-0.75	-0.83	-0.92	-1.03	-1.09	-3.28	0.00	-2.49	-2.62	-2.77	-2.94	-3.04	-4.97
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-1.11	-1.24	-1.38	-1.56	-1.68	-5.58	0.00	-3.71	-3.90	-4.14	-4.41	-4.58	-8.12
Knoxville, TN	x	x	100	100	0.00	-7.69	-8.55	-9.45	-10.65	-11.26	-33.60	0.00	-25.65	-26.98	-28.52	-30.37	-31.31	-51.00
Lancaster, PA	-	x	-	100	0.00	-2.87	-3.19	-3.53	-3.98	-4.21	-12.56	0.00	-9.58	-10.07	-10.65	-11.34	-11.69	-19.06
Las Vegas, NV	x	-	100	-	0.00	-12.66	-14.07	-15.54	-17.51	-18.50	-54.97	0.00	-42.21	-44.39	-46.91	-49.95	-51.49	-83.60
Libby, MT	-	x	-	100	0.00	-0.05	-0.05	-0.06	-0.07	-0.07	-0.21	0.00	-0.16	-0.17	-0.18	-0.19	-0.19	-0.32
Liberty-Clairton, PA	-	x	-	100	0.00	-0.08	-0.09	-0.10	-0.11	-0.12	-0.38	0.00	-0.27	-0.29	-0.30	-0.32	-0.33	-0.56
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-110.37	-122.69	-135.58	-152.74	-161.52	-481.87	0.00	-368.05	-387.07	-409.16	-435.63	-449.21	-731.59
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-5.78	-6.42	-7.11	-8.01	-8.49	-25.72	0.00	-19.26	-20.26	-21.43	-22.81	-23.55	-38.81
Louisville, KY-IN	-	x	-	100	0.00	-7.11	-7.91	-8.72	-9.83	-10.37	-30.45	0.00	-23.72	-24.95	-26.36	-28.06	-28.91	-46.52
Macon, GA	-	x	-	100	0.00	-1.33	-1.48	-1.63	-1.83	-1.93	-5.64	0.00	-4.43	-4.65	-4.92	-5.23	-5.39	-8.64
Manitowoc Co., WI	x	-		-	0.00	-0.69	-0.77	-0.85	-0.96	-1.01	-3.04	0.00	-2.30	-2.42	-2.56	-2.73	-2.81	-4.61
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.87	-0.96	-1.07	-1.20	-1.27	-3.80	0.00	-2.89	-3.04	-3.22	-3.42	-3.53	-5.76
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-3.53	-3.92	-4.33	-4.88	-5.16	-15.41	0.00	-11.76	-12.36	-13.07	-13.92	-14.35	-23.39
Memphis, TN-AR	x	-	100	-	0.00	-6.48	-7.21	-7.97	-8.97	-9.49	-28.35	0.00	-21.62	-22.74	-24.04	-25.59	-26.39	-43.02
Milwaukee-Racine, WI	x	-	100	-	0.00	-11.58	-12.87	-14.23	-16.03	-16.96	-50.70	0.00	-38.62	-40.61	-42.93	-45.71	-47.14	-76.91
Nevada (Western Part), CA	x	-	100	-	0.00	-0.73	-0.81	-0.90	-1.01	-1.07	-3.21	0.00	-2.44	-2.57	-2.72	-2.89	-2.98	-4.87
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-95.73	-106.42	-117.62	-132.51	-140.18	-419.04	0.00	-319.24	-335.74	-354.93	-377.89	-389.72	-635.68
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.98	-1.09	-1.20	-1.35	-1.43	-4.25	0.00	-3.26	-3.43	-3.63	-3.86	-3.98	-6.46
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-48.63	-54.05	-59.75	-67.32	-71.22	-213.18	0.00	-162.15	-170.53	-180.28	-191.95	-197.97	-323.23
Phoenix-Mesa, AZ	x	-	100	-	0.00	-33.41	-37.14	-40.99	-46.18	-48.74	-143.46	0.00	-111.42	-117.19	-123.82	-131.82	-135.82	-218.98
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-12.05	-13.39	-14.80	-16.68	-17.63	-52.60	0.00	-40.18	-42.26	-44.67	-47.56	-49.04	-79.86
Poughkeepsie, NY	x	x	100	100	0.00	-9.14	-10.16	-11.23	-12.65	-13.38	-39.97	0.00	-30.48	-32.05	-33.88	-36.07	-37.20	-60.65

Table B2-23
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-6.03	-6.70	-7.41	-8.34	-8.83	-26.37	0.00	-20.10	-21.14	-22.35	-23.79	-24.54	-40.02
Reading, PA	-	x	-	100	0.00	-2.69	-2.99	-3.31	-3.73	-3.94	-11.78	0.00	-8.98	-9.44	-9.98	-10.63	-10.96	-17.87
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-7.69	-8.55	-9.46	-10.66	-11.28	-33.94	0.00	-25.65	-26.98	-28.53	-30.37	-31.34	-51.36
Rochester, NY	x	-	100	-	0.00	-8.57	-9.53	-10.53	-11.87	-12.55	-37.50	0.00	-28.59	-30.07	-31.79	-33.84	-34.90	-56.90
Rome, GA	-	x	-	100	0.00	-0.73	-0.82	-0.90	-1.02	-1.08	-3.21	0.00	-2.45	-2.58	-2.72	-2.90	-2.99	-4.87
Sacramento Metro, CA	x	-	50	-	0.00	-16.70	-18.56	-20.51	-23.11	-24.45	-73.08	0.00	-55.68	-58.56	-61.90	-65.91	-67.97	-110.86
San Diego, CA	x	-	100	-	0.00	-19.70	-21.90	-24.20	-27.26	-28.84	-86.13	0.00	-65.68	-69.08	-73.02	-77.75	-80.18	-130.70
San Francisco Bay Area, CA	x	-	100	-	0.00	-42.62	-47.40	-52.19	-58.78	-61.83	-177.68	0.00	-142.18	-149.55	-157.88	-168.06	-172.93	-273.86
San Joaquin Valley, CA	x	x	50	100	0.00	-36.30	-40.36	-44.58	-50.22	-53.08	-157.72	0.00	-121.06	-127.32	-134.57	-143.27	-147.70	-239.83
Sheboygan, WI	x	-	100	-	0.00	-0.81	-0.90	-0.99	-1.12	-1.19	-3.56	0.00	-2.70	-2.84	-3.00	-3.19	-3.29	-5.39
Springfield (Western MA), MA	x	-	100	-	0.00	-6.26	-6.96	-7.69	-8.67	-9.17	-27.38	0.00	-20.88	-21.96	-23.22	-24.72	-25.49	-41.55
St. Louis, MO-IL	x	x	100	100	0.00	-20.55	-22.84	-25.26	-28.46	-30.13	-90.60	0.00	-68.53	-72.07	-76.20	-81.14	-83.70	-137.12
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.65	-0.72	-0.80	-0.90	-0.95	-2.83	0.00	-2.16	-2.27	-2.40	-2.56	-2.64	-4.30
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-4.22	-4.69	-5.18	-5.83	-6.17	-18.43	0.00	-14.06	-14.78	-15.63	-16.64	-17.16	-27.97
Washington, DC-MD-VA	x	x	100	100	0.00	-35.69	-39.67	-43.86	-49.41	-52.29	-156.84	0.00	-119.00	-125.15	-132.32	-140.88	-145.32	-237.62
Wheeling, WV-OH	-	x	-	100	0.00	-1.05	-1.17	-1.29	-1.46	-1.54	-4.60	0.00	-3.51	-3.69	-3.90	-4.15	-4.28	-6.98
York, PA	-	x	-	100	0.00	-2.98	-3.32	-3.67	-4.13	-4.37	-13.06	0.00	-9.95	-10.47	-11.07	-11.78	-12.15	-19.81

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-24
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-12.32	-13.71	-15.10	-17.09	-18.01	-53.41	0.00	-50.66	-53.03	-55.80	-59.16	-60.79	-90.25
Allegan Co., MI	x	-	100	-	0.00	-1.34	-1.49	-1.64	-1.86	-1.96	-5.81	0.00	-5.51	-5.77	-6.07	-6.44	-6.61	-9.82
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-1.57	-1.75	-1.93	-2.18	-2.30	-6.83	0.00	-6.47	-6.78	-7.13	-7.56	-7.77	-11.54
Atlanta, GA	x	x	100	100	0.00	-97.99	-109.02	-120.09	-135.92	-143.28	-424.64	0.00	-402.95	-421.85	-443.83	-470.61	-483.54	-717.71
Baltimore, MD	x	x	100	100	0.00	-26.77	-29.78	-32.81	-37.14	-39.16	-116.31	0.00	-110.08	-115.24	-121.25	-128.57	-132.12	-196.39
Baton Rouge, LA	x	-	100	-	0.00	-6.77	-7.54	-8.30	-9.40	-9.91	-29.38	0.00	-27.86	-29.17	-30.69	-32.54	-33.43	-49.64
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-3.53	-3.92	-4.32	-4.89	-5.16	-15.33	0.00	-14.50	-15.18	-15.97	-16.93	-17.40	-25.88
Birmingham, AL	-	x	-	100	0.00	-9.14	-10.17	-11.20	-12.68	-13.36	-39.50	0.00	-37.60	-39.36	-41.41	-43.91	-45.11	-66.85
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-37.90	-42.17	-46.46	-52.58	-55.44	-164.46	0.00	-155.87	-163.18	-171.69	-182.05	-187.06	-277.84
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-5.61	-6.24	-6.86	-7.77	-8.16	-23.65	0.00	-23.08	-24.17	-25.41	-26.94	-27.65	-40.40
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-8.74	-9.73	-10.72	-12.13	-12.79	-37.95	0.00	-35.96	-37.65	-39.61	-42.00	-43.16	-64.11
Canton-Massillon, OH	-	x	-	100	0.00	-2.53	-2.82	-3.10	-3.51	-3.70	-10.97	0.00	-10.41	-10.89	-11.46	-12.15	-12.49	-18.54
Charleston, WV	-	x	-	100	0.00	-2.17	-2.42	-2.66	-3.02	-3.18	-9.42	0.00	-8.94	-9.36	-9.85	-10.44	-10.73	-15.93
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-22.43	-24.97	-27.42	-31.03	-32.57	-93.62	0.00	-92.29	-96.63	-101.57	-107.68	-110.47	-160.58
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-4.59	-5.11	-5.64	-6.39	-6.76	-20.54	0.00	-18.89	-19.77	-20.82	-22.08	-22.71	-34.30
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-65.05	-72.44	-79.33	-89.74	-93.83	-262.09	0.00	-267.72	-280.34	-294.41	-312.07	-319.75	-455.85
Chico, CA	x	-	100	-	0.00	-1.78	-1.98	-2.18	-2.46	-2.60	-7.70	0.00	-7.30	-7.64	-8.04	-8.53	-8.76	-13.01
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-17.31	-19.27	-21.20	-24.00	-25.27	-74.27	0.00	-71.21	-74.55	-78.41	-83.14	-85.39	-126.03
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-1.26	-1.40	-1.55	-1.75	-1.84	-5.47	0.00	-5.18	-5.43	-5.71	-6.05	-6.22	-9.24
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-20.65	-22.97	-25.31	-28.64	-30.19	-89.56	0.00	-84.90	-88.88	-93.52	-99.16	-101.89	-151.31
Columbus, OH	x	x	100	100	0.00	-17.95	-19.98	-22.01	-24.91	-26.25	-77.82	0.00	-73.84	-77.30	-81.33	-86.23	-88.60	-131.52
Dallas-Fort Worth, TX	x	-	100	-	0.00	-89.00	-99.02	-109.08	-123.46	-130.15	-385.82	0.00	-366.00	-383.16	-403.13	-427.46	-439.20	-652.03
Dayton-Springfield, OH	-	x	-	100	0.00	-6.30	-7.01	-7.72	-8.74	-9.21	-27.30	0.00	-25.90	-27.11	-28.53	-30.25	-31.08	-46.14
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-35.82	-39.86	-43.90	-49.68	-52.36	-154.99	0.00	-147.31	-154.22	-162.25	-172.04	-176.75	-262.12
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-40.33	-44.87	-49.43	-55.95	-58.98	-174.88	0.00	-165.85	-173.63	-182.68	-193.70	-199.03	-295.52
Door Co., WI	x	-	100	-	0.00	-0.25	-0.28	-0.31	-0.35	-0.37	-1.11	0.00	-1.05	-1.10	-1.15	-1.22	-1.26	-1.87
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.04	0.00	-0.04	-0.05	-0.05	-0.05	-0.05	-0.08
Evansville, IN	-	x	-	100	0.00	-2.87	-3.20	-3.51	-3.97	-4.15	-11.78	0.00	-11.81	-12.37	-13.00	-13.78	-14.12	-20.34
Greater Connecticut, CT	x	-	100	-	0.00	-15.73	-17.51	-19.29	-21.83	-23.03	-68.48	0.00	-64.70	-67.74	-71.27	-75.58	-77.66	-115.55
Greene Co., PA	x	-	100	-	0.00	-0.27	-0.30	-0.33	-0.38	-0.40	-1.18	0.00	-1.12	-1.17	-1.23	-1.31	-1.35	-2.00
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-7.16	-7.96	-8.77	-9.93	-10.47	-31.03	0.00	-29.44	-30.82	-32.42	-34.38	-35.32	-52.44
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-6.12	-6.81	-7.50	-8.49	-8.95	-26.55	0.00	-25.18	-26.36	-27.73	-29.41	-30.21	-44.86

Table B2-24
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.04	-0.04	-0.05	-0.06	-0.06	-0.16	0.00	-0.17	-0.17	-0.18	-0.19	-0.20	-0.28
Hickory, NC	-	x	-	100	0.00	-1.81	-2.01	-2.22	-2.51	-2.65	-7.87	0.00	-7.44	-7.79	-8.20	-8.70	-8.94	-13.28
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-52.68	-58.62	-64.57	-73.08	-77.04	-228.40	0.00	-216.66	-226.81	-238.64	-253.03	-259.99	-385.98
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-2.84	-3.17	-3.42	-3.86	-3.95	-9.20	0.00	-11.71	-12.27	-12.82	-13.58	-13.81	-17.56
Imperial Co., CA	x	-	100	-	0.00	-2.97	-3.30	-3.64	-4.12	-4.34	-12.87	0.00	-12.21	-12.78	-13.45	-14.26	-14.65	-21.75
Indianapolis, IN	-	x	-	100	0.00	-16.75	-18.63	-20.53	-23.23	-24.49	-72.60	0.00	-68.87	-72.10	-75.85	-80.43	-82.64	-122.69
Jamestown, NY	x	-	100	-	0.00	-1.15	-1.28	-1.41	-1.60	-1.69	-5.01	0.00	-4.75	-4.97	-5.23	-5.54	-5.69	-8.46
Jefferson Co., NY	x	-	100	-	0.00	-1.42	-1.58	-1.74	-1.97	-2.08	-6.16	0.00	-5.84	-6.11	-6.43	-6.82	-7.01	-10.41
Johnstown, PA	-	x	-	100	0.00	-0.86	-0.96	-1.06	-1.20	-1.26	-3.76	0.00	-3.54	-3.71	-3.90	-4.14	-4.25	-6.34
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-1.89	-2.10	-2.35	-2.67	-2.88	-9.94	0.00	-7.76	-8.12	-8.59	-9.11	-9.44	-15.67
Knoxville, TN	x	x	100	100	0.00	-10.30	-11.46	-12.63	-14.29	-15.06	-44.62	0.00	-42.37	-44.36	-46.67	-49.48	-50.84	-75.43
Lancaster, PA	-	x	-	100	0.00	-3.66	-4.07	-4.48	-5.07	-5.35	-15.85	0.00	-15.03	-15.74	-16.56	-17.56	-18.04	-26.79
Las Vegas, NV	x	-	100	-	0.00	-21.48	-23.90	-26.31	-29.77	-31.35	-92.17	0.00	-88.34	-92.48	-97.28	-103.14	-105.94	-156.38
Libby, MT	-	x	-	100	0.00	-0.06	-0.07	-0.07	-0.08	-0.09	-0.26	0.00	-0.25	-0.26	-0.28	-0.29	-0.30	-0.45
Liberty-Clairton, PA	-	x	-	100	0.00	-0.09	-0.10	-0.11	-0.12	-0.13	-0.42	0.00	-0.36	-0.38	-0.40	-0.43	-0.44	-0.69
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-161.34	-179.52	-197.70	-223.76	-235.78	-697.03	0.00	-663.52	-694.64	-730.78	-774.86	-796.05	-1,179.52
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-8.74	-9.72	-10.74	-12.16	-12.87	-39.25	0.00	-35.94	-37.62	-39.61	-42.01	-43.23	-65.45
Louisville, KY-IN	-	x	-	100	0.00	-8.71	-9.69	-10.66	-12.06	-12.68	-36.98	0.00	-35.82	-37.50	-39.43	-41.81	-42.92	-62.99
Macon, GA	-	x	-	100	0.00	-1.63	-1.81	-1.99	-2.25	-2.37	-6.84	0.00	-6.70	-7.01	-7.37	-7.81	-8.02	-11.70
Manitowoc Co., WI	x	-		-	0.00	-0.84	-0.93	-1.03	-1.16	-1.23	-3.66	0.00	-3.44	-3.60	-3.79	-4.02	-4.13	-6.16
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-1.37	-1.52	-1.67	-1.89	-2.00	-5.93	0.00	-5.61	-5.88	-6.18	-6.56	-6.74	-10.01
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-5.80	-6.45	-7.11	-8.05	-8.48	-25.15	0.00	-23.85	-24.97	-26.27	-27.86	-28.63	-42.50
Memphis, TN-AR	x	-	100	-	0.00	-8.01	-8.91	-9.81	-11.11	-11.71	-34.71	0.00	-32.93	-34.47	-36.27	-38.46	-39.51	-58.66
Milwaukee-Racine, WI	x	-	100	-	0.00	-14.47	-16.10	-17.74	-20.08	-21.17	-62.81	0.00	-59.51	-62.30	-65.55	-69.50	-71.41	-106.09
Nevada (Western Part), CA	x	-	100	-	0.00	-1.02	-1.13	-1.25	-1.41	-1.49	-4.43	0.00	-4.19	-4.39	-4.62	-4.90	-5.03	-7.48
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-119.80	-133.29	-146.84	-166.20	-175.22	-519.82	0.00	-492.65	-515.75	-542.65	-575.39	-591.22	-878.17
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-1.15	-1.28	-1.41	-1.60	-1.68	-4.96	0.00	-4.74	-4.96	-5.22	-5.53	-5.68	-8.40
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-65.00	-72.32	-79.69	-90.19	-95.10	-282.50	0.00	-267.31	-279.84	-294.45	-312.22	-320.83	-476.96
Phoenix-Mesa, AZ	x	-	100	-	0.00	-54.57	-60.73	-66.80	-75.59	-79.53	-232.45	0.00	-224.45	-234.98	-247.12	-262.01	-269.02	-395.49
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-14.04	-15.63	-17.21	-19.48	-20.53	-60.78	0.00	-57.75	-60.46	-63.61	-67.45	-69.30	-102.78
Poughkeepsie, NY	x	x	100	100	0.00	-12.40	-13.80	-15.20	-17.21	-18.14	-53.78	0.00	-51.00	-53.40	-56.18	-59.57	-61.21	-90.87

Table B2-24
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-7.46	-8.30	-9.14	-10.34	-10.90	-32.34	0.00	-30.66	-32.10	-33.77	-35.81	-36.80	-54.64
Reading, PA	-	x	-	100	0.00	-3.66	-4.07	-4.49	-5.08	-5.35	-15.87	0.00	-15.06	-15.76	-16.58	-17.58	-18.07	-26.82
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-15.01	-16.69	-18.41	-20.84	-22.00	-65.92	0.00	-61.70	-64.59	-67.98	-72.09	-74.11	-110.84
Rochester, NY	x	-	100	-	0.00	-10.78	-12.00	-13.22	-14.96	-15.77	-46.76	0.00	-44.35	-46.42	-48.84	-51.79	-53.22	-79.01
Rome, GA	-	x	-	100	0.00	-0.90	-1.01	-1.11	-1.25	-1.32	-3.92	0.00	-3.71	-3.89	-4.09	-4.34	-4.46	-6.62
Sacramento Metro, CA	x	-	50	-	0.00	-24.76	-27.55	-30.36	-34.36	-36.23	-107.64	0.00	-101.83	-106.60	-112.17	-118.94	-122.22	-181.72
San Diego, CA	x	-	100	-	0.00	-24.16	-26.88	-29.61	-33.52	-35.33	-104.73	0.00	-99.36	-104.02	-109.44	-116.04	-119.23	-177.00
San Francisco Bay Area, CA	x	-	100	-	0.00	-53.91	-60.02	-65.87	-74.53	-78.17	-223.42	0.00	-221.81	-232.25	-244.07	-258.75	-265.39	-384.26
San Joaquin Valley, CA	x	x	50	100	0.00	-56.72	-63.11	-69.46	-78.61	-82.77	-243.26	0.00	-233.27	-244.21	-256.87	-272.36	-279.72	-412.80
Sheboygan, WI	x	-	100	-	0.00	-1.03	-1.14	-1.26	-1.43	-1.51	-4.48	0.00	-4.23	-4.43	-4.66	-4.94	-5.08	-7.56
Springfield (Western MA), MA	x	-	100	-	0.00	-8.00	-8.91	-9.81	-11.10	-11.70	-34.70	0.00	-32.91	-34.46	-36.25	-38.44	-39.50	-58.64
St. Louis, MO-IL	x	x	100	100	0.00	-26.23	-29.18	-32.16	-36.40	-38.41	-114.62	0.00	-107.84	-112.89	-118.80	-125.98	-129.48	-193.10
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.74	-0.82	-0.90	-1.02	-1.08	-3.19	0.00	-3.03	-3.17	-3.34	-3.54	-3.64	-5.40
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-5.28	-5.87	-6.47	-7.32	-7.71	-22.87	0.00	-21.70	-22.71	-23.90	-25.34	-26.04	-38.65
Washington, DC-MD-VA	x	x	100	100	0.00	-51.54	-57.34	-63.19	-71.52	-75.43	-224.54	0.00	-211.92	-221.85	-233.45	-247.54	-254.39	-378.74
Wheeling, WV-OH	-	x	-	100	0.00	-1.23	-1.37	-1.51	-1.71	-1.80	-5.33	0.00	-5.06	-5.30	-5.57	-5.91	-6.07	-9.02
York, PA	-	x	-	100	0.00	-4.26	-4.73	-5.22	-5.90	-6.22	-18.46	0.00	-17.50	-18.32	-19.28	-20.44	-21.00	-31.18

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-25
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-0.01	-0.04	0.14	0.17	0.32	3.44	0.00	-0.01	-0.04	0.14	0.17	0.32	3.44
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.03	0.38	0.00	0.00	0.00	0.02	0.02	0.03	0.38
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.02	0.03	0.34	0.00	0.00	0.00	0.01	0.02	0.03	0.34
Atlanta, GA	x	x	100	100	0.00	-0.07	-0.19	0.73	0.90	1.68	18.29	0.00	-0.07	-0.19	0.73	0.90	1.68	18.29
Baltimore, MD	x	x	100	100	0.00	-0.03	-0.08	0.30	0.37	0.70	7.60	0.00	-0.03	-0.08	0.30	0.37	0.70	7.60
Baton Rouge, LA	x	-	100	-	0.00	-0.64	-0.73	-0.82	-0.90	-1.10	-5.36	0.00	-0.65	-0.73	-0.82	-0.90	-1.11	-5.37
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1.29	-1.43	-1.75	-1.93	-2.45	-13.27	0.00	-1.29	-1.44	-1.76	-1.93	-2.46	-13.27
Birmingham, AL	-	x	-	100	0.00	-0.01	-0.03	0.11	0.14	0.26	2.78	0.00	-0.01	-0.03	0.11	0.14	0.26	2.78
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-0.05	-0.13	0.49	0.61	1.14	12.37	0.00	-0.05	-0.13	0.49	0.61	1.14	12.37
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.01	-0.02	0.07	0.08	0.15	1.67	0.00	-0.01	-0.02	0.07	0.08	0.15	1.67
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-0.01	-0.03	0.12	0.15	0.27	2.97	0.00	-0.01	-0.03	0.12	0.15	0.27	2.97
Canton-Massillon, OH	-	x	-	100	0.00	-0.09	-0.10	-0.08	-0.09	-0.09	-0.08	0.00	-0.09	-0.10	-0.08	-0.09	-0.09	-0.08
Charleston, WV	-	x	-	100	0.00	0.00	-0.01	0.03	0.04	0.07	0.80	0.00	0.00	-0.01	0.03	0.04	0.07	0.80
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-0.02	-0.05	0.19	0.24	0.44	4.81	0.00	-0.02	-0.05	0.19	0.24	0.44	4.81
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.01	-0.01	0.06	0.07	0.13	1.42	0.00	-0.01	-0.01	0.06	0.07	0.13	1.42
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-1.00	-1.23	-0.55	-0.51	-0.12	8.40	0.00	-1.01	-1.23	-0.55	-0.52	-0.12	8.40
Chico, CA	x	-	100	-	0.00	0.00	-0.01	0.02	0.03	0.05	0.51	0.00	0.00	-0.01	0.02	0.03	0.05	0.51
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-0.02	-0.05	0.20	0.24	0.45	4.92	0.00	-0.02	-0.05	0.20	0.24	0.45	4.92
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.04	0.47	0.00	0.00	0.00	0.02	0.02	0.04	0.47
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-0.03	-0.07	0.28	0.35	0.65	7.09	0.00	-0.03	-0.07	0.28	0.35	0.65	7.09
Columbus, OH	x	x	100	100	0.00	-0.02	-0.05	0.18	0.22	0.42	4.59	0.00	-0.02	-0.05	0.18	0.22	0.42	4.59
Dallas-Fort Worth, TX	x	-	100	-	0.00	-0.07	-0.19	0.74	0.91	1.71	18.58	0.00	-0.07	-0.19	0.74	0.91	1.71	18.58
Dayton-Springfield, OH	-	x	-	100	0.00	-0.01	-0.02	0.09	0.11	0.20	2.15	0.00	-0.01	-0.02	0.09	0.11	0.20	2.15
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.14	-0.21	0.19	0.26	0.58	7.41	0.00	-0.14	-0.21	0.19	0.26	0.58	7.41
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.17	-0.26	0.36	0.46	0.96	11.68	0.00	-0.17	-0.26	0.36	0.46	0.96	11.68
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.00	0.00	0.01	0.09
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	-0.01	0.04	0.05	0.08	0.92	0.00	0.00	-0.01	0.04	0.05	0.08	0.92
Greater Connecticut, CT	x	-	100	-	0.00	-0.02	-0.05	0.19	0.23	0.43	4.70	0.00	-0.02	-0.05	0.19	0.23	0.43	4.70
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.11	0.00	0.00	0.00	0.00	0.01	0.01	0.11
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-0.01	-0.02	0.09	0.10	0.20	2.13	0.00	-0.01	-0.02	0.09	0.10	0.20	2.13
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-0.01	-0.02	0.08	0.09	0.18	1.93	0.00	-0.01	-0.02	0.08	0.09	0.18	1.93

Table B2-25
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Hickory, NC	-	x	-	100	0.00	0.00	-0.01	0.02	0.02	0.05	0.50	0.00	0.00	-0.01	0.02	0.02	0.05	0.50
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-2.68	-3.05	-3.12	-3.38	-3.96	-15.70	0.00	-2.69	-3.07	-3.14	-3.40	-3.98	-15.72
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.26	-0.29	-0.31	-0.33	-0.40	-1.67	0.00	-0.26	-0.29	-0.31	-0.33	-0.40	-1.67
Imperial Co., CA	x	-	100	-	0.00	0.00	-0.01	0.02	0.03	0.05	0.59	0.00	0.00	-0.01	0.02	0.03	0.05	0.59
Indianapolis, IN	-	x	-	100	0.00	-0.02	-0.04	0.17	0.21	0.39	4.28	0.00	-0.02	-0.04	0.17	0.21	0.39	4.28
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.04	0.40	0.00	0.00	0.00	0.02	0.02	0.04	0.40
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.01	0.02	0.03	0.37	0.00	0.00	0.00	0.01	0.02	0.03	0.37
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.02	0.03	0.32	0.00	0.00	0.00	0.01	0.02	0.03	0.32
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.02	0.03	0.31	0.00	0.00	0.00	0.01	0.02	0.03	0.31
Knoxville, TN	x	x	100	100	0.00	-0.01	-0.03	0.12	0.14	0.27	2.91	0.00	-0.01	-0.03	0.12	0.14	0.27	2.91
Lancaster, PA	-	x	-	100	0.00	0.00	-0.01	0.05	0.06	0.10	1.14	0.00	0.00	-0.01	0.05	0.06	0.10	1.14
Las Vegas, NV	x	-	100	-	0.00	-0.01	-0.04	0.15	0.18	0.35	3.77	0.00	-0.01	-0.04	0.15	0.18	0.35	3.77
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-1.57	-1.98	-0.40	-0.25	0.81	23.56	0.00	-1.57	-1.98	-0.41	-0.26	0.80	23.55
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-0.01	-0.02	0.08	0.10	0.18	1.94	0.00	-0.01	-0.02	0.08	0.10	0.18	1.94
Louisville, KY-IN	-	x	-	100	0.00	-0.01	-0.03	0.12	0.15	0.27	2.99	0.00	-0.01	-0.03	0.12	0.15	0.27	2.99
Macon, GA	-	x	-	100	0.00	0.00	-0.01	0.02	0.03	0.05	0.56	0.00	0.00	-0.01	0.02	0.03	0.05	0.56
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.01	0.01	0.03	0.29	0.00	0.00	0.00	0.01	0.01	0.03	0.29
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.03	0.28	0.00	0.00	0.00	0.01	0.01	0.03	0.28
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.00	-0.01	0.04	0.05	0.10	1.09	0.00	0.00	-0.01	0.04	0.05	0.10	1.09
Memphis, TN-AR	x	-	100	-	0.00	-0.22	-0.25	-0.18	-0.19	-0.16	0.35	0.00	-0.22	-0.26	-0.18	-0.19	-0.17	0.35
Milwaukee-Racine, WI	x	-	100	-	0.00	-0.02	-0.05	0.19	0.23	0.43	4.68	0.00	-0.02	-0.05	0.19	0.23	0.43	4.68
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.02	0.26	0.00	0.00	0.00	0.01	0.01	0.02	0.26
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.51	-0.80	1.03	1.33	2.83	34.52	0.00	-0.52	-0.80	1.03	1.33	2.82	34.51
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.04	0.42	0.00	0.00	0.00	0.02	0.02	0.04	0.42
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-1.42	-1.69	-1.15	-1.18	-0.99	3.30	0.00	-1.43	-1.70	-1.16	-1.19	-1.00	3.29
Phoenix-Mesa, AZ	x	-	100	-	0.00	-0.04	-0.11	0.42	0.51	0.96	10.47	0.00	-0.04	-0.11	0.42	0.51	0.96	10.47
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-0.02	-0.05	0.21	0.26	0.48	5.24	0.00	-0.02	-0.05	0.21	0.26	0.48	5.24
Poughkeepsie, NY	x	x	100	100	0.00	-0.01	-0.04	0.14	0.17	0.31	3.39	0.00	-0.01	-0.04	0.14	0.17	0.31	3.39

Table B2-25
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-0.01	-0.03	0.10	0.12	0.23	2.46	0.00	-0.01	-0.03	0.10	0.12	0.23	2.46
Reading, PA	-	x	-	100	0.00	0.00	-0.01	0.04	0.05	0.09	1.00	0.00	0.00	-0.01	0.04	0.05	0.09	1.00
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-0.01	-0.02	0.08	0.10	0.18	1.98	0.00	-0.01	-0.02	0.08	0.10	0.18	1.98
Rochester, NY	x	-	100	-	0.00	-0.01	-0.04	0.14	0.17	0.32	3.44	0.00	-0.01	-0.04	0.14	0.17	0.32	3.44
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.03	0.30	0.00	0.00	0.00	0.01	0.01	0.03	0.30
Sacramento Metro, CA	x	-	50	-	0.00	-0.02	-0.06	0.23	0.28	0.53	5.78	0.00	-0.02	-0.06	0.23	0.28	0.53	5.78
San Diego, CA	x	-	100	-	0.00	-0.03	-0.08	0.32	0.40	0.74	8.09	0.00	-0.03	-0.08	0.32	0.40	0.74	8.09
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.82	-1.02	-0.35	-0.30	0.13	9.29	0.00	-0.83	-1.03	-0.35	-0.30	0.13	9.29
San Joaquin Valley, CA	x	x	50	100	0.00	-0.17	-0.26	0.29	0.38	0.83	10.37	0.00	-0.17	-0.26	0.29	0.38	0.83	10.37
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.01	0.02	0.03	0.32	0.00	0.00	0.00	0.01	0.02	0.03	0.32
Springfield (Western MA), MA	x	-	100	-	0.00	-0.01	-0.03	0.10	0.12	0.23	2.47	0.00	-0.01	-0.03	0.10	0.12	0.23	2.47
St. Louis, MO-IL	x	x	100	100	0.00	-0.38	-0.47	-0.16	-0.14	0.06	4.27	0.00	-0.38	-0.47	-0.16	-0.14	0.06	4.26
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.02	-0.03	-0.02	-0.02	-0.02	0.03	0.00	-0.02	-0.03	-0.02	-0.02	-0.02	0.03
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-0.01	-0.02	0.06	0.08	0.15	1.66	0.00	-0.01	-0.02	0.06	0.08	0.15	1.66
Washington, DC-MD-VA	x	x	100	100	0.00	-0.05	-0.13	0.52	0.64	1.20	13.00	0.00	-0.05	-0.13	0.52	0.64	1.20	13.00
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.02	0.02	0.04	0.45	0.00	0.00	0.00	0.02	0.02	0.04	0.45
York, PA	-	x	-	100	0.00	0.00	-0.01	0.04	0.05	0.10	1.05	0.00	0.00	-0.01	0.04	0.05	0.10	1.05

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-26
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.05	0.00	0.49	0.57	0.74	9.68	0.00	0.14	0.09	0.62	0.71	0.90	10.10
Allegan Co., MI	x	-	100	-	0.00	0.01	0.00	0.05	0.06	0.08	1.06	0.00	0.02	0.01	0.07	0.08	0.10	1.10
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.05	0.06	0.08	1.02	0.00	0.01	0.01	0.07	0.08	0.10	1.07
Atlanta, GA	x	x	100	100	0.00	0.27	-0.03	2.83	3.32	4.31	56.09	0.00	0.81	0.52	3.57	4.14	5.22	58.56
Baltimore, MD	x	x	100	100	0.00	0.10	-0.01	1.07	1.26	1.64	21.27	0.00	0.31	0.20	1.35	1.57	1.98	22.21
Baton Rouge, LA	x	-	100	-	0.00	-1.89	-2.11	-2.29	-2.57	-3.06	-12.85	0.00	-4.39	-4.68	-4.95	-5.32	-5.88	-15.38
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-3.83	-4.24	-4.97	-5.59	-6.71	-32.99	0.00	-8.95	-9.48	-10.42	-11.25	-12.50	-38.38
Birmingham, AL	-	x	-	100	0.00	0.04	0.00	0.38	0.45	0.58	7.60	0.00	0.11	0.07	0.48	0.56	0.71	7.93
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.16	-0.02	1.68	1.97	2.56	33.35	0.00	0.48	0.31	2.12	2.46	3.10	34.82
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.02	0.00	0.23	0.28	0.36	4.66	0.00	0.07	0.04	0.30	0.34	0.43	4.87
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.04	0.00	0.40	0.47	0.61	7.97	0.00	0.11	0.07	0.51	0.59	0.74	8.32
Canton-Massillon, OH	-	x	-	100	0.00	-0.24	-0.28	-0.22	-0.24	-0.27	-0.05	0.00	-0.55	-0.60	-0.54	-0.58	-0.62	-0.31
Charleston, WV	-	x	-	100	0.00	0.01	0.00	0.11	0.12	0.16	2.09	0.00	0.03	0.02	0.13	0.15	0.19	2.18
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.07	-0.01	0.73	0.86	1.12	14.51	0.00	0.21	0.13	0.92	1.07	1.35	15.16
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.02	0.00	0.19	0.23	0.30	3.87	0.00	0.06	0.04	0.25	0.29	0.36	4.04
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-2.54	-3.09	-1.06	-1.08	-0.99	26.46	0.00	-5.76	-6.41	-4.35	-4.43	-4.37	24.77
Chico, CA	x	-	100	-	0.00	0.01	0.00	0.07	0.08	0.11	1.44	0.00	0.02	0.01	0.09	0.11	0.13	1.50
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.06	-0.01	0.68	0.80	1.04	13.56	0.00	0.20	0.13	0.86	1.00	1.26	14.16
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.01	0.00	0.06	0.07	0.09	1.22	0.00	0.02	0.01	0.08	0.09	0.11	1.28
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.09	-0.01	0.95	1.12	1.46	18.94	0.00	0.27	0.17	1.20	1.40	1.76	19.78
Columbus, OH	x	x	100	100	0.00	0.06	-0.01	0.66	0.77	1.01	13.09	0.00	0.19	0.12	0.83	0.97	1.22	13.67
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.26	-0.03	2.80	3.29	4.28	55.59	0.00	0.80	0.51	3.54	4.10	5.17	58.05
Dayton-Springfield, OH	-	x	-	100	0.00	0.03	0.00	0.29	0.34	0.44	5.76	0.00	0.08	0.05	0.37	0.43	0.54	6.01
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.20	-0.37	0.83	0.99	1.34	21.93	0.00	-0.39	-0.56	0.70	0.88	1.25	22.57
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.17	-0.39	1.32	1.56	2.09	31.95	0.00	-0.29	-0.52	1.29	1.58	2.14	33.01
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.02	0.23	0.00	0.00	0.00	0.01	0.02	0.02	0.24
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Evansville, IN	-	x	-	100	0.00	0.01	0.00	0.13	0.15	0.19	2.53	0.00	0.04	0.02	0.16	0.19	0.24	2.65
Greater Connecticut, CT	x	-	100	-	0.00	0.06	-0.01	0.66	0.77	1.00	13.01	0.00	0.19	0.12	0.83	0.96	1.21	13.58
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.01	0.02	0.02	0.28	0.00	0.00	0.00	0.02	0.02	0.03	0.29
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.03	0.00	0.30	0.35	0.45	5.90	0.00	0.09	0.05	0.38	0.44	0.55	6.16
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.03	0.00	0.27	0.31	0.40	5.27	0.00	0.08	0.05	0.33	0.39	0.49	5.50

Table B2-26
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Hickory, NC	-	x	-	100	0.00	0.01	0.00	0.07	0.08	0.11	1.41	0.00	0.02	0.01	0.09	0.10	0.13	1.47
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-7.70	-8.69	-8.53	-9.53	-11.23	-35.01	0.00	-17.85	-19.11	-19.26	-20.62	-22.55	-44.61
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.74	-0.84	-0.85	-0.95	-1.13	-3.96	0.00	-1.73	-1.85	-1.89	-2.03	-2.23	-4.91
Imperial Co., CA	x	-	100	-	0.00	0.01	0.00	0.09	0.11	0.14	1.82	0.00	0.03	0.02	0.12	0.13	0.17	1.90
Indianapolis, IN	-	x	-	100	0.00	0.06	-0.01	0.61	0.72	0.94	12.19	0.00	0.18	0.11	0.78	0.90	1.13	12.73
Jamestown, NY	x	-	100	-	0.00	0.01	0.00	0.05	0.06	0.08	1.06	0.00	0.02	0.01	0.07	0.08	0.10	1.11
Jefferson Co., NY	x	-	100	-	0.00	0.01	0.00	0.05	0.06	0.08	1.05	0.00	0.02	0.01	0.07	0.08	0.10	1.10
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.04	0.05	0.07	0.85	0.00	0.01	0.01	0.05	0.06	0.08	0.88
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.05	0.06	0.07	0.95	0.00	0.01	0.01	0.06	0.07	0.09	0.99
Knoxville, TN	x	x	100	100	0.00	0.04	0.00	0.41	0.48	0.63	8.16	0.00	0.12	0.08	0.52	0.60	0.76	8.52
Lancaster, PA	-	x	-	100	0.00	0.01	0.00	0.16	0.18	0.24	3.12	0.00	0.04	0.03	0.20	0.23	0.29	3.25
Las Vegas, NV	x	-	100	-	0.00	0.06	-0.01	0.60	0.71	0.92	11.94	0.00	0.17	0.11	0.76	0.88	1.11	12.47
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.09	0.00	0.00	0.00	0.01	0.01	0.01	0.10
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-3.70	-4.72	0.07	0.34	1.07	73.67	0.00	-8.27	-9.43	-4.49	-4.27	-3.53	72.58
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.03	0.00	0.29	0.34	0.44	5.72	0.00	0.08	0.05	0.36	0.42	0.53	5.98
Louisville, KY-IN	-	x	-	100	0.00	0.04	0.00	0.40	0.47	0.62	8.02	0.00	0.12	0.07	0.51	0.59	0.75	8.37
Macon, GA	-	x	-	100	0.00	0.01	0.00	0.08	0.09	0.12	1.50	0.00	0.02	0.01	0.10	0.11	0.14	1.57
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.04	0.05	0.06	0.76	0.00	0.01	0.01	0.05	0.06	0.07	0.80
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.04	0.05	0.07	0.85	0.00	0.01	0.01	0.05	0.06	0.08	0.88
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.02	0.00	0.17	0.20	0.26	3.38	0.00	0.05	0.03	0.21	0.25	0.31	3.53
Memphis, TN-AR	x	-	100	-	0.00	-0.58	-0.68	-0.46	-0.50	-0.56	1.38	0.00	-1.33	-1.46	-1.24	-1.31	-1.38	0.82
Milwaukee-Racine, WI	x	-	100	-	0.00	0.06	-0.01	0.64	0.75	0.98	12.69	0.00	0.18	0.12	0.81	0.94	1.18	13.25
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.04	0.04	0.06	0.76	0.00	0.01	0.01	0.05	0.06	0.07	0.79
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.59	-1.24	3.83	4.56	6.10	94.58	0.00	-1.03	-1.72	3.66	4.49	6.14	97.64
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.01	0.00	0.06	0.07	0.09	1.11	0.00	0.02	0.01	0.07	0.08	0.10	1.16
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-3.81	-4.48	-2.79	-3.03	-3.34	13.61	0.00	-8.72	-9.54	-7.90	-8.27	-8.66	10.07
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.15	-0.01	1.64	1.92	2.50	32.51	0.00	0.47	0.30	2.07	2.40	3.03	33.95
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.07	-0.01	0.69	0.81	1.05	13.71	0.00	0.20	0.13	0.87	1.01	1.28	14.31
Poughkeepsie, NY	x	x	100	100	0.00	0.05	0.00	0.48	0.57	0.74	9.61	0.00	0.14	0.09	0.61	0.71	0.89	10.03

Table B2-26
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.03	0.00	0.33	0.39	0.51	6.63	0.00	0.10	0.06	0.42	0.49	0.62	6.93
Reading, PA	-	x	-	100	0.00	0.01	0.00	0.14	0.17	0.22	2.83	0.00	0.04	0.03	0.18	0.21	0.26	2.95
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.03	0.00	0.34	0.40	0.52	6.71	0.00	0.10	0.06	0.43	0.50	0.62	7.00
Rochester, NY	x	-	100	-	0.00	0.04	0.00	0.47	0.55	0.72	9.36	0.00	0.13	0.09	0.60	0.69	0.87	9.78
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.04	0.05	0.06	0.81	0.00	0.01	0.01	0.05	0.06	0.08	0.85
Sacramento Metro, CA	x	-	50	-	0.00	0.08	-0.01	0.85	1.00	1.30	16.90	0.00	0.24	0.16	1.07	1.25	1.57	17.65
San Diego, CA	x	-	100	-	0.00	0.10	-0.01	1.10	1.29	1.67	21.77	0.00	0.31	0.20	1.38	1.61	2.03	22.74
San Francisco Bay Area, CA	x	-	100	-	0.00	-2.04	-2.52	-0.58	-0.54	-0.36	27.19	0.00	-4.60	-5.15	-3.17	-3.18	-3.02	26.07
San Joaquin Valley, CA	x	x	50	100	0.00	-0.21	-0.43	1.30	1.54	2.07	32.21	0.00	-0.37	-0.61	1.23	1.51	2.07	33.24
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.04	0.05	0.07	0.87	0.00	0.01	0.01	0.06	0.06	0.08	0.91
Springfield (Western MA), MA	x	-	100	-	0.00	0.03	0.00	0.34	0.40	0.52	6.78	0.00	0.10	0.06	0.43	0.50	0.63	7.08
St. Louis, MO-IL	x	x	100	100	0.00	-0.94	-1.16	-0.27	-0.26	-0.18	12.45	0.00	-2.12	-2.38	-1.47	-1.48	-1.40	11.93
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.06	-0.08	-0.05	-0.06	-0.07	0.10	0.00	-0.15	-0.16	-0.14	-0.15	-0.16	0.04
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.01	-0.01	0.22	0.26	0.34	4.52	0.00	0.04	0.02	0.27	0.31	0.40	4.71
Washington, DC-MD-VA	x	x	100	100	0.00	0.18	-0.02	1.86	2.18	2.83	36.85	0.00	0.53	0.34	2.34	2.72	3.43	38.48
Wheeling, WV-OH	-	x	-	100	0.00	0.01	0.00	0.06	0.07	0.09	1.19	0.00	0.02	0.01	0.08	0.09	0.11	1.24
York, PA	-	x	-	100	0.00	0.01	0.00	0.15	0.18	0.24	3.06	0.00	0.04	0.03	0.19	0.23	0.28	3.19

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-27
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.11	0.04	0.75	0.87	1.07	14.29	0.00	0.41	0.35	1.14	1.31	1.55	15.61
Allegan Co., MI	x	-	100	-	0.00	0.01	0.00	0.08	0.10	0.12	1.56	0.00	0.05	0.04	0.12	0.14	0.17	1.70
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.00	0.08	0.10	0.12	1.61	0.00	0.05	0.04	0.13	0.15	0.17	1.76
Atlanta, GA	x	x	100	100	0.00	0.70	0.27	4.78	5.58	6.86	91.23	0.00	2.65	2.25	7.29	8.35	9.91	99.66
Baltimore, MD	x	x	100	100	0.00	0.24	0.09	1.64	1.91	2.35	31.26	0.00	0.91	0.77	2.50	2.86	3.39	34.15
Baton Rouge, LA	x	-	100	-	0.00	-2.94	-3.27	-3.54	-4.00	-4.70	-19.26	0.00	-9.67	-10.17	-10.69	-11.39	-12.27	-25.84
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-6.00	-6.61	-7.69	-8.71	-10.29	-49.61	0.00	-19.78	-20.74	-22.40	-23.93	-25.87	-63.86
Birmingham, AL	-	x	-	100	0.00	0.08	0.03	0.57	0.67	0.82	10.96	0.00	0.32	0.27	0.88	1.00	1.19	11.97
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.36	0.14	2.48	2.89	3.56	47.31	0.00	1.37	1.16	3.78	4.33	5.14	51.69
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.05	0.02	0.36	0.42	0.51	6.82	0.00	0.20	0.17	0.54	0.62	0.74	7.45
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.09	0.03	0.59	0.68	0.84	11.20	0.00	0.32	0.28	0.90	1.03	1.22	12.24
Canton-Massillon, OH	-	x	-	100	0.00	-0.37	-0.42	-0.34	-0.39	-0.45	-0.28	0.00	-1.20	-1.27	-1.22	-1.28	-1.36	-0.93
Charleston, WV	-	x	-	100	0.00	0.02	0.01	0.15	0.18	0.22	2.88	0.00	0.08	0.07	0.23	0.26	0.31	3.15
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.18	0.07	1.21	1.41	1.73	23.05	0.00	0.67	0.57	1.84	2.11	2.50	25.18
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.04	0.02	0.29	0.34	0.41	5.52	0.00	0.16	0.14	0.44	0.51	0.60	6.03
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-3.78	-4.57	-1.67	-1.75	-1.85	38.58	0.00	-12.17	-13.20	-10.28	-10.52	-10.66	35.14
Chico, CA	x	-	100	-	0.00	0.02	0.01	0.11	0.13	0.16	2.10	0.00	0.06	0.05	0.17	0.19	0.23	2.29
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.15	0.06	1.04	1.21	1.49	19.86	0.00	0.58	0.49	1.59	1.82	2.16	21.70
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.01	0.00	0.09	0.10	0.13	1.68	0.00	0.05	0.04	0.13	0.15	0.18	1.84
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.20	0.08	1.39	1.62	2.00	26.54	0.00	0.77	0.65	2.12	2.43	2.88	28.99
Columbus, OH	x	x	100	100	0.00	0.15	0.06	1.03	1.20	1.48	19.71	0.00	0.57	0.49	1.58	1.81	2.14	21.53
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.67	0.26	4.60	5.37	6.61	87.92	0.00	2.55	2.16	7.03	8.05	9.55	96.04
Dayton-Springfield, OH	-	x	-	100	0.00	0.06	0.02	0.42	0.49	0.61	8.09	0.00	0.23	0.20	0.65	0.74	0.88	8.84
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.21	-0.44	1.33	1.58	1.98	33.61	0.00	-0.56	-0.80	1.15	1.46	1.94	35.91
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.15	-0.44	1.92	2.26	2.82	45.28	0.00	-0.32	-0.62	1.98	2.42	3.10	48.61
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.02	0.33	0.00	0.01	0.01	0.03	0.03	0.04	0.36
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Evansville, IN	-	x	-	100	0.00	0.03	0.01	0.19	0.22	0.27	3.65	0.00	0.11	0.09	0.29	0.33	0.40	3.99
Greater Connecticut, CT	x	-	100	-	0.00	0.14	0.06	0.99	1.15	1.42	18.87	0.00	0.55	0.46	1.51	1.73	2.05	20.62
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.03	0.38	0.00	0.01	0.01	0.03	0.03	0.04	0.41
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.07	0.03	0.45	0.52	0.65	8.58	0.00	0.25	0.21	0.69	0.79	0.93	9.37
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.06	0.02	0.40	0.46	0.57	7.54	0.00	0.22	0.19	0.60	0.69	0.82	8.24

Table B2-27
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.06
Hickory, NC	-	x	-	100	0.00	0.02	0.01	0.11	0.13	0.16	2.09	0.00	0.06	0.05	0.17	0.19	0.23	2.28
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-11.90	-13.39	-13.18	-14.83	-17.37	-52.56	0.00	-39.07	-41.25	-41.94	-44.50	-47.65	-77.20
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-1.16	-1.29	-1.33	-1.50	-1.76	-6.21	0.00	-3.80	-4.00	-4.13	-4.39	-4.72	-8.69
Imperial Co., CA	x	-	100	-	0.00	0.02	0.01	0.15	0.18	0.22	2.92	0.00	0.08	0.07	0.23	0.27	0.32	3.19
Indianapolis, IN	-	x	-	100	0.00	0.14	0.05	0.96	1.12	1.38	18.34	0.00	0.53	0.45	1.47	1.68	1.99	20.04
Jamestown, NY	x	-	100	-	0.00	0.01	0.00	0.08	0.09	0.11	1.49	0.00	0.04	0.04	0.12	0.14	0.16	1.62
Jefferson Co., NY	x	-	100	-	0.00	0.01	0.00	0.08	0.10	0.12	1.59	0.00	0.05	0.04	0.13	0.15	0.17	1.73
Johnstown, PA	-	x	-	100	0.00	0.01	0.00	0.06	0.07	0.09	1.16	0.00	0.03	0.03	0.09	0.11	0.13	1.27
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.01	0.00	0.08	0.09	0.11	1.52	0.00	0.04	0.04	0.12	0.14	0.16	1.66
Knoxville, TN	x	x	100	100	0.00	0.09	0.04	0.63	0.73	0.90	12.02	0.00	0.35	0.30	0.96	1.10	1.30	13.13
Lancaster, PA	-	x	-	100	0.00	0.03	0.01	0.23	0.27	0.34	4.48	0.00	0.13	0.11	0.36	0.41	0.49	4.90
Las Vegas, NV	x	-	100	-	0.00	0.15	0.06	1.04	1.21	1.49	19.86	0.00	0.58	0.49	1.59	1.82	2.16	21.70
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.01	0.01	0.01	0.08
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.12	0.00	0.00	0.00	0.01	0.01	0.01	0.13
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-5.33	-6.79	0.31	0.65	1.28	112.99	0.00	-16.93	-18.73	-11.28	-11.01	-10.31	112.79
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.07	0.03	0.46	0.54	0.67	8.87	0.00	0.26	0.22	0.71	0.81	0.96	9.69
Louisville, KY-IN	-	x	-	100	0.00	0.09	0.03	0.59	0.69	0.85	11.30	0.00	0.33	0.28	0.90	1.03	1.23	12.34
Macon, GA	-	x	-	100	0.00	0.02	0.01	0.11	0.13	0.16	2.12	0.00	0.06	0.05	0.17	0.19	0.23	2.32
Manitowoc Co., WI	x	-		-	0.00	0.01	0.00	0.06	0.07	0.08	1.07	0.00	0.03	0.03	0.09	0.10	0.12	1.17
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.00	0.07	0.08	0.10	1.35	0.00	0.04	0.03	0.11	0.12	0.15	1.48
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.04	0.02	0.29	0.34	0.41	5.50	0.00	0.16	0.14	0.44	0.50	0.60	6.01
Memphis, TN-AR	x	-	100	-	0.00	-0.89	-1.03	-0.74	-0.82	-0.94	1.49	0.00	-2.89	-3.09	-2.83	-2.96	-3.11	0.08
Milwaukee-Racine, WI	x	-	100	-	0.00	0.14	0.05	0.94	1.10	1.36	18.05	0.00	0.52	0.44	1.44	1.65	1.96	19.71
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.00	0.06	0.07	0.09	1.14	0.00	0.03	0.03	0.09	0.10	0.12	1.25
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.57	-1.43	5.58	6.59	8.23	133.98	0.00	-1.30	-2.22	5.50	6.79	8.76	143.64
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.01	0.00	0.08	0.09	0.12	1.54	0.00	0.04	0.04	0.12	0.14	0.17	1.68
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-5.77	-6.75	-4.37	-4.82	-5.48	18.90	0.00	-18.76	-20.09	-17.90	-18.68	-19.52	10.47
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.40	0.16	2.77	3.24	3.98	52.95	0.00	1.54	1.30	4.23	4.85	5.75	57.84
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.14	0.06	0.99	1.15	1.42	18.83	0.00	0.55	0.46	1.50	1.72	2.04	20.57
Poughkeepsie, NY	x	x	100	100	0.00	0.11	0.04	0.75	0.87	1.07	14.26	0.00	0.41	0.35	1.14	1.31	1.55	15.57

Table B2-27
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.07	0.03	0.49	0.57	0.71	9.40	0.00	0.27	0.23	0.75	0.86	1.02	10.27
Reading, PA	-	x	-	100	0.00	0.03	0.01	0.22	0.26	0.32	4.20	0.00	0.12	0.10	0.34	0.38	0.46	4.59
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.09	0.03	0.62	0.73	0.90	11.91	0.00	0.35	0.29	0.95	1.09	1.29	13.01
Rochester, NY	x	-	100	-	0.00	0.10	0.04	0.70	0.82	1.01	13.37	0.00	0.39	0.33	1.07	1.22	1.45	14.61
Rome, GA	-	x	-	100	0.00	0.01	0.00	0.06	0.07	0.09	1.15	0.00	0.03	0.03	0.09	0.10	0.12	1.25
Sacramento Metro, CA	x	-	50	-	0.00	0.20	0.08	1.36	1.59	1.96	26.03	0.00	0.75	0.64	2.08	2.38	2.83	28.43
San Diego, CA	x	-	100	-	0.00	0.23	0.09	1.61	1.88	2.31	30.73	0.00	0.89	0.76	2.46	2.81	3.34	33.57
San Francisco Bay Area, CA	x	-	100	-	0.00	-3.02	-3.70	-1.04	-1.05	-1.04	37.47	0.00	-9.71	-10.57	-7.86	-7.98	-7.99	35.25
San Joaquin Valley, CA	x	x	50	100	0.00	-0.16	-0.49	2.20	2.60	3.24	51.64	0.00	-0.31	-0.65	2.31	2.82	3.59	55.46
Sheboygan, WI	x	-	100	-	0.00	0.01	0.00	0.07	0.08	0.09	1.26	0.00	0.04	0.03	0.10	0.12	0.14	1.37
Springfield (Western MA), MA	x	-	100	-	0.00	0.07	0.03	0.51	0.60	0.73	9.77	0.00	0.28	0.24	0.78	0.89	1.06	10.67
St. Louis, MO-IL	x	x	100	100	0.00	-1.40	-1.71	-0.49	-0.49	-0.49	17.17	0.00	-4.49	-4.88	-3.64	-3.70	-3.71	16.13
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.10	-0.11	-0.09	-0.10	-0.11	0.05	0.00	-0.32	-0.35	-0.32	-0.34	-0.36	-0.11
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.04	0.00	0.32	0.38	0.47	6.44	0.00	0.14	0.11	0.47	0.54	0.65	7.01
Washington, DC-MD-VA	x	x	100	100	0.00	0.42	0.16	2.90	3.39	4.17	55.43	0.00	1.61	1.36	4.43	5.08	6.02	60.55
Wheeling, WV-OH	-	x	-	100	0.00	0.01	0.00	0.09	0.10	0.12	1.64	0.00	0.05	0.04	0.13	0.15	0.18	1.79
York, PA	-	x	-	100	0.00	0.04	0.01	0.24	0.28	0.35	4.65	0.00	0.14	0.11	0.37	0.43	0.51	5.08

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.

b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.

c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)

EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-28
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.18	0.10	0.99	1.16	1.39	18.45	0.00	0.86	0.80	1.81	2.06	2.37	21.18
Allegan Co., MI	x	-	100	-	0.00	0.02	0.01	0.11	0.13	0.15	2.01	0.00	0.09	0.09	0.20	0.22	0.26	2.30
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.01	0.13	0.15	0.18	2.36	0.00	0.11	0.10	0.23	0.26	0.30	2.70
Atlanta, GA	x	x	100	100	0.00	1.44	0.82	7.91	9.23	11.07	146.86	0.00	6.82	6.33	14.42	16.36	18.86	168.54
Baltimore, MD	x	x	100	100	0.00	0.39	0.22	2.16	2.51	3.02	40.02	0.00	1.86	1.73	3.93	4.46	5.14	45.93
Baton Rouge, LA	x	-	100	-	0.00	-4.09	-4.54	-4.94	-5.61	-6.56	-26.45	0.00	-16.54	-17.31	-18.20	-19.31	-20.55	-38.41
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-8.37	-9.23	-10.77	-12.25	-14.34	-68.42	0.00	-34.00	-35.50	-38.13	-40.56	-43.33	-94.73
Birmingham, AL	-	x	-	100	0.00	0.13	0.08	0.74	0.86	1.04	13.74	0.00	0.64	0.59	1.35	1.53	1.76	15.77
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.56	0.32	3.06	3.57	4.28	56.75	0.00	2.64	2.45	5.57	6.32	7.29	65.12
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.08	0.05	0.46	0.54	0.65	8.62	0.00	0.40	0.37	0.85	0.96	1.11	9.89
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.13	0.07	0.70	0.82	0.99	13.09	0.00	0.61	0.56	1.29	1.46	1.68	15.02
Canton-Massillon, OH	-	x	-	100	0.00	-0.51	-0.58	-0.51	-0.58	-0.67	-0.99	0.00	-2.05	-2.15	-2.13	-2.25	-2.37	-2.19
Charleston, WV	-	x	-	100	0.00	0.03	0.02	0.18	0.20	0.25	3.26	0.00	0.15	0.14	0.32	0.36	0.42	3.74
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.34	0.19	1.87	2.18	2.62	34.75	0.00	1.61	1.50	3.41	3.87	4.46	39.88
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.07	0.04	0.36	0.42	0.50	6.69	0.00	0.31	0.29	0.66	0.75	0.86	7.68
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-5.09	-6.13	-2.42	-2.60	-2.86	50.31	0.00	-20.00	-21.42	-17.82	-18.27	-18.57	45.99
Chico, CA	x	-	100	-	0.00	0.03	0.01	0.14	0.17	0.20	2.66	0.00	0.12	0.11	0.26	0.30	0.34	3.05
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.26	0.15	1.41	1.65	1.97	26.19	0.00	1.22	1.13	2.57	2.92	3.36	30.05
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.02	0.01	0.10	0.12	0.14	1.89	0.00	0.09	0.08	0.19	0.21	0.24	2.17
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.30	0.17	1.66	1.94	2.33	30.92	0.00	1.44	1.33	3.03	3.44	3.97	35.48
Columbus, OH	x	x	100	100	0.00	0.26	0.15	1.45	1.69	2.03	26.91	0.00	1.25	1.16	2.64	3.00	3.46	30.88
Dallas-Fort Worth, TX	x	-	100	-	0.00	1.31	0.75	7.18	8.38	10.05	133.35	0.00	6.19	5.75	13.09	14.86	17.12	153.04
Dayton-Springfield, OH	-	x	-	100	0.00	0.09	0.05	0.51	0.59	0.71	9.44	0.00	0.44	0.41	0.93	1.05	1.21	10.83
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.18	-0.47	1.97	2.33	2.82	47.61	0.00	-0.36	-0.67	2.05	2.55	3.23	53.28
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.16	-0.48	2.27	2.68	3.25	53.87	0.00	-0.24	-0.57	2.50	3.07	3.85	60.38
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.02	0.02	0.03	0.38	0.00	0.02	0.02	0.04	0.04	0.05	0.44
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Evansville, IN	-	x	-	100	0.00	0.04	0.03	0.24	0.28	0.34	4.51	0.00	0.21	0.19	0.44	0.50	0.58	5.17
Greater Connecticut, CT	x	-	100	-	0.00	0.23	0.13	1.26	1.48	1.77	23.49	0.00	1.09	1.01	2.31	2.62	3.02	26.96
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.02	0.03	0.03	0.41	0.00	0.02	0.02	0.04	0.05	0.05	0.47
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.11	0.06	0.58	0.67	0.81	10.72	0.00	0.50	0.46	1.05	1.19	1.38	12.31
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.09	0.05	0.49	0.58	0.69	9.17	0.00	0.43	0.40	0.90	1.02	1.18	10.52

Table B2-28
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.01	0.01	0.01	0.08
Hickory, NC	-	x	-	100	0.00	0.03	0.02	0.15	0.17	0.20	2.71	0.00	0.13	0.12	0.27	0.30	0.35	3.11
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-16.47	-18.51	-18.37	-20.79	-24.23	-71.90	0.00	-66.44	-69.73	-71.36	-75.44	-79.95	-115.70
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-1.61	-1.80	-1.90	-2.15	-2.51	-9.31	0.00	-6.51	-6.82	-7.11	-7.53	-8.01	-13.88
Imperial Co., CA	x	-	100	-	0.00	0.04	0.02	0.24	0.28	0.34	4.45	0.00	0.21	0.19	0.44	0.50	0.57	5.11
Indianapolis, IN	-	x	-	100	0.00	0.25	0.14	1.35	1.58	1.89	25.09	0.00	1.17	1.08	2.46	2.80	3.22	28.80
Jamestown, NY	x	-	100	-	0.00	0.02	0.01	0.09	0.11	0.13	1.73	0.00	0.08	0.07	0.17	0.19	0.22	1.98
Jefferson Co., NY	x	-	100	-	0.00	0.02	0.01	0.11	0.13	0.16	2.13	0.00	0.10	0.09	0.21	0.24	0.27	2.44
Johnstown, PA	-	x	-	100	0.00	0.01	0.01	0.07	0.08	0.10	1.28	0.00	0.06	0.06	0.13	0.14	0.16	1.47
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.02	0.01	0.12	0.14	0.17	2.29	0.00	0.11	0.10	0.22	0.25	0.29	2.62
Knoxville, TN	x	x	100	100	0.00	0.15	0.09	0.83	0.97	1.17	15.45	0.00	0.72	0.67	1.52	1.72	1.98	17.73
Lancaster, PA	-	x	-	100	0.00	0.05	0.03	0.29	0.34	0.41	5.48	0.00	0.25	0.24	0.54	0.61	0.70	6.29
Las Vegas, NV	x	-	100	-	0.00	0.32	0.18	1.75	2.04	2.45	32.48	0.00	1.51	1.40	3.19	3.62	4.17	37.27
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.09	0.00	0.00	0.00	0.01	0.01	0.01	0.11
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.12	0.00	0.01	0.01	0.01	0.01	0.02	0.14
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-6.91	-8.85	0.88	1.37	2.04	161.30	0.00	-26.48	-28.92	-18.78	-18.33	-17.35	167.25
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.12	0.07	0.68	0.80	0.96	12.67	0.00	0.59	0.55	1.24	1.41	1.63	14.54
Louisville, KY-IN	-	x	-	100	0.00	0.13	0.07	0.72	0.83	1.00	13.29	0.00	0.62	0.57	1.30	1.48	1.71	15.25
Macon, GA	-	x	-	100	0.00	0.02	0.01	0.13	0.16	0.19	2.50	0.00	0.12	0.11	0.25	0.28	0.32	2.87
Manitowoc Co., WI	x	-		-	0.00	0.01	0.01	0.07	0.08	0.09	1.25	0.00	0.06	0.05	0.12	0.14	0.16	1.43
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.01	0.11	0.13	0.15	2.04	0.00	0.09	0.09	0.20	0.23	0.26	2.34
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.09	0.05	0.47	0.55	0.66	8.69	0.00	0.40	0.37	0.85	0.97	1.12	9.97
Memphis, TN-AR	x	-	100	-	0.00	-1.23	-1.41	-1.12	-1.26	-1.45	0.21	0.00	-4.92	-5.20	-5.00	-5.24	-5.50	-2.35
Milwaukee-Racine, WI	x	-	100	-	0.00	0.21	0.12	1.17	1.36	1.63	21.66	0.00	1.01	0.93	2.13	2.41	2.78	24.85
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.01	0.08	0.10	0.11	1.52	0.00	0.07	0.07	0.15	0.17	0.20	1.75
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.62	-1.61	6.53	7.71	9.36	158.53	0.00	-1.35	-2.36	6.69	8.35	10.60	177.35
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.02	0.01	0.09	0.11	0.13	1.74	0.00	0.08	0.07	0.17	0.19	0.22	1.99
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-7.92	-9.21	-6.40	-7.14	-8.20	19.58	0.00	-31.55	-33.43	-31.16	-32.51	-33.86	5.40
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.82	0.46	4.47	5.22	6.26	83.05	0.00	3.86	3.58	8.15	9.25	10.66	95.31
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.21	0.12	1.13	1.32	1.59	21.07	0.00	0.98	0.91	2.07	2.35	2.71	24.19
Poughkeepsie, NY	x	x	100	100	0.00	0.18	0.10	1.00	1.17	1.40	18.58	0.00	0.86	0.80	1.82	2.07	2.39	21.32

Table B2-28
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.11	0.06	0.60	0.70	0.84	11.17	0.00	0.52	0.48	1.10	1.24	1.43	12.81
Reading, PA	-	x	-	100	0.00	0.05	0.03	0.30	0.34	0.41	5.48	0.00	0.25	0.24	0.54	0.61	0.70	6.29
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.22	0.12	1.20	1.40	1.67	22.21	0.00	1.03	0.96	2.18	2.47	2.85	25.49
Rochester, NY	x	-	100	-	0.00	0.16	0.09	0.87	1.01	1.22	16.15	0.00	0.75	0.70	1.59	1.80	2.07	18.54
Rome, GA	-	x	-	100	0.00	0.01	0.01	0.07	0.09	0.10	1.35	0.00	0.06	0.06	0.13	0.15	0.17	1.55
Sacramento Metro, CA	x	-	50	-	0.00	0.36	0.21	1.99	2.33	2.79	37.01	0.00	1.72	1.60	3.63	4.12	4.75	42.47
San Diego, CA	x	-	100	-	0.00	0.36	0.20	1.95	2.27	2.73	36.20	0.00	1.68	1.56	3.55	4.03	4.65	41.55
San Francisco Bay Area, CA	x	-	100	-	0.00	-4.14	-4.98	-1.98	-2.13	-2.35	40.62	0.00	-16.26	-17.42	-14.51	-14.87	-15.12	37.07
San Joaquin Valley, CA	x	x	50	100	0.00	0.01	-0.43	3.53	4.15	5.02	78.53	0.00	0.61	0.17	4.61	5.50	6.68	88.52
Sheboygan, WI	x	-	100	-	0.00	0.02	0.01	0.08	0.10	0.12	1.53	0.00	0.07	0.07	0.15	0.17	0.20	1.76
Springfield (Western MA), MA	x	-	100	-	0.00	0.12	0.07	0.65	0.75	0.90	11.99	0.00	0.56	0.52	1.18	1.34	1.54	13.76
St. Louis, MO-IL	x	x	100	100	0.00	-1.91	-2.30	-0.90	-0.97	-1.07	18.97	0.00	-7.50	-8.03	-6.68	-6.84	-6.96	17.36
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.14	-0.16	-0.14	-0.15	-0.18	-0.21	0.00	-0.56	-0.59	-0.58	-0.61	-0.64	-0.52
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.06	0.02	0.40	0.47	0.56	7.72	0.00	0.28	0.25	0.68	0.78	0.91	8.82
Washington, DC-MD-VA	x	x	100	100	0.00	0.75	0.43	4.14	4.83	5.80	76.86	0.00	3.57	3.31	7.55	8.56	9.87	88.21
Wheeling, WV-OH	-	x	-	100	0.00	0.02	0.01	0.10	0.12	0.14	1.84	0.00	0.09	0.08	0.18	0.21	0.24	2.12
York, PA	-	x	-	100	0.00	0.06	0.04	0.34	0.40	0.48	6.37	0.00	0.30	0.27	0.63	0.71	0.82	7.31

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-29
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-1.76	-2.04	-2.31	-2.34	-4.06	-28.02	0.00	-1.78	-2.06	-2.32	-2.35	-4.08	-28.04
Allegan Co., MI	x	-	100	-	0.00	-0.19	-0.22	-0.25	-0.26	-0.44	-3.07	0.00	-0.19	-0.22	-0.25	-0.26	-0.45	-3.07
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.18	-0.20	-0.23	-0.23	-0.40	-2.79	0.00	-0.18	-0.20	-0.23	-0.23	-0.41	-2.79
Atlanta, GA	x	x	100	100	0.00	-9.36	-10.85	-12.25	-12.41	-21.60	-148.94	0.00	-9.44	-10.93	-12.33	-12.50	-21.69	-149.03
Baltimore, MD	x	x	100	100	0.00	-3.91	-4.52	-5.11	-5.18	-9.00	-62.04	0.00	-3.94	-4.56	-5.15	-5.22	-9.04	-62.07
Baton Rouge, LA	x	-	100	-	0.00	-33.90	-37.89	-45.61	-49.96	-63.10	-322.52	0.00	-34.08	-38.08	-45.80	-50.16	-63.30	-322.72
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-66.99	-74.83	-90.17	-98.91	-124.13	-629.30	0.00	-67.34	-75.19	-90.55	-99.30	-124.52	-629.69
Birmingham, AL	-	x	-	100	0.00	-1.42	-1.64	-1.85	-1.88	-3.27	-22.59	0.00	-1.43	-1.65	-1.87	-1.89	-3.29	-22.60
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-6.34	-7.35	-8.30	-8.41	-14.63	-100.84	0.00	-6.40	-7.41	-8.36	-8.47	-14.69	-100.90
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.82	-0.95	-1.07	-1.08	-1.90	-13.25	0.00	-0.82	-0.95	-1.07	-1.08	-1.91	-13.25
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-1.53	-1.77	-2.00	-2.02	-3.52	-24.25	0.00	-1.54	-1.78	-2.01	-2.04	-3.53	-24.26
Canton-Massillon, OH	-	x	-	100	0.00	-4.74	-5.31	-6.37	-6.94	-8.97	-47.14	0.00	-4.77	-5.34	-6.40	-6.97	-9.00	-47.17
Charleston, WV	-	x	-	100	0.00	-0.41	-0.47	-0.53	-0.54	-0.94	-6.49	0.00	-0.41	-0.48	-0.54	-0.54	-0.94	-6.49
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-2.18	-2.53	-2.84	-2.84	-5.15	-36.50	0.00	-2.19	-2.55	-2.86	-2.86	-5.17	-36.52
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.71	-0.83	-0.93	-0.95	-1.66	-11.46	0.00	-0.72	-0.83	-0.94	-0.95	-1.66	-11.47
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-57.53	-64.65	-77.09	-83.55	-110.79	-600.52	0.00	-57.86	-64.99	-77.44	-83.92	-111.16	-600.89
Chico, CA	x	-	100	-	0.00	-0.26	-0.31	-0.34	-0.35	-0.61	-4.19	0.00	-0.27	-0.31	-0.35	-0.35	-0.61	-4.19
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-2.49	-2.88	-3.25	-3.29	-5.75	-39.77	0.00	-2.51	-2.90	-3.27	-3.31	-5.77	-39.80
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.24	-0.28	-0.31	-0.32	-0.55	-3.80	0.00	-0.24	-0.28	-0.31	-0.32	-0.55	-3.80
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-3.64	-4.22	-4.76	-4.82	-8.39	-57.84	0.00	-3.67	-4.25	-4.79	-4.86	-8.43	-57.87
Columbus, OH	x	x	100	100	0.00	-2.35	-2.72	-3.07	-3.11	-5.42	-37.36	0.00	-2.37	-2.74	-3.09	-3.14	-5.44	-37.38
Dallas-Fort Worth, TX	x	-	100	-	0.00	-9.52	-11.03	-12.46	-12.62	-21.96	-151.40	0.00	-9.60	-11.11	-12.54	-12.71	-22.05	-151.49
Dayton-Springfield, OH	-	x	-	100	0.00	-1.10	-1.28	-1.44	-1.46	-2.54	-17.53	0.00	-1.11	-1.29	-1.45	-1.47	-2.55	-17.54
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-9.95	-11.30	-13.24	-14.04	-20.43	-121.92	0.00	-10.02	-11.37	-13.31	-14.12	-20.50	-121.99
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-12.54	-14.28	-16.64	-17.53	-26.23	-160.70	0.00	-12.63	-14.37	-16.73	-17.62	-26.33	-160.80
Door Co., WI	x	-	100	-	0.00	-0.04	-0.05	-0.06	-0.06	-0.10	-0.71	0.00	-0.05	-0.05	-0.06	-0.06	-0.10	-0.71
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	0.00	0.00	0.00	-0.03
Evansville, IN	-	x	-	100	0.00	-0.43	-0.50	-0.56	-0.56	-1.01	-7.12	0.00	-0.43	-0.50	-0.57	-0.57	-1.02	-7.13
Greater Connecticut, CT	x	-	100	-	0.00	-2.42	-2.81	-3.17	-3.22	-5.59	-38.46	0.00	-2.44	-2.83	-3.19	-3.24	-5.61	-38.49
Greene Co., PA	x	-	100	-	0.00	-0.06	-0.06	-0.07	-0.07	-0.13	-0.88	0.00	-0.06	-0.06	-0.07	-0.07	-0.13	-0.88
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-1.09	-1.26	-1.43	-1.45	-2.51	-17.34	0.00	-1.10	-1.27	-1.44	-1.46	-2.52	-17.35
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-0.99	-1.14	-1.29	-1.31	-2.28	-15.71	0.00	-1.00	-1.15	-1.30	-1.32	-2.29	-15.72

Table B2-29
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.11	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.11
Hickory, NC	-	x	-	100	0.00	-0.26	-0.30	-0.34	-0.34	-0.59	-4.08	0.00	-0.26	-0.30	-0.34	-0.34	-0.59	-4.08
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-142.99	-159.98	-192.25	-210.25	-267.62	-1,381.43	0.00	-143.75	-160.76	-193.07	-211.10	-268.48	-1,382.28
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-13.53	-15.14	-18.20	-19.91	-25.29	-130.29	0.00	-13.60	-15.21	-18.27	-19.99	-25.38	-130.37
Imperial Co., CA	x	-	100	-	0.00	-0.30	-0.35	-0.40	-0.40	-0.70	-4.83	0.00	-0.31	-0.35	-0.40	-0.41	-0.70	-4.84
Indianapolis, IN	-	x	-	100	0.00	-2.19	-2.54	-2.87	-2.91	-5.06	-34.88	0.00	-2.21	-2.56	-2.89	-2.93	-5.08	-34.90
Jamestown, NY	x	-	100	-	0.00	-0.20	-0.24	-0.27	-0.27	-0.47	-3.23	0.00	-0.20	-0.24	-0.27	-0.27	-0.47	-3.23
Jefferson Co., NY	x	-	100	-	0.00	-0.19	-0.22	-0.25	-0.25	-0.44	-3.00	0.00	-0.19	-0.22	-0.25	-0.25	-0.44	-3.00
Johnstown, PA	-	x	-	100	0.00	-0.17	-0.19	-0.22	-0.22	-0.39	-2.65	0.00	-0.17	-0.19	-0.22	-0.22	-0.39	-2.65
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.18	-0.20	-0.23	-0.23	-0.40	-2.68	0.00	-0.18	-0.20	-0.23	-0.24	-0.40	-2.69
Knoxville, TN	x	x	100	100	0.00	-1.49	-1.72	-1.95	-1.97	-3.43	-23.68	0.00	-1.50	-1.74	-1.96	-1.99	-3.45	-23.69
Lancaster, PA	-	x	-	100	0.00	-0.58	-0.68	-0.76	-0.77	-1.34	-9.27	0.00	-0.59	-0.68	-0.77	-0.78	-1.35	-9.27
Las Vegas, NV	x	-	100	-	0.00	-1.92	-2.23	-2.51	-2.55	-4.44	-30.61	0.00	-1.94	-2.24	-2.53	-2.56	-4.45	-30.63
Libby, MT	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.15	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.15
Liberty-Clairton, PA	-	x	-	100	0.00	-0.02	-0.02	-0.03	-0.03	-0.04	-0.31	0.00	-0.02	-0.02	-0.03	-0.03	-0.04	-0.31
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-93.36	-105.11	-124.94	-134.91	-181.87	-1,004.35	0.00	-93.91	-105.67	-125.52	-135.52	-182.49	-1,004.96
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-1.00	-1.16	-1.31	-1.33	-2.31	-15.89	0.00	-1.01	-1.17	-1.32	-1.34	-2.32	-15.90
Louisville, KY-IN	-	x	-	100	0.00	-1.49	-1.72	-1.94	-1.97	-3.45	-23.94	0.00	-1.50	-1.74	-1.96	-1.98	-3.46	-23.95
Macon, GA	-	x	-	100	0.00	-0.28	-0.32	-0.36	-0.36	-0.64	-4.45	0.00	-0.28	-0.32	-0.36	-0.37	-0.64	-4.45
Manitowoc Co., WI	x	-		-	0.00	-0.15	-0.17	-0.19	-0.20	-0.34	-2.34	0.00	-0.15	-0.17	-0.19	-0.20	-0.34	-2.34
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.14	-0.17	-0.19	-0.19	-0.33	-2.27	0.00	-0.14	-0.17	-0.19	-0.19	-0.33	-2.27
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.56	-0.65	-0.73	-0.74	-1.29	-8.88	0.00	-0.56	-0.65	-0.74	-0.75	-1.29	-8.89
Memphis, TN-AR	x	-	100	-	0.00	-11.98	-13.43	-16.08	-17.50	-22.77	-120.76	0.00	-12.04	-13.50	-16.15	-17.57	-22.84	-120.83
Milwaukee-Racine, WI	x	-	100	-	0.00	-2.40	-2.79	-3.15	-3.19	-5.54	-38.21	0.00	-2.42	-2.81	-3.17	-3.21	-5.57	-38.24
Nevada (Western Part), CA	x	-	100	-	0.00	-0.14	-0.16	-0.18	-0.18	-0.31	-2.16	0.00	-0.14	-0.16	-0.18	-0.18	-0.31	-2.16
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-38.56	-43.89	-51.17	-53.98	-80.34	-489.83	0.00	-38.82	-44.16	-51.45	-54.27	-80.64	-490.12
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.21	-0.25	-0.28	-0.28	-0.49	-3.42	0.00	-0.22	-0.25	-0.28	-0.29	-0.50	-3.42
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-79.42	-89.09	-106.57	-115.94	-151.18	-803.65	0.00	-79.86	-89.54	-107.05	-116.43	-151.67	-804.14
Phoenix-Mesa, AZ	x	-	100	-	0.00	-5.23	-6.07	-6.84	-6.91	-12.13	-84.05	0.00	-5.27	-6.11	-6.89	-6.96	-12.18	-84.10
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-2.68	-3.10	-3.50	-3.55	-6.18	-42.61	0.00	-2.70	-3.12	-3.53	-3.57	-6.20	-42.64
Poughkeepsie, NY	x	x	100	100	0.00	-1.74	-2.02	-2.28	-2.31	-4.01	-27.67	0.00	-1.75	-2.03	-2.29	-2.32	-4.03	-27.68

Table B2-29
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-1.26	-1.46	-1.65	-1.67	-2.90	-20.02	0.00	-1.27	-1.47	-1.66	-1.68	-2.92	-20.03
Reading, PA	-	x	-	100	0.00	-0.51	-0.59	-0.67	-0.68	-1.18	-8.13	0.00	-0.52	-0.60	-0.67	-0.68	-1.18	-8.13
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-1.02	-1.18	-1.33	-1.35	-2.35	-16.19	0.00	-1.03	-1.19	-1.34	-1.36	-2.36	-16.20
Rochester, NY	x	-	100	-	0.00	-1.76	-2.04	-2.31	-2.34	-4.07	-28.03	0.00	-1.78	-2.06	-2.32	-2.35	-4.08	-28.05
Rome, GA	-	x	-	100	0.00	-0.15	-0.18	-0.20	-0.20	-0.36	-2.45	0.00	-0.16	-0.18	-0.20	-0.21	-0.36	-2.45
Sacramento Metro, CA	x	-	50	-	0.00	-2.96	-3.43	-3.87	-3.92	-6.82	-47.05	0.00	-2.98	-3.45	-3.90	-3.95	-6.85	-47.08
San Diego, CA	x	-	100	-	0.00	-4.14	-4.80	-5.42	-5.50	-9.56	-65.91	0.00	-4.18	-4.84	-5.46	-5.53	-9.60	-65.95
San Francisco Bay Area, CA	x	-	100	-	0.00	-47.62	-53.56	-63.77	-69.00	-92.22	-504.43	0.00	-47.90	-53.85	-64.07	-69.30	-92.53	-504.74
San Joaquin Valley, CA	x	x	50	100	0.00	-12.57	-14.29	-16.69	-17.66	-26.01	-157.03	0.00	-12.65	-14.38	-16.78	-17.75	-26.10	-157.13
Sheboygan, WI	x	-	100	-	0.00	-0.16	-0.19	-0.22	-0.22	-0.38	-2.61	0.00	-0.17	-0.19	-0.22	-0.22	-0.38	-2.61
Springfield (Western MA), MA	x	-	100	-	0.00	-1.26	-1.47	-1.66	-1.68	-2.92	-20.12	0.00	-1.28	-1.48	-1.67	-1.69	-2.93	-20.13
St. Louis, MO-IL	x	x	100	100	0.00	-22.29	-25.07	-29.85	-32.31	-43.13	-235.65	0.00	-22.42	-25.20	-29.99	-32.45	-43.28	-235.79
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-1.33	-1.49	-1.78	-1.94	-2.52	-13.36	0.00	-1.33	-1.50	-1.79	-1.95	-2.53	-13.37
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-1.03	-1.19	-1.36	-1.40	-2.31	-15.37	0.00	-1.04	-1.20	-1.37	-1.41	-2.32	-15.38
Washington, DC-MD-VA	x	x	100	100	0.00	-6.70	-7.77	-8.78	-8.90	-15.45	-106.34	0.00	-6.76	-7.82	-8.84	-8.96	-15.51	-106.40
Wheeling, WV-OH	-	x	-	100	0.00	-0.23	-0.27	-0.30	-0.31	-0.54	-3.69	0.00	-0.23	-0.27	-0.31	-0.31	-0.54	-3.69
York, PA	-	x	-	100	0.00	-0.54	-0.63	-0.71	-0.72	-1.25	-8.59	0.00	-0.54	-0.63	-0.71	-0.72	-1.25	-8.60

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-30
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-3.94	-3.54	-10.06	-11.36	-20.74	-201.85	0.00	-9.98	-9.61	-16.88	-18.25	-27.68	-198.93
Allegan Co., MI	x	-	100	-	0.00	-0.43	-0.39	-1.10	-1.24	-2.27	-22.07	0.00	-1.09	-1.05	-1.85	-2.00	-3.03	-21.75
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.42	-0.38	-1.07	-1.20	-2.20	-21.37	0.00	-1.06	-1.02	-1.79	-1.93	-2.93	-21.07
Atlanta, GA	x	x	100	100	0.00	-22.79	-20.49	-58.29	-65.83	-120.18	-1,169.83	0.00	-57.77	-55.61	-97.75	-105.70	-160.38	-1,152.89
Baltimore, MD	x	x	100	100	0.00	-8.69	-7.82	-22.17	-25.03	-45.66	-444.07	0.00	-22.02	-21.21	-37.20	-40.23	-60.98	-437.72
Baton Rouge, LA	x	-	100	-	0.00	-100.20	-110.50	-131.37	-147.54	-177.40	-866.16	0.00	-234.31	-247.95	-276.03	-297.26	-330.76	-1,010.24
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-198.85	-219.88	-257.12	-288.71	-341.95	-1,595.62	0.00	-464.44	-492.17	-543.37	-585.11	-645.63	-1,887.86
Birmingham, AL	-	x	-	100	0.00	-3.07	-2.76	-7.88	-8.89	-16.25	-158.36	0.00	-7.79	-7.49	-13.20	-14.27	-21.67	-156.04
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-13.59	-12.23	-34.71	-39.19	-71.52	-695.82	0.00	-34.44	-33.16	-58.22	-62.96	-95.48	-685.81
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-1.78	-1.58	-4.70	-5.31	-9.80	-96.41	0.00	-4.54	-4.34	-7.82	-8.46	-12.97	-94.83
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-3.25	-2.92	-8.30	-9.37	-17.09	-166.30	0.00	-8.23	-7.93	-13.92	-15.05	-22.82	-163.91
Canton-Massillon, OH	-	x	-	100	0.00	-13.75	-15.02	-18.85	-21.18	-26.65	-147.01	0.00	-32.27	-33.99	-38.88	-41.88	-47.84	-165.33
Charleston, WV	-	x	-	100	0.00	-0.85	-0.77	-2.18	-2.46	-4.48	-43.63	0.00	-2.16	-2.08	-3.65	-3.94	-5.98	-43.00
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-5.13	-4.46	-14.10	-15.93	-29.80	-296.80	0.00	-13.16	-12.50	-23.21	-25.11	-39.04	-291.28
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-1.56	-1.41	-4.01	-4.53	-8.27	-80.59	0.00	-3.97	-3.82	-6.72	-7.27	-11.03	-79.41
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-163.56	-176.63	-237.38	-266.88	-354.00	-2,198.89	0.00	-386.10	-404.11	-478.80	-515.98	-608.64	-2,393.96
Chico, CA	x	-	100	-	0.00	-0.58	-0.53	-1.49	-1.69	-3.08	-29.94	0.00	-1.48	-1.42	-2.50	-2.71	-4.11	-29.51
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-5.41	-4.84	-13.96	-15.77	-28.88	-282.06	0.00	-13.72	-13.19	-23.35	-25.25	-38.44	-277.81
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.50	-0.45	-1.27	-1.44	-2.62	-25.51	0.00	-1.26	-1.22	-2.13	-2.31	-3.50	-25.14
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-7.71	-6.94	-19.71	-22.25	-40.61	-395.17	0.00	-19.55	-18.82	-33.06	-35.75	-54.22	-389.48
Columbus, OH	x	x	100	100	0.00	-5.32	-4.79	-13.61	-15.37	-28.06	-273.11	0.00	-13.49	-12.99	-22.82	-24.68	-37.45	-269.16
Dallas-Fort Worth, TX	x	-	100	-	0.00	-22.61	-20.34	-57.81	-65.28	-119.16	-1,159.69	0.00	-57.32	-55.18	-96.95	-104.84	-159.04	-1,142.94
Dayton-Springfield, OH	-	x	-	100	0.00	-2.34	-2.11	-5.99	-6.76	-12.35	-120.17	0.00	-5.94	-5.72	-10.05	-10.86	-16.48	-118.43
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-26.64	-27.38	-47.12	-53.08	-81.44	-648.03	0.00	-64.21	-65.57	-88.39	-95.38	-124.49	-664.98
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-31.86	-32.30	-59.12	-66.62	-105.15	-869.39	0.00	-77.25	-78.37	-109.12	-117.78	-157.17	-884.85
Door Co., WI	x	-	100	-	0.00	-0.10	-0.09	-0.24	-0.27	-0.50	-4.87	0.00	-0.24	-0.23	-0.41	-0.44	-0.67	-4.80
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.21	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.20
Evansville, IN	-	x	-	100	0.00	-0.92	-0.80	-2.49	-2.81	-5.24	-51.97	0.00	-2.34	-2.23	-4.11	-4.44	-6.88	-51.03
Greater Connecticut, CT	x	-	100	-	0.00	-5.33	-4.80	-13.58	-15.34	-27.96	-271.72	0.00	-13.51	-13.02	-22.80	-24.66	-37.35	-267.86
Greene Co., PA	x	-	100	-	0.00	-0.11	-0.10	-0.29	-0.33	-0.60	-5.81	0.00	-0.29	-0.28	-0.49	-0.53	-0.80	-5.73
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-2.40	-2.16	-6.13	-6.93	-12.64	-123.05	0.00	-6.08	-5.85	-10.29	-11.12	-16.87	-121.27
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-2.14	-1.93	-5.48	-6.18	-11.29	-109.84	0.00	-5.43	-5.23	-9.19	-9.93	-15.07	-108.25

Table B2-30
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.01	-0.01	-0.04	-0.04	-0.08	-0.75	0.00	-0.04	-0.03	-0.06	-0.07	-0.10	-0.74
Hickory, NC	-	x	-	100	0.00	-0.58	-0.52	-1.47	-1.66	-3.03	-29.45	0.00	-1.46	-1.41	-2.47	-2.67	-4.04	-29.03
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-420.26	-461.97	-560.12	-629.16	-769.64	-3,944.50	0.00	-984.20	-1,039.71	-1,168.96	-1,259.01	-1,414.58	-4,532.89
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-39.77	-43.77	-52.74	-59.24	-72.08	-364.07	0.00	-93.10	-98.41	-110.30	-118.79	-133.07	-420.23
Imperial Co., CA	x	-	100	-	0.00	-0.74	-0.66	-1.89	-2.13	-3.89	-37.90	0.00	-1.87	-1.80	-3.17	-3.43	-5.20	-37.35
Indianapolis, IN	-	x	-	100	0.00	-4.96	-4.46	-12.68	-14.32	-26.14	-254.37	0.00	-12.57	-12.10	-21.26	-22.99	-34.88	-250.69
Jamestown, NY	x	-	100	-	0.00	-0.43	-0.39	-1.10	-1.24	-2.27	-22.09	0.00	-1.09	-1.05	-1.85	-2.00	-3.03	-21.77
Jefferson Co., NY	x	-	100	-	0.00	-0.43	-0.39	-1.10	-1.24	-2.26	-22.01	0.00	-1.09	-1.05	-1.84	-1.99	-3.02	-21.70
Johnstown, PA	-	x	-	100	0.00	-0.35	-0.31	-0.88	-1.00	-1.82	-17.68	0.00	-0.88	-0.85	-1.48	-1.60	-2.43	-17.43
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.47	-0.44	-1.09	-1.24	-2.18	-20.44	0.00	-1.17	-1.15	-1.88	-2.04	-2.98	-20.27
Knoxville, TN	x	x	100	100	0.00	-3.31	-2.98	-8.47	-9.57	-17.48	-170.16	0.00	-8.39	-8.08	-14.21	-15.36	-23.32	-167.69
Lancaster, PA	-	x	-	100	0.00	-1.27	-1.14	-3.24	-3.66	-6.68	-65.02	0.00	-3.21	-3.10	-5.44	-5.88	-8.92	-64.09
Las Vegas, NV	x	-	100	-	0.00	-4.82	-4.32	-12.36	-13.96	-25.53	-248.82	0.00	-12.21	-11.75	-20.71	-22.40	-34.03	-245.15
Libby, MT	-	x	-	100	0.00	-0.02	-0.02	-0.05	-0.06	-0.11	-1.07	0.00	-0.05	-0.05	-0.09	-0.10	-0.15	-1.06
Liberty-Clairton, PA	-	x	-	100	0.00	-0.04	-0.04	-0.10	-0.11	-0.20	-1.93	0.00	-0.10	-0.10	-0.17	-0.18	-0.27	-1.91
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-263.79	-282.44	-397.62	-447.20	-612.47	-4,052.64	0.00	-625.01	-651.33	-790.39	-851.97	-1,025.91	-4,341.38
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-2.38	-2.15	-6.01	-6.79	-12.35	-119.79	0.00	-6.01	-5.80	-10.11	-10.93	-16.53	-118.13
Louisville, KY-IN	-	x	-	100	0.00	-3.14	-2.80	-8.18	-9.24	-16.98	-166.36	0.00	-7.98	-7.66	-13.65	-14.76	-22.55	-163.76
Macon, GA	-	x	-	100	0.00	-0.58	-0.52	-1.52	-1.72	-3.17	-31.07	0.00	-1.48	-1.42	-2.54	-2.74	-4.20	-30.58
Manitowoc Co., WI	x	-		-	0.00	-0.31	-0.28	-0.80	-0.90	-1.64	-15.95	0.00	-0.80	-0.77	-1.34	-1.45	-2.20	-15.73
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.35	-0.31	-0.88	-1.00	-1.82	-17.67	0.00	-0.88	-0.84	-1.48	-1.60	-2.43	-17.42
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-1.37	-1.24	-3.51	-3.97	-7.24	-70.45	0.00	-3.48	-3.35	-5.89	-6.37	-9.66	-69.43
Memphis, TN-AR	x	-	100	-	0.00	-34.51	-37.60	-48.05	-53.99	-68.96	-394.12	0.00	-81.14	-85.32	-98.51	-106.13	-122.31	-438.85
Milwaukee-Racine, WI	x	-	100	-	0.00	-5.17	-4.66	-13.21	-14.92	-27.22	-264.81	0.00	-13.11	-12.63	-22.16	-23.97	-36.34	-261.00
Nevada (Western Part), CA	x	-	100	-	0.00	-0.31	-0.28	-0.79	-0.89	-1.63	-15.84	0.00	-0.78	-0.76	-1.33	-1.43	-2.17	-15.61
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-98.53	-100.22	-180.78	-203.69	-319.44	-2,618.75	0.00	-238.53	-242.38	-334.93	-361.48	-479.90	-2,670.13
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.45	-0.40	-1.15	-1.30	-2.37	-23.16	0.00	-1.13	-1.09	-1.92	-2.08	-3.16	-22.81
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-229.16	-249.33	-321.15	-360.93	-463.88	-2,689.58	0.00	-539.14	-566.49	-656.77	-707.60	-818.49	-2,982.88
Phoenix-Mesa, AZ	x	-	100	-	0.00	-12.79	-11.41	-33.25	-37.55	-68.95	-674.84	0.00	-32.51	-31.20	-55.52	-60.04	-91.61	-664.40
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-5.56	-4.99	-14.23	-16.07	-29.35	-285.78	0.00	-14.09	-13.56	-23.85	-25.79	-39.15	-281.62
Poughkeepsie, NY	x	x	100	100	0.00	-3.91	-3.52	-9.99	-11.28	-20.59	-200.39	0.00	-9.91	-9.54	-16.76	-18.12	-27.49	-197.49

Table B2-30
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-2.70	-2.43	-6.90	-7.79	-14.22	-138.41	0.00	-6.85	-6.59	-11.58	-12.52	-18.99	-136.42
Reading, PA	-	x	-	100	0.00	-1.15	-1.03	-2.94	-3.32	-6.06	-58.97	0.00	-2.92	-2.81	-4.93	-5.33	-8.09	-58.12
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-2.76	-2.49	-7.01	-7.92	-14.43	-140.14	0.00	-6.99	-6.74	-11.78	-12.74	-19.29	-138.17
Rochester, NY	x	-	100	-	0.00	-3.81	-3.43	-9.74	-11.00	-20.07	-195.35	0.00	-9.66	-9.30	-16.33	-17.66	-26.79	-192.53
Rome, GA	-	x	-	100	0.00	-0.33	-0.30	-0.84	-0.95	-1.74	-16.91	0.00	-0.84	-0.80	-1.41	-1.53	-2.32	-16.67
Sacramento Metro, CA	x	-	50	-	0.00	-6.87	-6.18	-17.57	-19.84	-36.22	-352.55	0.00	-17.42	-16.77	-29.47	-31.87	-48.35	-347.45
San Diego, CA	x	-	100	-	0.00	-8.86	-7.96	-22.64	-25.57	-46.67	-454.20	0.00	-22.45	-21.61	-37.97	-41.06	-62.29	-447.64
San Francisco Bay Area, CA	x	-	100	-	0.00	-134.39	-144.69	-197.74	-222.35	-298.45	-1,899.09	0.00	-317.67	-331.97	-396.73	-427.57	-508.18	-2,054.66
San Joaquin Valley, CA	x	x	50	100	0.00	-33.92	-34.53	-62.08	-69.94	-109.53	-896.20	0.00	-82.09	-83.44	-115.11	-124.23	-164.74	-914.16
Sheboygan, WI	x	-	100	-	0.00	-0.36	-0.32	-0.91	-1.03	-1.88	-18.27	0.00	-0.91	-0.88	-1.53	-1.66	-2.51	-18.01
Springfield (Western MA), MA	x	-	100	-	0.00	-2.76	-2.48	-7.05	-7.96	-14.54	-141.48	0.00	-6.99	-6.73	-11.83	-12.79	-19.40	-139.43
St. Louis, MO-IL	x	x	100	100	0.00	-62.91	-67.76	-92.34	-103.83	-139.09	-881.58	0.00	-148.66	-155.39	-185.44	-199.85	-237.22	-954.77
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-3.81	-4.16	-5.29	-5.94	-7.56	-42.75	0.00	-8.96	-9.43	-10.86	-11.70	-13.45	-47.73
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-2.37	-2.23	-5.43	-6.13	-10.72	-100.04	0.00	-5.90	-5.80	-9.38	-10.14	-14.78	-99.37
Washington, DC-MD-VA	x	x	100	100	0.00	-15.13	-13.63	-38.50	-43.47	-79.23	-769.86	0.00	-38.32	-36.92	-64.64	-69.90	-105.88	-758.95
Wheeling, WV-OH	-	x	-	100	0.00	-0.48	-0.44	-1.24	-1.40	-2.55	-24.83	0.00	-1.23	-1.18	-2.08	-2.24	-3.40	-24.47
York, PA	-	x	-	100	0.00	-1.25	-1.12	-3.18	-3.59	-6.56	-63.82	0.00	-3.16	-3.04	-5.34	-5.77	-8.75	-62.90

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.

b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.

c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)

EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-31
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area)

NOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-5.06	-3.10	-22.26	-25.51	-43.07	-500.92	0.00	-15.71	-13.36	-36.12	-39.50	-57.43	-481.65
Allegan Co., MI	x	-	100	-	0.00	-0.55	-0.34	-2.43	-2.79	-4.71	-54.72	0.00	-1.72	-1.46	-3.95	-4.31	-6.27	-52.62
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.57	-0.35	-2.51	-2.88	-4.86	-56.47	0.00	-1.77	-1.51	-4.08	-4.46	-6.48	-54.30
Atlanta, GA	x	x	100	100	0.00	-32.26	-19.77	-142.10	-162.84	-274.98	-3,198.57	0.00	-100.15	-85.16	-230.49	-252.05	-366.56	-3,075.40
Baltimore, MD	x	x	100	100	0.00	-11.12	-6.85	-48.78	-55.89	-94.33	-1,096.46	0.00	-34.54	-29.42	-79.23	-86.64	-125.89	-1,054.44
Baton Rouge, LA	x	-	100	-	0.00	-156.14	-171.14	-206.75	-233.42	-277.77	-1,400.30	0.00	-515.19	-538.69	-594.70	-634.80	-688.81	-1,775.83
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-310.54	-342.24	-399.39	-450.64	-526.61	-2,439.52	0.00	-1,025.40	-1,074.51	-1,170.01	-1,248.19	-1,343.33	-3,210.24
Birmingham, AL	-	x	-	100	0.00	-3.85	-2.35	-17.03	-19.52	-32.98	-383.95	0.00	-11.94	-10.14	-27.58	-30.17	-43.91	-369.09
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-16.78	-10.31	-73.76	-84.53	-142.70	-1,659.22	0.00	-52.12	-44.35	-119.74	-130.93	-190.34	-1,595.48
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-2.25	-1.30	-10.41	-11.94	-20.28	-237.86	0.00	-6.94	-5.79	-16.61	-18.18	-26.69	-228.24
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-3.97	-2.44	-17.47	-20.02	-33.79	-392.87	0.00	-12.34	-10.50	-28.35	-31.00	-45.07	-377.78
Canton-Massillon, OH	-	x	-	100	0.00	-21.18	-22.84	-30.48	-34.48	-43.02	-261.28	0.00	-69.74	-72.44	-83.32	-89.08	-98.94	-307.30
Charleston, WV	-	x	-	100	0.00	-1.02	-0.63	-4.49	-5.15	-8.70	-101.15	0.00	-3.17	-2.70	-7.29	-7.97	-11.60	-97.26
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-7.10	-3.83	-34.56	-39.63	-67.72	-800.31	0.00	-21.82	-17.86	-54.28	-59.46	-88.09	-766.54
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-1.99	-1.24	-8.65	-9.91	-16.70	-193.72	0.00	-6.19	-5.29	-14.09	-15.41	-22.34	-186.38
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-249.20	-261.74	-402.72	-456.46	-602.61	-4,364.54	0.00	-817.66	-840.65	-1,027.95	-1,101.67	-1,263.53	-4,816.95
Chico, CA	x	-	100	-	0.00	-0.74	-0.46	-3.27	-3.75	-6.33	-73.64	0.00	-2.31	-1.96	-5.31	-5.81	-8.44	-70.81
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-6.86	-4.12	-30.73	-35.22	-59.60	-695.22	0.00	-21.27	-17.97	-49.57	-54.22	-79.11	-667.99
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.60	-0.37	-2.62	-3.01	-5.08	-59.04	0.00	-1.85	-1.58	-4.26	-4.66	-6.77	-56.77
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-9.41	-5.78	-41.37	-47.41	-80.04	-930.72	0.00	-29.22	-24.86	-67.15	-73.42	-106.75	-894.95
Columbus, OH	x	x	100	100	0.00	-6.97	-4.27	-30.70	-35.19	-59.41	-691.05	0.00	-21.65	-18.41	-49.81	-54.46	-79.21	-664.45
Dallas-Fort Worth, TX	x	-	100	-	0.00	-31.12	-19.09	-136.98	-156.98	-265.04	-3,082.64	0.00	-96.63	-82.18	-222.24	-243.03	-353.39	-2,964.04
Dayton-Springfield, OH	-	x	-	100	0.00	-2.86	-1.76	-12.60	-14.44	-24.39	-283.63	0.00	-8.89	-7.56	-20.45	-22.36	-32.52	-272.72
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-39.27	-36.75	-92.14	-105.00	-157.74	-1,527.24	0.00	-127.03	-124.92	-193.04	-208.48	-263.81	-1,540.61
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-45.19	-41.21	-112.92	-128.78	-196.61	-1,959.15	0.00	-145.76	-141.96	-229.61	-248.31	-319.14	-1,960.63
Door Co., WI	x	-	100	-	0.00	-0.12	-0.07	-0.51	-0.59	-0.99	-11.49	0.00	-0.36	-0.31	-0.83	-0.91	-1.32	-11.05
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	-0.02	-0.02	-0.04	-0.50	0.00	-0.01	-0.01	-0.03	-0.04	-0.06	-0.48
Evansville, IN	-	x	-	100	0.00	-1.13	-0.61	-5.48	-6.29	-10.74	-126.93	0.00	-3.47	-2.84	-8.62	-9.44	-13.98	-121.58
Greater Connecticut, CT	x	-	100	-	0.00	-6.74	-4.17	-29.48	-33.78	-56.99	-662.13	0.00	-20.94	-17.85	-47.94	-52.41	-76.12	-636.83
Greene Co., PA	x	-	100	-	0.00	-0.13	-0.08	-0.59	-0.67	-1.14	-13.23	0.00	-0.41	-0.35	-0.95	-1.04	-1.52	-12.72
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-3.04	-1.86	-13.36	-15.31	-25.85	-300.71	0.00	-9.43	-8.02	-21.68	-23.71	-34.47	-289.14
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-2.67	-1.64	-11.76	-13.47	-22.75	-264.55	0.00	-8.30	-7.06	-19.08	-20.86	-30.33	-254.38

Table B2-31
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area)

NOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.02	-0.01	-0.08	-0.09	-0.16	-1.84	0.00	-0.05	-0.04	-0.13	-0.14	-0.20	-1.76
Hickory, NC	-	x	-	100	0.00	-0.74	-0.46	-3.26	-3.73	-6.30	-73.26	0.00	-2.31	-1.97	-5.29	-5.79	-8.41	-70.45
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-652.99	-711.17	-893.85	-1,009.90	-1,225.61	-6,711.10	0.00	-2,152.75	-2,245.23	-2,518.76	-2,690.37	-2,946.61	-8,222.63
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-61.80	-67.48	-83.43	-94.24	-113.45	-601.22	0.00	-203.80	-212.78	-237.11	-253.19	-276.24	-746.61
Imperial Co., CA	x	-	100	-	0.00	-1.03	-0.63	-4.55	-5.21	-8.79	-102.29	0.00	-3.21	-2.73	-7.37	-8.06	-11.73	-98.35
Indianapolis, IN	-	x	-	100	0.00	-6.49	-3.98	-28.58	-32.75	-55.29	-643.09	0.00	-20.16	-17.14	-46.36	-50.70	-73.72	-618.35
Jamestown, NY	x	-	100	-	0.00	-0.53	-0.32	-2.31	-2.65	-4.48	-52.08	0.00	-1.64	-1.39	-3.76	-4.11	-5.97	-50.08
Jefferson Co., NY	x	-	100	-	0.00	-0.56	-0.35	-2.48	-2.84	-4.79	-55.67	0.00	-1.75	-1.49	-4.02	-4.39	-6.39	-53.53
Johnstown, PA	-	x	-	100	0.00	-0.41	-0.26	-1.81	-2.07	-3.50	-40.64	0.00	-1.29	-1.10	-2.95	-3.22	-4.68	-39.09
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.74	-0.55	-2.61	-2.99	-4.90	-54.60	0.00	-2.32	-2.11	-4.58	-4.99	-6.95	-53.06
Knoxville, TN	x	x	100	100	0.00	-4.24	-2.60	-18.71	-21.44	-36.20	-421.21	0.00	-13.17	-11.19	-30.33	-33.17	-48.25	-404.97
Lancaster, PA	-	x	-	100	0.00	-1.59	-0.97	-6.98	-8.00	-13.51	-157.12	0.00	-4.93	-4.19	-11.33	-12.39	-18.01	-151.08
Las Vegas, NV	x	-	100	-	0.00	-6.93	-4.20	-30.81	-35.31	-59.70	-695.62	0.00	-21.49	-18.21	-49.82	-54.49	-79.39	-668.57
Libby, MT	-	x	-	100	0.00	-0.03	-0.02	-0.12	-0.13	-0.22	-2.60	0.00	-0.08	-0.07	-0.19	-0.21	-0.30	-2.50
Liberty-Clairton, PA	-	x	-	100	0.00	-0.05	-0.03	-0.19	-0.22	-0.37	-4.24	0.00	-0.15	-0.13	-0.33	-0.36	-0.51	-4.10
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-401.30	-413.27	-701.03	-795.60	-1,085.35	-8,565.12	0.00	-1,313.42	-1,339.95	-1,712.23	-1,837.96	-2,153.20	-9,187.65
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-3.27	-2.07	-13.98	-16.02	-26.95	-311.95	0.00	-10.17	-8.74	-22.90	-25.03	-36.20	-300.31
Louisville, KY-IN	-	x	-	100	0.00	-3.82	-2.25	-17.37	-19.91	-33.76	-394.84	0.00	-11.82	-9.93	-27.88	-30.51	-44.64	-379.14
Macon, GA	-	x	-	100	0.00	-0.71	-0.41	-3.25	-3.72	-6.32	-74.01	0.00	-2.18	-1.83	-5.19	-5.68	-8.33	-71.04
Manitowoc Co., WI	x	-		-	0.00	-0.39	-0.24	-1.68	-1.92	-3.24	-37.58	0.00	-1.20	-1.02	-2.73	-2.99	-4.33	-36.15
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.48	-0.30	-2.11	-2.42	-4.08	-47.42	0.00	-1.49	-1.27	-3.42	-3.74	-5.44	-45.60
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-1.95	-1.19	-8.57	-9.82	-16.58	-192.85	0.00	-6.04	-5.14	-13.90	-15.20	-22.11	-185.43
Memphis, TN-AR	x	-	100	-	0.00	-53.00	-56.78	-78.55	-88.89	-112.63	-720.54	0.00	-174.34	-180.65	-210.93	-225.66	-252.71	-831.09
Milwaukee-Racine, WI	x	-	100	-	0.00	-6.41	-3.94	-28.14	-32.25	-54.43	-632.87	0.00	-19.89	-16.93	-45.69	-49.96	-72.62	-608.57
Nevada (Western Part), CA	x	-	100	-	0.00	-0.41	-0.25	-1.78	-2.04	-3.44	-40.01	0.00	-1.26	-1.07	-2.89	-3.16	-4.59	-38.47
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-140.24	-128.96	-343.59	-391.75	-595.17	-5,879.58	0.00	-452.76	-442.34	-705.14	-762.25	-974.96	-5,897.97
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.53	-0.32	-2.38	-2.73	-4.62	-53.85	0.00	-1.66	-1.40	-3.85	-4.21	-6.14	-51.75
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-352.33	-375.99	-531.60	-601.77	-769.25	-5,064.40	0.00	-1,158.45	-1,198.49	-1,412.44	-1,511.62	-1,701.16	-5,780.39
Phoenix-Mesa, AZ	x	-	100	-	0.00	-18.00	-10.68	-81.56	-93.48	-158.40	-1,851.05	0.00	-55.76	-46.94	-131.08	-143.41	-209.67	-1,777.76
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-6.64	-4.06	-29.30	-33.58	-56.72	-659.99	0.00	-20.61	-17.51	-47.50	-51.94	-75.57	-634.52
Poughkeepsie, NY	x	x	100	100	0.00	-5.05	-3.10	-22.21	-25.46	-42.98	-499.86	0.00	-15.68	-13.33	-36.04	-39.42	-57.31	-480.63

Table B2-31
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area)

NOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-3.33	-2.05	-14.65	-16.79	-28.34	-329.62	0.00	-10.35	-8.80	-23.78	-26.00	-37.80	-316.95
Reading, PA	-	x	-	100	0.00	-1.49	-0.91	-6.54	-7.50	-12.66	-147.28	0.00	-4.62	-3.93	-10.62	-11.61	-16.89	-141.61
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-4.30	-2.68	-18.66	-21.38	-36.04	-418.19	0.00	-13.36	-11.42	-30.42	-33.25	-48.23	-402.34
Rochester, NY	x	-	100	-	0.00	-4.74	-2.91	-20.84	-23.88	-40.32	-468.92	0.00	-14.71	-12.51	-33.81	-36.98	-53.77	-450.89
Rome, GA	-	x	-	100	0.00	-0.41	-0.25	-1.79	-2.05	-3.45	-40.17	0.00	-1.26	-1.07	-2.90	-3.17	-4.61	-38.63
Sacramento Metro, CA	x	-	50	-	0.00	-9.23	-5.67	-40.58	-46.50	-78.50	-912.78	0.00	-28.67	-24.39	-65.87	-72.02	-104.70	-877.71
San Diego, CA	x	-	100	-	0.00	-10.88	-6.67	-47.88	-54.87	-92.65	-1,077.55	0.00	-33.77	-28.72	-77.68	-84.95	-123.53	-1,036.09
San Francisco Bay Area, CA	x	-	100	-	0.00	-204.00	-213.29	-335.95	-380.90	-507.04	-3,756.40	0.00	-668.97	-686.53	-848.30	-909.49	-1,048.51	-4,114.10
San Joaquin Valley, CA	x	x	50	100	0.00	-50.35	-45.71	-127.10	-144.97	-221.88	-2,220.55	0.00	-162.31	-157.82	-257.21	-278.22	-358.48	-2,219.58
Sheboygan, WI	x	-	100	-	0.00	-0.45	-0.28	-1.96	-2.25	-3.80	-44.09	0.00	-1.40	-1.19	-3.20	-3.49	-5.07	-42.41
Springfield (Western MA), MA	x	-	100	-	0.00	-3.46	-2.12	-15.22	-17.44	-29.45	-342.55	0.00	-10.74	-9.13	-24.70	-27.01	-39.27	-329.37
St. Louis, MO-IL	x	x	100	100	0.00	-95.48	-99.93	-156.61	-177.55	-235.94	-1,739.76	0.00	-313.15	-321.49	-396.36	-424.91	-489.33	-1,908.45
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-5.85	-6.28	-8.55	-9.67	-12.17	-76.09	0.00	-19.25	-19.97	-23.15	-24.76	-27.62	-88.52
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-3.10	-2.28	-11.22	-12.84	-21.10	-236.28	0.00	-9.77	-8.81	-19.51	-21.25	-29.73	-229.34
Washington, DC-MD-VA	x	x	100	100	0.00	-19.84	-12.28	-86.64	-99.29	-167.47	-1,945.14	0.00	-61.65	-52.58	-140.95	-154.11	-223.75	-1,870.92
Wheeling, WV-OH	-	x	-	100	0.00	-0.58	-0.36	-2.56	-2.93	-4.94	-57.51	0.00	-1.80	-1.53	-4.15	-4.53	-6.59	-55.30
York, PA	-	x	-	100	0.00	-1.65	-1.01	-7.25	-8.31	-14.03	-163.22	0.00	-5.12	-4.36	-11.77	-12.87	-18.72	-156.94

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-32
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-5.32	-0.36	-43.76	-50.22	-74.68	-965.39	0.00	-9.96	-3.12	-57.39	-64.03	-89.96	-904.25
Allegan Co., MI	x	-	100	-	0.00	-0.58	-0.04	-4.76	-5.46	-8.13	-105.04	0.00	-1.08	-0.34	-6.24	-6.97	-9.79	-98.39
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.68	-0.05	-5.59	-6.42	-9.54	-123.31	0.00	-1.28	-0.41	-7.34	-8.19	-11.50	-115.50
Atlanta, GA	x	x	100	100	0.00	-42.31	-2.78	-348.16	-399.54	-594.23	-7,682.28	0.00	-78.98	-24.53	-456.46	-509.25	-715.58	-7,195.54
Baltimore, MD	x	x	100	100	0.00	-11.62	-0.86	-95.00	-109.02	-162.10	-2,094.35	0.00	-21.89	-7.06	-124.81	-139.22	-195.48	-1,961.99
Baton Rouge, LA	x	-	100	-	0.00	-217.16	-237.02	-295.99	-335.81	-395.65	-2,078.85	0.00	-877.48	-912.34	-1,011.81	-1,076.45	-1,154.56	-2,758.22
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-432.87	-476.93	-560.00	-634.89	-735.26	-3,392.42	0.00	-1,758.60	-1,834.41	-1,990.08	-2,114.77	-2,250.75	-4,810.55
Birmingham, AL	-	x	-	100	0.00	-3.92	-0.22	-32.53	-37.33	-55.54	-718.54	0.00	-7.25	-2.15	-42.55	-47.48	-66.78	-672.88
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-16.41	-1.14	-134.61	-154.47	-229.71	-2,968.92	0.00	-30.75	-9.73	-176.65	-197.06	-276.81	-2,781.03
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-2.29	0.05	-20.19	-23.17	-34.55	-449.49	0.00	-3.84	-0.61	-25.90	-28.94	-41.00	-420.27
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-3.79	-0.26	-31.05	-35.63	-52.99	-684.88	0.00	-7.10	-2.25	-40.76	-45.47	-63.86	-641.54
Canton-Massillon, OH	-	x	-	100	0.00	-29.07	-31.00	-44.50	-50.56	-61.65	-400.45	0.00	-115.92	-119.56	-139.80	-149.13	-162.79	-481.00
Charleston, WV	-	x	-	100	0.00	-0.94	-0.06	-7.72	-8.86	-13.18	-170.40	0.00	-1.76	-0.55	-10.13	-11.30	-15.88	-159.61
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-8.97	0.50	-81.05	-93.03	-138.87	-1,810.15	0.00	-14.44	-1.37	-103.23	-115.42	-163.93	-1,691.51
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-2.11	-0.33	-16.09	-18.46	-27.37	-351.20	0.00	-4.34	-1.89	-21.62	-24.08	-33.53	-329.64
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-336.69	-341.13	-635.30	-723.54	-927.45	-7,642.08	0.00	-1,304.61	-1,321.48	-1,726.21	-1,850.83	-2,088.00	-8,319.46
Chico, CA	x	-	100	-	0.00	-0.77	-0.05	-6.31	-7.24	-10.77	-139.17	0.00	-1.43	-0.45	-8.27	-9.23	-12.97	-130.35
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-7.32	-0.25	-61.80	-70.93	-105.60	-1,368.30	0.00	-13.19	-3.44	-80.39	-89.74	-126.46	-1,280.77
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.55	-0.04	-4.48	-5.14	-7.64	-98.74	0.00	-1.02	-0.32	-5.87	-6.55	-9.21	-92.49
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-8.93	-0.61	-73.32	-84.14	-125.14	-1,617.43	0.00	-16.73	-5.27	-96.21	-107.33	-150.77	-1,515.05
Columbus, OH	x	x	100	100	0.00	-7.75	-0.51	-63.79	-73.21	-108.88	-1,407.55	0.00	-14.48	-4.50	-83.64	-93.31	-131.12	-1,318.38
Dallas-Fort Worth, TX	x	-	100	-	0.00	-38.46	-2.56	-316.19	-362.84	-539.64	-6,976.04	0.00	-71.86	-22.43	-414.65	-462.59	-649.96	-6,534.19
Dayton-Springfield, OH	-	x	-	100	0.00	-2.72	-0.18	-22.37	-25.67	-38.18	-493.61	0.00	-5.09	-1.59	-29.34	-32.73	-45.99	-462.35
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-51.44	-40.76	-173.09	-197.99	-277.05	-3,072.20	0.00	-175.26	-161.81	-331.62	-361.18	-447.43	-3,013.67
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-55.76	-43.54	-191.91	-219.54	-307.93	-3,437.42	0.00	-188.61	-173.12	-363.27	-395.91	-492.22	-3,364.84
Door Co., WI	x	-	100	-	0.00	-0.11	-0.01	-0.90	-1.04	-1.54	-19.96	0.00	-0.21	-0.06	-1.19	-1.32	-1.86	-18.70
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	-0.04	-0.05	-0.07	-0.89	0.00	-0.01	0.00	-0.05	-0.05	-0.08	-0.83
Evansville, IN	-	x	-	100	0.00	-1.11	0.13	-10.45	-11.99	-17.93	-234.50	0.00	-1.65	0.06	-13.14	-14.71	-20.98	-218.92
Greater Connecticut, CT	x	-	100	-	0.00	-6.85	-0.54	-55.80	-64.03	-95.19	-1,229.45	0.00	-12.98	-4.28	-73.40	-81.87	-114.90	-1,151.87
Greene Co., PA	x	-	100	-	0.00	-0.12	-0.01	-0.97	-1.11	-1.65	-21.36	0.00	-0.22	-0.07	-1.27	-1.42	-1.99	-20.01
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-3.09	-0.21	-25.43	-29.18	-43.40	-561.05	0.00	-5.78	-1.80	-33.35	-37.20	-52.27	-525.51
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-2.65	-0.18	-21.75	-24.96	-37.12	-479.77	0.00	-4.95	-1.55	-28.53	-31.83	-44.71	-449.39

Table B2-32
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.01	0.00	-0.15	-0.17	-0.26	-3.44	0.00	-0.01	0.01	-0.18	-0.20	-0.30	-3.20
Hickory, NC	-	x	-	100	0.00	-0.79	-0.06	-6.42	-7.37	-10.96	-141.64	0.00	-1.48	-0.48	-8.44	-9.42	-13.22	-132.69
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-905.71	-977.56	-1,307.89	-1,485.01	-1,780.83	-10,509.33	0.00	-3,636.47	-3,766.40	-4,285.49	-4,565.23	-4,939.33	-13,186.33
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-85.68	-93.15	-119.24	-135.32	-160.48	-881.77	0.00	-345.44	-358.68	-401.41	-427.26	-459.70	-1,144.59
Imperial Co., CA	x	-	100	-	0.00	-1.28	-0.09	-10.55	-12.10	-18.00	-232.71	0.00	-2.40	-0.75	-13.83	-15.43	-21.68	-217.97
Indianapolis, IN	-	x	-	100	0.00	-7.24	-0.48	-59.49	-68.27	-101.54	-1,312.65	0.00	-13.52	-4.22	-78.02	-87.04	-122.30	-1,229.51
Jamestown, NY	x	-	100	-	0.00	-0.50	-0.03	-4.10	-4.70	-6.99	-90.39	0.00	-0.94	-0.29	-5.38	-6.00	-8.43	-84.67
Jefferson Co., NY	x	-	100	-	0.00	-0.62	-0.04	-5.04	-5.79	-8.60	-111.20	0.00	-1.15	-0.37	-6.62	-7.38	-10.37	-104.16
Johnstown, PA	-	x	-	100	0.00	-0.38	-0.03	-3.05	-3.50	-5.20	-67.06	0.00	-0.72	-0.25	-4.02	-4.48	-6.29	-62.85
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-1.17	-0.60	-6.07	-6.95	-10.09	-123.30	0.00	-3.29	-2.54	-9.43	-10.39	-13.76	-117.41
Knoxville, TN	x	x	100	100	0.00	-4.44	-0.28	-36.62	-42.02	-62.51	-808.23	0.00	-8.27	-2.54	-47.98	-53.53	-75.24	-756.98
Lancaster, PA	-	x	-	100	0.00	-1.58	-0.11	-12.99	-14.90	-22.16	-286.50	0.00	-2.95	-0.92	-17.03	-19.00	-26.70	-268.36
Las Vegas, NV	x	-	100	-	0.00	-9.09	-0.32	-76.66	-87.98	-130.98	-1,697.02	0.00	-16.39	-4.30	-99.74	-111.33	-156.89	-1,588.50
Libby, MT	-	x	-	100	0.00	-0.03	0.00	-0.22	-0.25	-0.37	-4.79	0.00	-0.05	-0.01	-0.28	-0.32	-0.45	-4.49
Liberty-Clairton, PA	-	x	-	100	0.00	-0.05	-0.01	-0.30	-0.35	-0.51	-6.42	0.00	-0.11	-0.07	-0.43	-0.47	-0.65	-6.05
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-544.52	-529.30	-1,177.37	-1,342.58	-1,766.83	-16,114.92	0.00	-2,062.45	-2,058.12	-2,925.58	-3,147.88	-3,630.07	-16,890.93
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-4.05	-0.68	-30.55	-35.05	-51.94	-665.86	0.00	-8.43	-3.80	-41.21	-45.88	-63.80	-625.17
Louisville, KY-IN	-	x	-	100	0.00	-3.61	-0.01	-31.22	-35.84	-53.41	-693.58	0.00	-6.25	-1.28	-40.29	-45.01	-63.61	-648.79
Macon, GA	-	x	-	100	0.00	-0.66	0.02	-5.86	-6.73	-10.03	-130.60	0.00	-1.10	-0.16	-7.51	-8.39	-11.89	-122.09
Manitowoc Co., WI	x	-		-	0.00	-0.37	-0.03	-2.96	-3.40	-5.05	-65.23	0.00	-0.70	-0.24	-3.91	-4.36	-6.11	-61.12
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.59	-0.04	-4.85	-5.56	-8.27	-106.90	0.00	-1.11	-0.35	-6.36	-7.10	-9.97	-100.14
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-2.51	-0.17	-20.61	-23.65	-35.17	-454.68	0.00	-4.68	-1.46	-27.02	-30.15	-42.36	-425.88
Memphis, TN-AR	x	-	100	-	0.00	-72.44	-76.49	-116.01	-131.88	-162.73	-1,126.05	0.00	-287.25	-295.24	-352.95	-376.90	-414.32	-1,315.89
Milwaukee-Racine, WI	x	-	100	-	0.00	-6.27	-0.44	-51.38	-58.96	-87.68	-1,133.13	0.00	-11.76	-3.74	-67.44	-75.24	-105.67	-1,061.44
Nevada (Western Part), CA	x	-	100	-	0.00	-0.44	-0.03	-3.62	-4.15	-6.17	-79.69	0.00	-0.84	-0.27	-4.75	-5.30	-7.44	-74.66
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-173.73	-138.32	-580.11	-663.53	-927.72	-10,263.86	0.00	-593.28	-548.79	-1,115.94	-1,215.16	-1,503.53	-10,075.66
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.49	-0.02	-4.11	-4.71	-7.02	-90.84	0.00	-0.89	-0.25	-5.35	-5.98	-8.41	-85.05
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-482.44	-504.20	-807.21	-918.15	-1,145.38	-8,367.14	0.00	-1,902.03	-1,947.94	-2,381.42	-2,545.73	-2,817.72	-9,557.51
Phoenix-Mesa, AZ	x	-	100	-	0.00	-22.76	-0.28	-195.40	-224.25	-334.10	-4,335.86	0.00	-39.90	-8.89	-252.77	-282.29	-398.62	-4,056.71
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-6.05	-0.37	-49.93	-57.30	-85.23	-1,102.24	0.00	-11.23	-3.42	-65.39	-72.96	-102.56	-1,032.31
Poughkeepsie, NY	x	x	100	100	0.00	-5.36	-0.36	-44.06	-50.56	-75.19	-972.01	0.00	-10.02	-3.14	-57.79	-64.47	-90.58	-910.45

Table B2-32
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-3.23	-0.22	-26.48	-30.39	-45.20	-584.18	0.00	-6.04	-1.90	-34.74	-38.76	-54.45	-547.20
Reading, PA	-	x	-	100	0.00	-1.58	-0.11	-13.01	-14.92	-22.20	-286.92	0.00	-2.96	-0.93	-17.06	-19.03	-26.74	-268.75
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-6.66	-0.71	-52.99	-60.80	-90.30	-1,163.82	0.00	-13.00	-4.81	-70.22	-78.28	-109.57	-1,091.06
Rochester, NY	x	-	100	-	0.00	-4.66	-0.31	-38.31	-43.96	-65.38	-845.09	0.00	-8.72	-2.73	-50.24	-56.05	-78.75	-791.57
Rome, GA	-	x	-	100	0.00	-0.39	-0.03	-3.21	-3.68	-5.48	-70.80	0.00	-0.73	-0.23	-4.21	-4.70	-6.60	-66.31
Sacramento Metro, CA	x	-	50	-	0.00	-10.76	-0.81	-87.86	-100.83	-149.91	-1,936.77	0.00	-20.29	-6.59	-115.47	-128.80	-180.83	-1,814.42
San Diego, CA	x	-	100	-	0.00	-10.44	-0.69	-85.84	-98.51	-146.51	-1,893.96	0.00	-19.50	-6.08	-112.56	-125.58	-176.45	-1,773.99
San Francisco Bay Area, CA	x	-	100	-	0.00	-275.21	-279.06	-517.75	-589.64	-755.35	-6,207.97	0.00	-1,066.87	-1,080.98	-1,409.61	-1,511.26	-1,704.11	-6,764.94
San Joaquin Valley, CA	x	x	50	100	0.00	-66.52	-47.84	-256.47	-293.56	-416.35	-4,790.23	0.00	-216.30	-192.03	-457.96	-500.70	-633.71	-4,645.01
Sheboygan, WI	x	-	100	-	0.00	-0.45	-0.04	-3.65	-4.18	-6.22	-80.28	0.00	-0.86	-0.29	-4.80	-5.35	-7.51	-75.22
Springfield (Western MA), MA	x	-	100	-	0.00	-3.46	-0.23	-28.43	-32.63	-48.53	-627.35	0.00	-6.46	-2.02	-37.29	-41.60	-58.45	-587.62
St. Louis, MO-IL	x	x	100	100	0.00	-128.79	-130.68	-241.68	-275.23	-352.39	-2,889.78	0.00	-499.45	-506.19	-659.11	-706.59	-796.43	-3,151.73
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-7.98	-8.49	-12.35	-14.03	-17.15	-113.12	0.00	-31.79	-32.77	-38.50	-41.08	-44.92	-134.98
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-3.35	-1.34	-20.11	-23.05	-33.77	-421.28	0.00	-8.63	-5.89	-29.49	-32.64	-44.06	-398.66
Washington, DC-MD-VA	x	x	100	100	0.00	-22.49	-1.84	-182.66	-209.61	-311.59	-4,023.27	0.00	-42.76	-14.33	-240.50	-268.23	-376.33	-3,769.69
Wheeling, WV-OH	-	x	-	100	0.00	-0.53	-0.04	-4.37	-5.02	-7.46	-96.45	0.00	-0.99	-0.31	-5.73	-6.40	-8.99	-90.34
York, PA	-	x	-	100	0.00	-1.84	-0.13	-15.11	-17.35	-25.80	-333.43	0.00	-3.44	-1.08	-19.83	-22.12	-31.08	-312.32

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-33
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.16	0.20	0.06	0.06	0.14	2.65	0.00	0.16	0.20	0.06	0.05	0.14	2.65
Allegan Co., MI	x	-	100	-	0.00	0.02	0.02	0.01	0.01	0.02	0.29	0.00	0.02	0.02	0.01	0.01	0.01	0.29
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.02	0.01	0.01	0.01	0.26	0.00	0.02	0.02	0.01	0.01	0.01	0.26
Atlanta, GA	x	x	100	100	0.00	0.87	1.07	0.33	0.29	0.73	14.10	0.00	0.87	1.07	0.33	0.29	0.73	14.10
Baltimore, MD	x	x	100	100	0.00	0.36	0.44	0.14	0.12	0.30	5.86	0.00	0.36	0.44	0.13	0.12	0.30	5.86
Baton Rouge, LA	x	-	100	-	0.00	-5.77	-6.40	-8.15	-9.00	-11.55	-63.85	0.00	-5.80	-6.43	-8.18	-9.04	-11.58	-63.88
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-11.73	-13.02	-16.45	-18.17	-23.35	-130.45	0.00	-11.79	-13.08	-16.52	-18.24	-23.42	-130.52
Birmingham, AL	-	x	-	100	0.00	0.13	0.16	0.05	0.04	0.11	2.15	0.00	0.13	0.16	0.05	0.04	0.11	2.14
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.59	0.72	0.22	0.20	0.49	9.53	0.00	0.59	0.72	0.22	0.20	0.49	9.53
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.08	0.10	0.03	0.03	0.07	1.30	0.00	0.08	0.10	0.03	0.03	0.07	1.30
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.14	0.17	0.05	0.05	0.12	2.29	0.00	0.14	0.17	0.05	0.05	0.12	2.29
Canton-Massillon, OH	-	x	-	100	0.00	-0.72	-0.80	-1.05	-1.17	-1.48	-7.86	0.00	-0.73	-0.80	-1.06	-1.17	-1.49	-7.87
Charleston, WV	-	x	-	100	0.00	0.04	0.05	0.01	0.01	0.03	0.61	0.00	0.04	0.05	0.01	0.01	0.03	0.61
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.24	0.29	0.09	0.09	0.20	3.77	0.00	0.24	0.29	0.09	0.09	0.20	3.77
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.07	0.08	0.03	0.02	0.06	1.10	0.00	0.07	0.08	0.03	0.02	0.06	1.10
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-7.63	-8.38	-11.59	-12.87	-16.19	-80.59	0.00	-7.68	-8.42	-11.64	-12.92	-16.24	-80.64
Chico, CA	x	-	100	-	0.00	0.02	0.03	0.01	0.01	0.02	0.40	0.00	0.02	0.03	0.01	0.01	0.02	0.40
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.24	0.29	0.09	0.08	0.20	3.81	0.00	0.24	0.29	0.09	0.08	0.20	3.81
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.02	0.03	0.01	0.01	0.02	0.36	0.00	0.02	0.03	0.01	0.01	0.02	0.36
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.34	0.42	0.13	0.11	0.28	5.47	0.00	0.34	0.41	0.13	0.11	0.28	5.47
Columbus, OH	x	x	100	100	0.00	0.22	0.27	0.08	0.07	0.18	3.54	0.00	0.22	0.27	0.08	0.07	0.18	3.54
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.89	1.09	0.33	0.30	0.74	14.33	0.00	0.89	1.09	0.33	0.30	0.74	14.32
Dayton-Springfield, OH	-	x	-	100	0.00	0.10	0.13	0.04	0.03	0.09	1.66	0.00	0.10	0.13	0.04	0.03	0.09	1.66
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.57	-0.59	-1.22	-1.38	-1.61	-4.33	0.00	-0.58	-0.59	-1.23	-1.39	-1.62	-4.34
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.43	-0.40	-1.23	-1.41	-1.56	-1.68	0.00	-0.43	-0.41	-1.24	-1.42	-1.57	-1.69
Door Co., WI	x	-	100	-	0.00	0.00	0.01	0.00	0.00	0.00	0.07	0.00	0.00	0.01	0.00	0.00	0.00	0.07
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.04	0.05	0.02	0.02	0.04	0.72	0.00	0.04	0.05	0.02	0.02	0.04	0.72
Greater Connecticut, CT	x	-	100	-	0.00	0.22	0.28	0.08	0.07	0.19	3.62	0.00	0.22	0.27	0.08	0.07	0.19	3.62
Greene Co., PA	x	-	100	-	0.00	0.01	0.01	0.00	0.00	0.00	0.08	0.00	0.01	0.01	0.00	0.00	0.00	0.08
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.10	0.12	0.04	0.03	0.08	1.64	0.00	0.10	0.12	0.04	0.03	0.08	1.64
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.09	0.11	0.03	0.03	0.08	1.49	0.00	0.09	0.11	0.03	0.03	0.08	1.49

Table B2-33
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Hickory, NC	-	x	-	100	0.00	0.02	0.03	0.01	0.01	0.02	0.39	0.00	0.02	0.03	0.01	0.01	0.02	0.39
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-23.46	-25.98	-33.47	-37.01	-47.34	-258.20	0.00	-23.59	-26.12	-33.60	-37.15	-47.48	-258.34
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-2.26	-2.51	-3.22	-3.56	-4.56	-24.96	0.00	-2.28	-2.52	-3.24	-3.58	-4.57	-24.97
Imperial Co., CA	x	-	100	-	0.00	0.03	0.03	0.01	0.01	0.02	0.46	0.00	0.03	0.03	0.01	0.01	0.02	0.46
Indianapolis, IN	-	x	-	100	0.00	0.20	0.25	0.08	0.07	0.17	3.30	0.00	0.20	0.25	0.08	0.07	0.17	3.30
Jamestown, NY	x	-	100	-	0.00	0.02	0.02	0.01	0.01	0.02	0.31	0.00	0.02	0.02	0.01	0.01	0.02	0.31
Jefferson Co., NY	x	-	100	-	0.00	0.02	0.02	0.01	0.01	0.01	0.28	0.00	0.02	0.02	0.01	0.01	0.01	0.28
Johnstown, PA	-	x	-	100	0.00	0.02	0.02	0.01	0.01	0.01	0.25	0.00	0.02	0.02	0.01	0.01	0.01	0.25
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.01	0.02	0.01	0.00	0.01	0.24	0.00	0.01	0.02	0.01	0.00	0.01	0.24
Knoxville, TN	x	x	100	100	0.00	0.14	0.17	0.05	0.05	0.12	2.24	0.00	0.14	0.17	0.05	0.05	0.12	2.24
Lancaster, PA	-	x	-	100	0.00	0.05	0.07	0.02	0.02	0.05	0.88	0.00	0.05	0.07	0.02	0.02	0.05	0.88
Las Vegas, NV	x	-	100	-	0.00	0.18	0.22	0.07	0.06	0.15	2.91	0.00	0.18	0.22	0.07	0.06	0.15	2.91
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-11.10	-12.11	-17.44	-19.41	-24.20	-114.31	0.00	-11.17	-12.19	-17.52	-19.49	-24.28	-114.39
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.09	0.11	0.03	0.03	0.08	1.50	0.00	0.09	0.11	0.03	0.03	0.08	1.50
Louisville, KY-IN	-	x	-	100	0.00	0.14	0.18	0.05	0.05	0.12	2.31	0.00	0.14	0.18	0.05	0.05	0.12	2.31
Macon, GA	-	x	-	100	0.00	0.03	0.03	0.01	0.01	0.02	0.43	0.00	0.03	0.03	0.01	0.01	0.02	0.43
Manitowoc Co., WI	x	-		-	0.00	0.01	0.02	0.01	0.00	0.01	0.22	0.00	0.01	0.02	0.01	0.00	0.01	0.22
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.02	0.00	0.00	0.01	0.21	0.00	0.01	0.02	0.00	0.00	0.01	0.21
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.05	0.06	0.02	0.02	0.04	0.84	0.00	0.05	0.06	0.02	0.02	0.04	0.84
Memphis, TN-AR	x	-	100	-	0.00	-1.76	-1.94	-2.59	-2.87	-3.64	-18.96	0.00	-1.77	-1.95	-2.60	-2.88	-3.65	-18.97
Milwaukee-Racine, WI	x	-	100	-	0.00	0.22	0.27	0.08	0.07	0.19	3.61	0.00	0.22	0.27	0.08	0.07	0.19	3.61
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.02	0.00	0.00	0.01	0.20	0.00	0.01	0.02	0.00	0.00	0.01	0.20
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-1.49	-1.44	-3.96	-4.52	-5.07	-7.36	0.00	-1.51	-1.46	-3.99	-4.54	-5.09	-7.39
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.02	0.02	0.01	0.01	0.02	0.33	0.00	0.02	0.02	0.01	0.01	0.02	0.33
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-11.52	-12.70	-17.01	-18.86	-23.90	-124.07	0.00	-11.59	-12.77	-17.08	-18.93	-23.97	-124.14
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.50	0.62	0.19	0.17	0.42	8.10	0.00	0.50	0.62	0.19	0.17	0.42	8.10
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.25	0.31	0.09	0.08	0.21	4.04	0.00	0.25	0.31	0.09	0.08	0.21	4.04
Poughkeepsie, NY	x	x	100	100	0.00	0.16	0.20	0.06	0.05	0.14	2.62	0.00	0.16	0.20	0.06	0.05	0.14	2.62

Table B2-33
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.12	0.14	0.04	0.04	0.10	1.89	0.00	0.12	0.14	0.04	0.04	0.10	1.89
Reading, PA	-	x	-	100	0.00	0.05	0.06	0.02	0.02	0.04	0.77	0.00	0.05	0.06	0.02	0.02	0.04	0.77
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.09	0.12	0.04	0.03	0.08	1.53	0.00	0.09	0.12	0.04	0.03	0.08	1.53
Rochester, NY	x	-	100	-	0.00	0.16	0.20	0.06	0.06	0.14	2.65	0.00	0.16	0.20	0.06	0.05	0.14	2.65
Rome, GA	-	x	-	100	0.00	0.01	0.02	0.01	0.00	0.01	0.23	0.00	0.01	0.02	0.01	0.00	0.01	0.23
Sacramento Metro, CA	x	-	50	-	0.00	0.28	0.34	0.10	0.09	0.23	4.46	0.00	0.28	0.34	0.10	0.09	0.23	4.46
San Diego, CA	x	-	100	-	0.00	0.39	0.47	0.14	0.13	0.32	6.24	0.00	0.39	0.47	0.14	0.13	0.32	6.24
San Francisco Bay Area, CA	x	-	100	-	0.00	-6.08	-6.65	-9.36	-10.40	-13.04	-63.49	0.00	-6.11	-6.69	-9.40	-10.45	-13.08	-63.53
San Joaquin Valley, CA	x	x	50	100	0.00	-0.60	-0.60	-1.41	-1.60	-1.84	-3.85	0.00	-0.61	-0.61	-1.42	-1.61	-1.84	-3.86
Sheboygan, WI	x	-	100	-	0.00	0.02	0.02	0.01	0.01	0.01	0.25	0.00	0.02	0.02	0.01	0.01	0.01	0.25
Springfield (Western MA), MA	x	-	100	-	0.00	0.12	0.14	0.04	0.04	0.10	1.90	0.00	0.12	0.14	0.04	0.04	0.10	1.90
St. Louis, MO-IL	x	x	100	100	0.00	-2.81	-3.08	-4.33	-4.81	-6.04	-29.41	0.00	-2.83	-3.10	-4.35	-4.83	-6.06	-29.43
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.20	-0.22	-0.29	-0.32	-0.40	-2.11	0.00	-0.20	-0.22	-0.29	-0.32	-0.41	-2.11
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.05	0.07	-0.01	-0.02	0.01	0.98	0.00	0.05	0.07	-0.01	-0.02	0.01	0.98
Washington, DC-MD-VA	x	x	100	100	0.00	0.62	0.76	0.23	0.21	0.52	10.01	0.00	0.62	0.76	0.23	0.21	0.52	10.01
Wheeling, WV-OH	-	x	-	100	0.00	0.02	0.03	0.01	0.01	0.02	0.35	0.00	0.02	0.03	0.01	0.01	0.02	0.35
York, PA	-	x	-	100	0.00	0.05	0.06	0.02	0.02	0.04	0.81	0.00	0.05	0.06	0.02	0.02	0.04	0.81

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-34
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.41	0.51	0.01	0.02	0.52	5.04	0.00	0.91	1.04	0.46	0.50	1.05	6.97
Allegan Co., MI	x	-	100	-	0.00	0.05	0.06	0.00	0.00	0.06	0.55	0.00	0.10	0.11	0.05	0.05	0.11	0.76
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.04	0.05	0.00	0.00	0.06	0.53	0.00	0.10	0.11	0.05	0.05	0.11	0.74
Atlanta, GA	x	x	100	100	0.00	2.39	2.98	0.05	0.11	3.02	29.20	0.00	5.26	6.02	2.69	2.90	6.09	40.43
Baltimore, MD	x	x	100	100	0.00	0.91	1.13	0.02	0.04	1.14	11.07	0.00	1.99	2.28	1.02	1.10	2.31	15.32
Baton Rouge, LA	x	-	100	-	0.00	-17.36	-19.08	-23.32	-26.31	-31.33	-160.70	0.00	-40.56	-42.88	-48.18	-52.06	-57.71	-184.95
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-35.25	-38.79	-46.97	-52.98	-63.47	-327.26	0.00	-82.34	-87.10	-97.35	-105.18	-116.97	-377.52
Birmingham, AL	-	x	-	100	0.00	0.32	0.40	0.01	0.02	0.41	3.96	0.00	0.71	0.82	0.36	0.39	0.83	5.48
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	1.42	1.77	0.03	0.07	1.79	17.35	0.00	3.12	3.58	1.60	1.72	3.62	24.03
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.20	0.25	0.01	0.01	0.26	2.45	0.00	0.44	0.51	0.23	0.25	0.51	3.39
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.34	0.42	0.01	0.02	0.43	4.15	0.00	0.75	0.85	0.38	0.41	0.86	5.74
Canton-Massillon, OH	-	x	-	100	0.00	-2.20	-2.40	-3.04	-3.43	-4.00	-20.14	0.00	-5.15	-5.43	-6.21	-6.71	-7.36	-22.98
Charleston, WV	-	x	-	100	0.00	0.09	0.11	0.00	0.00	0.11	1.09	0.00	0.20	0.22	0.10	0.11	0.23	1.51
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.63	0.79	0.03	0.05	0.81	7.70	0.00	1.40	1.60	0.74	0.80	1.63	10.63
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.17	0.21	0.00	0.01	0.21	2.01	0.00	0.36	0.42	0.19	0.20	0.42	2.79
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-23.37	-25.41	-33.96	-38.26	-43.24	-210.74	0.00	-54.90	-57.66	-68.08	-73.55	-79.23	-237.05
Chico, CA	x	-	100	-	0.00	0.06	0.08	0.00	0.00	0.08	0.75	0.00	0.13	0.15	0.07	0.07	0.16	1.03
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.58	0.72	0.02	0.03	0.73	7.08	0.00	1.28	1.46	0.66	0.71	1.48	9.80
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.05	0.06	0.00	0.00	0.07	0.64	0.00	0.11	0.13	0.06	0.06	0.13	0.88
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.81	1.01	0.02	0.04	1.02	9.86	0.00	1.77	2.03	0.91	0.98	2.05	13.65
Columbus, OH	x	x	100	100	0.00	0.56	0.70	0.01	0.03	0.71	6.82	0.00	1.23	1.40	0.63	0.68	1.42	9.44
Dallas-Fort Worth, TX	x	-	100	-	0.00	2.37	2.95	0.05	0.11	2.99	28.94	0.00	5.21	5.96	2.66	2.88	6.03	40.06
Dayton-Springfield, OH	-	x	-	100	0.00	0.25	0.31	0.01	0.01	0.31	3.00	0.00	0.54	0.62	0.28	0.30	0.63	4.15
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-1.89	-1.93	-3.90	-4.38	-3.97	-14.48	0.00	-4.56	-4.63	-6.95	-7.51	-7.09	-13.74
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-1.65	-1.59	-4.14	-4.64	-3.76	-10.92	0.00	-4.05	-4.00	-6.98	-7.54	-6.61	-8.41
Door Co., WI	x	-	100	-	0.00	0.01	0.01	0.00	0.00	0.01	0.12	0.00	0.02	0.03	0.01	0.01	0.03	0.17
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Evansville, IN	-	x	-	100	0.00	0.11	0.14	0.01	0.01	0.14	1.34	0.00	0.24	0.28	0.13	0.14	0.28	1.85
Greater Connecticut, CT	x	-	100	-	0.00	0.55	0.69	0.01	0.02	0.70	6.76	0.00	1.22	1.39	0.62	0.67	1.41	9.37
Greene Co., PA	x	-	100	-	0.00	0.01	0.01	0.00	0.00	0.02	0.15	0.00	0.03	0.03	0.01	0.01	0.03	0.20
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.25	0.31	0.01	0.01	0.32	3.07	0.00	0.55	0.63	0.28	0.31	0.64	4.25
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.22	0.28	0.00	0.01	0.28	2.74	0.00	0.49	0.56	0.25	0.27	0.57	3.79

Table B2-34
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Hickory, NC	-	x	-	100	0.00	0.06	0.07	0.00	0.00	0.08	0.73	0.00	0.13	0.15	0.07	0.07	0.15	1.02
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-70.77	-77.66	-96.11	-108.38	-128.17	-652.97	0.00	-165.50	-174.80	-197.72	-213.63	-235.92	-749.34
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-6.83	-7.50	-9.25	-10.43	-12.36	-63.13	0.00	-15.98	-16.88	-19.05	-20.59	-22.76	-72.52
Imperial Co., CA	x	-	100	-	0.00	0.08	0.10	0.00	0.00	0.10	0.95	0.00	0.17	0.19	0.09	0.09	0.20	1.31
Indianapolis, IN	-	x	-	100	0.00	0.52	0.65	0.01	0.02	0.66	6.35	0.00	1.14	1.31	0.58	0.63	1.32	8.79
Jamestown, NY	x	-	100	-	0.00	0.05	0.06	0.00	0.00	0.06	0.55	0.00	0.10	0.11	0.05	0.05	0.11	0.76
Jefferson Co., NY	x	-	100	-	0.00	0.04	0.06	0.00	0.00	0.06	0.55	0.00	0.10	0.11	0.05	0.05	0.11	0.76
Johnstown, PA	-	x	-	100	0.00	0.04	0.04	0.00	0.00	0.05	0.44	0.00	0.08	0.09	0.04	0.04	0.09	0.61
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.04	0.05	0.00	0.00	0.05	0.48	0.00	0.08	0.10	0.04	0.04	0.10	0.66
Knoxville, TN	x	x	100	100	0.00	0.35	0.43	0.01	0.02	0.44	4.25	0.00	0.76	0.88	0.39	0.42	0.89	5.88
Lancaster, PA	-	x	-	100	0.00	0.13	0.17	0.00	0.01	0.17	1.62	0.00	0.29	0.33	0.15	0.16	0.34	2.25
Las Vegas, NV	x	-	100	-	0.00	0.51	0.64	0.01	0.03	0.64	6.23	0.00	1.12	1.28	0.57	0.62	1.30	8.62
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00	0.01	0.04
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.01	0.01	0.00	0.00	0.01	0.07
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-34.15	-36.89	-51.65	-58.16	-64.01	-303.32	0.00	-80.42	-84.17	-102.00	-110.21	-116.95	-336.68
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.24	0.30	0.00	0.01	0.31	2.97	0.00	0.53	0.61	0.27	0.29	0.62	4.11
Louisville, KY-IN	-	x	-	100	0.00	0.34	0.43	0.01	0.02	0.44	4.20	0.00	0.76	0.87	0.39	0.42	0.88	5.81
Macon, GA	-	x	-	100	0.00	0.06	0.08	0.00	0.00	0.08	0.79	0.00	0.14	0.16	0.07	0.08	0.16	1.09
Manitowoc Co., WI	x	-		-	0.00	0.03	0.04	0.00	0.00	0.04	0.40	0.00	0.07	0.08	0.04	0.04	0.08	0.55
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.04	0.04	0.00	0.00	0.05	0.44	0.00	0.08	0.09	0.04	0.04	0.09	0.61
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.14	0.18	0.00	0.01	0.18	1.76	0.00	0.32	0.36	0.16	0.17	0.37	2.43
Memphis, TN-AR	x	-	100	-	0.00	-5.35	-5.85	-7.51	-8.46	-9.79	-48.87	0.00	-12.54	-13.21	-15.25	-16.48	-17.98	-55.58
Milwaukee-Racine, WI	x	-	100	-	0.00	0.54	0.67	0.01	0.02	0.68	6.60	0.00	1.19	1.36	0.61	0.66	1.38	9.14
Nevada (Western Part), CA	x	-	100	-	0.00	0.03	0.04	0.00	0.00	0.04	0.39	0.00	0.07	0.08	0.04	0.04	0.08	0.55
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-5.53	-5.44	-13.18	-14.76	-12.34	-38.40	0.00	-13.54	-13.47	-22.54	-24.35	-21.78	-31.81
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.05	0.06	0.00	0.00	0.06	0.58	0.00	0.10	0.12	0.05	0.06	0.12	0.80
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-35.06	-38.28	-49.42	-55.70	-64.24	-319.47	0.00	-82.18	-86.53	-100.21	-108.27	-117.94	-362.72
Phoenix-Mesa, AZ	x	-	100	-	0.00	1.39	1.74	0.04	0.08	1.77	17.01	0.00	3.07	3.51	1.58	1.71	3.56	23.53
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.58	0.73	0.01	0.03	0.74	7.14	0.00	1.28	1.47	0.66	0.71	1.49	9.88
Poughkeepsie, NY	x	x	100	100	0.00	0.41	0.51	0.01	0.02	0.52	5.00	0.00	0.90	1.03	0.46	0.50	1.04	6.92

Table B2-34
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.28	0.35	0.01	0.01	0.36	3.45	0.00	0.62	0.71	0.32	0.34	0.72	4.78
Reading, PA	-	x	-	100	0.00	0.12	0.15	0.00	0.01	0.15	1.47	0.00	0.26	0.30	0.14	0.15	0.31	2.04
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.29	0.36	0.01	0.01	0.36	3.48	0.00	0.63	0.72	0.32	0.34	0.73	4.83
Rochester, NY	x	-	100	-	0.00	0.40	0.50	0.01	0.02	0.50	4.87	0.00	0.88	1.00	0.45	0.48	1.02	6.75
Rome, GA	-	x	-	100	0.00	0.03	0.04	0.00	0.00	0.04	0.42	0.00	0.08	0.09	0.04	0.04	0.09	0.58
Sacramento Metro, CA	x	-	50	-	0.00	0.72	0.90	0.02	0.03	0.91	8.80	0.00	1.58	1.81	0.81	0.87	1.83	12.18
San Diego, CA	x	-	100	-	0.00	0.93	1.16	0.02	0.04	1.17	11.33	0.00	2.04	2.34	1.04	1.13	2.36	15.69
San Francisco Bay Area, CA	x	-	100	-	0.00	-18.73	-20.32	-27.57	-31.05	-34.80	-168.11	0.00	-44.04	-46.20	-54.99	-59.42	-63.70	-188.32
San Joaquin Valley, CA	x	x	50	100	0.00	-1.96	-1.94	-4.60	-5.15	-4.35	-13.79	0.00	-4.79	-4.78	-7.90	-8.53	-7.68	-11.65
Sheboygan, WI	x	-	100	-	0.00	0.04	0.05	0.00	0.00	0.05	0.45	0.00	0.08	0.09	0.04	0.05	0.09	0.63
Springfield (Western MA), MA	x	-	100	-	0.00	0.29	0.36	0.01	0.01	0.37	3.53	0.00	0.64	0.73	0.32	0.35	0.74	4.89
St. Louis, MO-IL	x	x	100	100	0.00	-8.67	-9.41	-12.75	-14.37	-16.11	-77.85	0.00	-20.39	-21.39	-25.45	-27.50	-29.49	-87.23
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.60	-0.65	-0.83	-0.94	-1.09	-5.46	0.00	-1.40	-1.47	-1.70	-1.83	-2.00	-6.21
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.11	0.15	-0.11	-0.12	0.09	1.58	0.00	0.23	0.28	-0.02	-0.02	0.21	2.38
Washington, DC-MD-VA	x	x	100	100	0.00	1.57	1.96	0.03	0.07	1.98	19.16	0.00	3.45	3.95	1.76	1.90	3.99	26.53
Wheeling, WV-OH	-	x	-	100	0.00	0.05	0.06	0.00	0.00	0.06	0.62	0.00	0.11	0.13	0.06	0.06	0.13	0.86
York, PA	-	x	-	100	0.00	0.13	0.16	0.00	0.01	0.16	1.59	0.00	0.29	0.33	0.15	0.16	0.33	2.20

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-35
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.62	0.77	-0.04	-0.01	0.86	7.07	0.00	1.99	2.23	1.24	1.34	2.34	12.54
Allegan Co., MI	x	-	100	-	0.00	0.07	0.08	0.00	0.00	0.09	0.77	0.00	0.22	0.24	0.14	0.15	0.26	1.37
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.07	0.09	0.00	0.00	0.10	0.80	0.00	0.22	0.25	0.14	0.15	0.26	1.41
Atlanta, GA	x	x	100	100	0.00	3.94	4.92	-0.22	-0.05	5.50	45.16	0.00	12.74	14.26	7.90	8.56	14.96	80.08
Baltimore, MD	x	x	100	100	0.00	1.35	1.68	-0.08	-0.02	1.88	15.46	0.00	4.36	4.88	2.70	2.93	5.12	27.42
Baton Rouge, LA	x	-	100	-	0.00	-27.20	-29.83	-36.11	-40.89	-47.89	-240.90	0.00	-89.80	-93.98	-103.14	-110.29	-118.93	-304.96
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-55.24	-60.64	-72.67	-82.33	-97.07	-490.39	0.00	-182.32	-190.92	-208.60	-223.08	-241.23	-623.53
Birmingham, AL	-	x	-	100	0.00	0.47	0.59	-0.03	0.00	0.66	5.43	0.00	1.53	1.71	0.95	1.03	1.80	9.62
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	2.04	2.55	-0.12	-0.03	2.85	23.41	0.00	6.60	7.39	4.09	4.43	7.75	41.52
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.30	0.37	-0.01	0.00	0.42	3.41	0.00	0.96	1.08	0.60	0.65	1.13	6.02
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.48	0.60	-0.03	-0.01	0.67	5.54	0.00	1.56	1.75	0.97	1.05	1.84	9.83
Canton-Massillon, OH	-	x	-	100	0.00	-3.46	-3.77	-4.72	-5.34	-6.12	-30.35	0.00	-11.41	-11.92	-13.27	-14.19	-15.16	-37.86
Charleston, WV	-	x	-	100	0.00	0.12	0.16	-0.01	0.00	0.17	1.43	0.00	0.40	0.45	0.25	0.27	0.47	2.53
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	1.02	1.27	-0.03	0.02	1.43	11.60	0.00	3.29	3.68	2.08	2.25	3.88	20.48
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.24	0.30	-0.01	0.00	0.33	2.72	0.00	0.77	0.86	0.47	0.51	0.90	4.83
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-36.76	-39.88	-52.78	-59.63	-65.77	-318.07	0.00	-121.56	-126.55	-144.53	-154.48	-162.39	-385.91
Chico, CA	x	-	100	-	0.00	0.09	0.11	-0.01	0.00	0.13	1.04	0.00	0.29	0.33	0.18	0.20	0.34	1.84
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.86	1.07	-0.04	-0.01	1.20	9.86	0.00	2.79	3.12	1.73	1.88	3.27	17.47
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.07	0.09	0.00	0.00	0.10	0.83	0.00	0.24	0.26	0.15	0.16	0.28	1.48
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	1.15	1.43	-0.07	-0.01	1.60	13.13	0.00	3.71	4.15	2.30	2.49	4.35	23.29
Columbus, OH	x	x	100	100	0.00	0.85	1.06	-0.05	-0.01	1.19	9.75	0.00	2.75	3.08	1.71	1.85	3.23	17.30
Dallas-Fort Worth, TX	x	-	100	-	0.00	3.80	4.74	-0.22	-0.05	5.30	43.51	0.00	12.28	13.74	7.61	8.25	14.42	77.17
Dayton-Springfield, OH	-	x	-	100	0.00	0.35	0.44	-0.02	0.00	0.49	4.00	0.00	1.13	1.26	0.70	0.76	1.33	7.10
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-2.98	-3.03	-6.16	-6.89	-5.83	-22.27	0.00	-9.95	-10.04	-14.15	-15.09	-13.95	-18.93
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-2.76	-2.71	-6.58	-7.34	-5.63	-18.98	0.00	-9.26	-9.20	-14.23	-15.16	-13.29	-11.79
Door Co., WI	x	-	100	-	0.00	0.01	0.02	0.00	0.00	0.02	0.16	0.00	0.05	0.05	0.03	0.03	0.05	0.29
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Evansville, IN	-	x	-	100	0.00	0.16	0.20	0.00	0.00	0.23	1.84	0.00	0.52	0.58	0.33	0.36	0.61	3.25
Greater Connecticut, CT	x	-	100	-	0.00	0.81	1.02	-0.05	-0.01	1.13	9.33	0.00	2.63	2.94	1.63	1.76	3.09	16.55
Greene Co., PA	x	-	100	-	0.00	0.02	0.02	0.00	0.00	0.02	0.19	0.00	0.05	0.06	0.03	0.04	0.06	0.33
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.37	0.46	-0.02	0.00	0.52	4.24	0.00	1.20	1.34	0.74	0.80	1.41	7.53
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.33	0.41	-0.02	0.00	0.45	3.73	0.00	1.05	1.18	0.65	0.71	1.24	6.62

Table B2-35
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.01	0.00	0.01	0.01	0.05
Hickory, NC	-	x	-	100	0.00	0.09	0.11	-0.01	0.00	0.13	1.03	0.00	0.29	0.33	0.18	0.20	0.34	1.83
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-110.95	-121.49	-148.88	-168.55	-195.74	-979.58	0.00	-366.36	-383.16	-422.75	-452.05	-485.77	-1,233.36
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-10.73	-11.75	-14.32	-16.22	-18.90	-94.82	0.00	-35.41	-37.05	-40.78	-43.61	-46.93	-119.68
Imperial Co., CA	x	-	100	-	0.00	0.13	0.16	-0.01	0.00	0.18	1.44	0.00	0.41	0.46	0.25	0.27	0.48	2.56
Indianapolis, IN	-	x	-	100	0.00	0.79	0.99	-0.04	-0.01	1.10	9.08	0.00	2.56	2.87	1.59	1.72	3.01	16.10
Jamestown, NY	x	-	100	-	0.00	0.06	0.08	0.00	0.00	0.09	0.73	0.00	0.21	0.23	0.13	0.14	0.24	1.30
Jefferson Co., NY	x	-	100	-	0.00	0.07	0.09	0.00	0.00	0.10	0.79	0.00	0.22	0.25	0.14	0.15	0.26	1.39
Johnstown, PA	-	x	-	100	0.00	0.05	0.06	0.00	0.00	0.07	0.57	0.00	0.16	0.18	0.10	0.11	0.19	1.02
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.06	0.08	-0.01	-0.01	0.08	0.71	0.00	0.20	0.22	0.12	0.13	0.23	1.28
Knoxville, TN	x	x	100	100	0.00	0.52	0.65	-0.03	-0.01	0.72	5.95	0.00	1.68	1.88	1.04	1.13	1.97	10.55
Lancaster, PA	-	x	-	100	0.00	0.19	0.24	-0.01	0.00	0.27	2.22	0.00	0.63	0.70	0.39	0.42	0.73	3.93
Las Vegas, NV	x	-	100	-	0.00	0.86	1.07	-0.05	-0.01	1.20	9.85	0.00	2.78	3.11	1.73	1.87	3.27	17.46
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.01	0.01	0.01	0.01	0.07
Liberty-Clairton, PA	-	x	-	100	0.00	0.01	0.01	0.00	0.00	0.01	0.06	0.00	0.02	0.02	0.01	0.01	0.02	0.10
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-53.62	-57.78	-80.48	-90.80	-96.85	-457.34	0.00	-177.47	-184.16	-215.32	-230.07	-238.30	-539.86
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.38	0.48	-0.03	-0.01	0.53	4.37	0.00	1.23	1.38	0.76	0.82	1.44	7.75
Louisville, KY-IN	-	x	-	100	0.00	0.49	0.61	-0.02	0.00	0.69	5.63	0.00	1.59	1.78	0.99	1.08	1.87	9.96
Macon, GA	-	x	-	100	0.00	0.09	0.12	0.00	0.00	0.13	1.06	0.00	0.30	0.33	0.19	0.20	0.35	1.87
Manitowoc Co., WI	x	-		-	0.00	0.05	0.06	0.00	0.00	0.06	0.53	0.00	0.15	0.17	0.09	0.10	0.17	0.94
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.06	0.07	0.00	0.00	0.08	0.67	0.00	0.19	0.21	0.12	0.13	0.22	1.19
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.24	0.30	-0.01	0.00	0.33	2.72	0.00	0.77	0.86	0.48	0.52	0.90	4.83
Memphis, TN-AR	x	-	100	-	0.00	-8.43	-9.19	-11.65	-13.17	-14.96	-73.76	0.00	-27.84	-29.06	-32.54	-34.79	-37.03	-91.45
Milwaukee-Racine, WI	x	-	100	-	0.00	0.78	0.97	-0.04	-0.01	1.09	8.93	0.00	2.52	2.82	1.56	1.69	2.96	15.83
Nevada (Western Part), CA	x	-	100	-	0.00	0.05	0.06	0.00	0.00	0.07	0.56	0.00	0.16	0.18	0.10	0.11	0.19	1.00
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-9.22	-9.16	-20.90	-23.34	-18.51	-65.33	0.00	-30.85	-30.82	-46.13	-49.16	-43.90	-46.30
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.07	0.08	0.00	0.00	0.09	0.76	0.00	0.22	0.24	0.13	0.15	0.25	1.35
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-55.10	-60.03	-76.70	-86.74	-97.94	-481.22	0.00	-182.06	-189.94	-213.51	-228.25	-242.37	-594.19
Phoenix-Mesa, AZ	x	-	100	-	0.00	2.30	2.87	-0.11	0.00	3.22	26.34	0.00	7.44	8.33	4.64	5.03	8.75	46.65
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.81	1.02	-0.05	-0.01	1.14	9.32	0.00	2.63	2.94	1.63	1.77	3.09	16.53
Poughkeepsie, NY	x	x	100	100	0.00	0.62	0.77	-0.04	-0.01	0.86	7.05	0.00	1.99	2.23	1.23	1.34	2.34	12.51

Table B2-35
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PM 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.41	0.51	-0.02	-0.01	0.57	4.65	0.00	1.31	1.47	0.81	0.88	1.54	8.25
Reading, PA	-	x	-	100	0.00	0.18	0.23	-0.01	0.00	0.25	2.08	0.00	0.59	0.66	0.36	0.39	0.69	3.69
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.51	0.64	-0.03	-0.01	0.71	5.88	0.00	1.66	1.86	1.02	1.11	1.95	10.43
Rochester, NY	x	-	100	-	0.00	0.58	0.72	-0.03	-0.01	0.81	6.62	0.00	1.87	2.09	1.16	1.25	2.19	11.74
Rome, GA	-	x	-	100	0.00	0.05	0.06	0.00	0.00	0.07	0.57	0.00	0.16	0.18	0.10	0.11	0.19	1.01
Sacramento Metro, CA	x	-	50	-	0.00	1.12	1.40	-0.06	-0.01	1.57	12.88	0.00	3.63	4.07	2.25	2.44	4.27	22.84
San Diego, CA	x	-	100	-	0.00	1.33	1.66	-0.08	-0.02	1.85	15.21	0.00	4.29	4.80	2.66	2.88	5.04	26.97
San Francisco Bay Area, CA	x	-	100	-	0.00	-29.59	-32.06	-42.89	-48.43	-53.05	-255.29	0.00	-97.87	-101.82	-116.86	-124.89	-130.88	-308.03
San Joaquin Valley, CA	x	x	50	100	0.00	-3.00	-2.93	-7.30	-8.14	-6.16	-20.34	0.00	-10.07	-9.98	-15.65	-16.67	-14.50	-11.81
Sheboygan, WI	x	-	100	-	0.00	0.05	0.07	0.00	0.00	0.08	0.62	0.00	0.18	0.20	0.11	0.12	0.21	1.10
Springfield (Western MA), MA	x	-	100	-	0.00	0.42	0.53	-0.02	-0.01	0.59	4.83	0.00	1.36	1.53	0.85	0.92	1.60	8.57
St. Louis, MO-IL	x	x	100	100	0.00	-13.70	-14.84	-19.84	-22.41	-24.55	-118.19	0.00	-45.30	-47.13	-54.07	-57.79	-60.58	-142.66
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.94	-1.03	-1.29	-1.46	-1.67	-8.25	0.00	-3.11	-3.25	-3.63	-3.88	-4.13	-10.26
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.15	0.20	-0.20	-0.21	0.15	2.03	0.00	0.46	0.55	0.05	0.06	0.48	4.21
Washington, DC-MD-VA	x	x	100	100	0.00	2.39	2.98	-0.14	-0.04	3.33	27.39	0.00	7.73	8.65	4.78	5.18	9.07	48.60
Wheeling, WV-OH	-	x	-	100	0.00	0.07	0.09	0.00	0.00	0.10	0.81	0.00	0.23	0.26	0.14	0.15	0.27	1.44
York, PA	-	x	-	100	0.00	0.20	0.25	-0.01	0.00	0.28	2.30	0.00	0.65	0.73	0.40	0.44	0.76	4.08

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-36
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.81	1.02	-0.12	-0.08	1.13	7.84	0.00	3.31	3.68	2.19	2.37	3.83	17.83
Allegan Co., MI	x	-	100	-	0.00	0.09	0.11	-0.01	-0.01	0.12	0.85	0.00	0.36	0.40	0.24	0.26	0.42	1.94
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.10	0.13	-0.02	-0.01	0.14	1.00	0.00	0.42	0.47	0.28	0.30	0.49	2.28
Atlanta, GA	x	x	100	100	0.00	6.43	8.09	-0.99	-0.64	9.02	62.44	0.00	26.38	29.26	17.44	18.89	30.50	141.94
Baltimore, MD	x	x	100	100	0.00	1.75	2.20	-0.27	-0.18	2.46	17.00	0.00	7.18	7.97	4.75	5.14	8.30	38.66
Baton Rouge, LA	x	-	100	-	0.00	-38.02	-41.71	-50.45	-57.39	-66.53	-329.91	0.00	-154.49	-161.06	-175.16	-186.48	-198.65	-448.20
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-77.20	-84.82	-101.47	-115.48	-134.89	-670.69	0.00	-313.78	-327.29	-354.47	-377.41	-403.12	-917.07
Birmingham, AL	-	x	-	100	0.00	0.60	0.76	-0.09	-0.06	0.85	5.85	0.00	2.47	2.74	1.64	1.77	2.86	13.29
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	2.48	3.12	-0.38	-0.25	3.48	24.12	0.00	10.19	11.30	6.73	7.29	11.78	54.83
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.38	0.48	-0.05	-0.03	0.54	3.70	0.00	1.56	1.73	1.04	1.13	1.81	8.38
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.57	0.72	-0.09	-0.06	0.80	5.56	0.00	2.35	2.61	1.55	1.68	2.72	12.65
Canton-Massillon, OH	-	x	-	100	0.00	-4.86	-5.31	-6.60	-7.50	-8.54	-42.03	0.00	-19.73	-20.54	-22.58	-24.04	-25.43	-56.15
Charleston, WV	-	x	-	100	0.00	0.14	0.18	-0.02	-0.01	0.20	1.38	0.00	0.58	0.65	0.39	0.42	0.68	3.15
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	1.54	1.94	-0.21	-0.12	2.17	14.96	0.00	6.33	7.01	4.23	4.57	7.33	33.84
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.29	0.36	-0.05	-0.03	0.40	2.81	0.00	1.19	1.32	0.78	0.84	1.37	6.42
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-51.45	-55.83	-74.05	-83.94	-91.40	-442.51	0.00	-208.95	-216.77	-244.45	-260.06	-270.75	-566.58
Chico, CA	x	-	100	-	0.00	0.12	0.15	-0.02	-0.01	0.16	1.13	0.00	0.48	0.53	0.32	0.34	0.55	2.57
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	1.15	1.45	-0.17	-0.11	1.62	11.17	0.00	4.72	5.24	3.13	3.39	5.46	25.37
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.08	0.10	-0.01	-0.01	0.12	0.80	0.00	0.34	0.38	0.22	0.24	0.39	1.82
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	1.35	1.70	-0.21	-0.14	1.90	13.14	0.00	5.55	6.16	3.67	3.97	6.42	29.88
Columbus, OH	x	x	100	100	0.00	1.18	1.48	-0.18	-0.12	1.65	11.44	0.00	4.83	5.36	3.20	3.46	5.59	26.01
Dallas-Fort Worth, TX	x	-	100	-	0.00	5.84	7.34	-0.90	-0.58	8.19	56.69	0.00	23.95	26.56	15.84	17.15	27.69	128.88
Dayton-Springfield, OH	-	x	-	100	0.00	0.41	0.52	-0.06	-0.04	0.58	4.01	0.00	1.69	1.88	1.12	1.21	1.96	9.12
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-4.11	-4.15	-8.83	-9.88	-7.99	-33.33	0.00	-16.62	-16.71	-23.26	-24.66	-22.59	-25.04
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-4.24	-4.24	-9.42	-10.52	-8.30	-34.11	0.00	-17.12	-17.14	-24.38	-25.83	-23.37	-23.55
Door Co., WI	x	-	100	-	0.00	0.02	0.02	0.00	0.00	0.02	0.16	0.00	0.07	0.08	0.05	0.05	0.08	0.37
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Evansville, IN	-	x	-	100	0.00	0.20	0.25	-0.03	-0.01	0.28	1.95	0.00	0.83	0.92	0.55	0.60	0.96	4.41
Greater Connecticut, CT	x	-	100	-	0.00	1.03	1.29	-0.16	-0.11	1.44	9.97	0.00	4.21	4.67	2.78	3.01	4.87	22.68
Greene Co., PA	x	-	100	-	0.00	0.02	0.02	0.00	0.00	0.03	0.17	0.00	0.07	0.08	0.05	0.05	0.08	0.39
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.47	0.59	-0.07	-0.05	0.66	4.56	0.00	1.93	2.14	1.27	1.38	2.23	10.37
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.40	0.51	-0.06	-0.04	0.56	3.90	0.00	1.65	1.83	1.09	1.18	1.90	8.86

Table B2-36
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.01	0.01	0.01	0.01	0.07
Hickory, NC	-	x	-	100	0.00	0.12	0.15	-0.02	-0.01	0.17	1.15	0.00	0.49	0.54	0.32	0.35	0.56	2.61
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-155.05	-169.88	-208.18	-236.68	-271.92	-1,343.93	0.00	-630.06	-656.40	-717.50	-763.79	-811.04	-1,811.36
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-15.03	-16.48	-20.02	-22.77	-26.32	-130.35	0.00	-61.06	-63.64	-69.33	-73.81	-78.55	-176.61
Imperial Co., CA	x	-	100	-	0.00	0.19	0.25	-0.03	-0.02	0.27	1.89	0.00	0.80	0.89	0.53	0.57	0.92	4.30
Indianapolis, IN	-	x	-	100	0.00	1.10	1.38	-0.17	-0.11	1.54	10.67	0.00	4.51	5.00	2.98	3.23	5.21	24.25
Jamestown, NY	x	-	100	-	0.00	0.08	0.10	-0.01	-0.01	0.11	0.73	0.00	0.31	0.34	0.21	0.22	0.36	1.67
Jefferson Co., NY	x	-	100	-	0.00	0.09	0.12	-0.01	-0.01	0.13	0.90	0.00	0.38	0.42	0.25	0.27	0.44	2.05
Johnstown, PA	-	x	-	100	0.00	0.06	0.07	-0.01	-0.01	0.08	0.54	0.00	0.23	0.25	0.15	0.16	0.27	1.24
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.09	0.11	-0.03	-0.03	0.12	0.88	0.00	0.37	0.41	0.22	0.24	0.42	2.09
Knoxville, TN	x	x	100	100	0.00	0.68	0.85	-0.10	-0.07	0.95	6.57	0.00	2.78	3.08	1.84	1.99	3.21	14.94
Lancaster, PA	-	x	-	100	0.00	0.24	0.30	-0.04	-0.02	0.34	2.33	0.00	0.98	1.09	0.65	0.70	1.14	5.29
Las Vegas, NV	x	-	100	-	0.00	1.43	1.79	-0.21	-0.13	2.01	13.86	0.00	5.86	6.49	3.88	4.20	6.77	31.46
Libby, MT	-	x	-	100	0.00	0.00	0.01	0.00	0.00	0.01	0.04	0.00	0.02	0.02	0.01	0.01	0.02	0.09
Liberty-Clairton, PA	-	x	-	100	0.00	0.01	0.01	0.00	0.00	0.01	0.05	0.00	0.02	0.02	0.01	0.01	0.02	0.11
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-74.69	-80.42	-113.39	-128.26	-134.06	-638.28	0.00	-303.19	-313.44	-362.41	-385.36	-394.97	-781.59
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.55	0.69	-0.10	-0.07	0.76	5.32	0.00	2.24	2.49	1.47	1.59	2.59	12.15
Louisville, KY-IN	-	x	-	100	0.00	0.59	0.74	-0.08	-0.05	0.82	5.69	0.00	2.41	2.67	1.60	1.73	2.78	12.90
Macon, GA	-	x	-	100	0.00	0.11	0.14	-0.02	-0.01	0.16	1.08	0.00	0.46	0.50	0.30	0.33	0.53	2.44
Manitowoc Co., WI	x	-		-	0.00	0.05	0.07	-0.01	-0.01	0.08	0.53	0.00	0.22	0.25	0.15	0.16	0.26	1.20
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.09	0.11	-0.01	-0.01	0.13	0.87	0.00	0.37	0.41	0.24	0.26	0.42	1.97
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.38	0.48	-0.06	-0.04	0.53	3.70	0.00	1.56	1.73	1.03	1.12	1.80	8.40
Memphis, TN-AR	x	-	100	-	0.00	-11.86	-12.95	-16.30	-18.52	-20.89	-102.52	0.00	-48.18	-50.12	-55.36	-58.92	-62.15	-135.88
Milwaukee-Racine, WI	x	-	100	-	0.00	0.95	1.19	-0.15	-0.10	1.33	9.20	0.00	3.89	4.31	2.57	2.78	4.49	20.93
Nevada (Western Part), CA	x	-	100	-	0.00	0.07	0.08	-0.01	-0.01	0.09	0.65	0.00	0.27	0.30	0.18	0.20	0.32	1.47
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-14.03	-14.17	-29.87	-33.41	-27.19	-113.91	0.00	-56.73	-57.06	-79.04	-83.78	-76.98	-87.25
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.08	0.10	-0.01	-0.01	0.11	0.74	0.00	0.31	0.35	0.21	0.22	0.36	1.68
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-77.29	-84.28	-107.48	-122.01	-136.42	-667.35	0.00	-313.98	-326.42	-362.41	-385.67	-405.50	-877.20
Phoenix-Mesa, AZ	x	-	100	-	0.00	3.66	4.60	-0.53	-0.33	5.15	35.52	0.00	15.01	16.65	9.98	10.80	17.37	80.56
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.92	1.16	-0.14	-0.09	1.30	8.96	0.00	3.79	4.20	2.51	2.71	4.38	20.37
Poughkeepsie, NY	x	x	100	100	0.00	0.81	1.02	-0.13	-0.08	1.14	7.90	0.00	3.34	3.70	2.21	2.39	3.86	17.96

Table B2-36
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	0.49	0.61	-0.08	-0.05	0.69	4.75	0.00	2.00	2.22	1.33	1.44	2.32	10.79
Reading, PA	-	x	-	100	0.00	0.24	0.30	-0.04	-0.02	0.34	2.33	0.00	0.98	1.09	0.65	0.71	1.14	5.30
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.97	1.22	-0.16	-0.11	1.36	9.40	0.00	3.97	4.40	2.61	2.83	4.59	21.41
Rochester, NY	x	-	100	-	0.00	0.71	0.89	-0.11	-0.07	0.99	6.87	0.00	2.90	3.22	1.92	2.08	3.35	15.61
Rome, GA	-	x	-	100	0.00	0.06	0.07	-0.01	-0.01	0.08	0.58	0.00	0.24	0.27	0.16	0.17	0.28	1.31
Sacramento Metro, CA	x	-	50	-	0.00	1.62	2.04	-0.25	-0.16	2.27	15.72	0.00	6.64	7.36	4.39	4.75	7.68	35.75
San Diego, CA	x	-	100	-	0.00	1.59	1.99	-0.24	-0.16	2.22	15.39	0.00	6.50	7.21	4.30	4.66	7.52	34.99
San Francisco Bay Area, CA	x	-	100	-	0.00	-41.85	-45.42	-60.21	-68.25	-74.34	-359.97	0.00	-169.97	-176.33	-198.82	-211.52	-220.24	-461.05
San Joaquin Valley, CA	x	x	50	100	0.00	-3.86	-3.65	-10.56	-11.74	-8.04	-29.75	0.00	-15.57	-15.23	-24.76	-26.18	-21.97	-7.84
Sheboygan, WI	x	-	100	-	0.00	0.07	0.08	-0.01	-0.01	0.09	0.65	0.00	0.27	0.30	0.18	0.20	0.32	1.48
Springfield (Western MA), MA	x	-	100	-	0.00	0.53	0.66	-0.08	-0.05	0.74	5.10	0.00	2.15	2.39	1.42	1.54	2.49	11.59
St. Louis, MO-IL	x	x	100	100	0.00	-19.35	-21.00	-27.85	-31.57	-34.37	-166.42	0.00	-78.58	-81.52	-91.94	-97.81	-101.83	-213.08
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-1.33	-1.45	-1.81	-2.06	-2.33	-11.49	0.00	-5.39	-5.61	-6.18	-6.58	-6.95	-15.32
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.15	0.22	-0.31	-0.32	0.15	1.69	0.00	0.64	0.76	0.06	0.08	0.64	5.35
Washington, DC-MD-VA	x	x	100	100	0.00	3.36	4.23	-0.53	-0.35	4.71	32.62	0.00	13.78	15.28	9.10	9.85	15.93	74.20
Wheeling, WV-OH	-	x	-	100	0.00	0.08	0.10	-0.01	-0.01	0.11	0.78	0.00	0.33	0.37	0.22	0.24	0.38	1.78
York, PA	-	x	-	100	0.00	0.28	0.35	-0.04	-0.03	0.39	2.71	0.00	1.14	1.27	0.76	0.82	1.32	6.16

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.

b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.

c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)

EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-37
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-0.50	-0.52	-1.01	-1.14	-1.80	-14.86	0.00	-0.51	-0.52	-1.02	-1.14	-1.81	-14.86
Allegan Co., MI	x	-	100	-	0.00	-0.06	-0.06	-0.11	-0.12	-0.20	-1.63	0.00	-0.06	-0.06	-0.11	-0.13	-0.20	-1.63
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.05	-0.05	-0.10	-0.11	-0.18	-1.48	0.00	-0.05	-0.05	-0.10	-0.11	-0.18	-1.48
Atlanta, GA	x	x	100	100	0.00	-2.68	-2.74	-5.38	-6.06	-9.58	-79.00	0.00	-2.70	-2.76	-5.40	-6.08	-9.60	-79.02
Baltimore, MD	x	x	100	100	0.00	-1.12	-1.14	-2.24	-2.52	-3.99	-32.86	0.00	-1.13	-1.15	-2.25	-2.53	-4.00	-32.87
Baton Rouge, LA	x	-	100	-	0.00	-25.08	-27.92	-34.55	-38.05	-48.44	-260.78	0.00	-25.22	-28.05	-34.69	-38.20	-48.59	-260.92
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-50.14	-55.84	-68.85	-75.80	-96.24	-514.41	0.00	-50.40	-56.11	-69.12	-76.08	-96.54	-514.70
Birmingham, AL	-	x	-	100	0.00	-0.41	-0.42	-0.82	-0.92	-1.45	-12.00	0.00	-0.41	-0.42	-0.82	-0.92	-1.46	-12.00
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-1.82	-1.86	-3.64	-4.10	-6.48	-53.45	0.00	-1.83	-1.87	-3.66	-4.12	-6.50	-53.46
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.24	-0.24	-0.48	-0.54	-0.86	-7.13	0.00	-0.24	-0.24	-0.48	-0.54	-0.86	-7.13
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-0.44	-0.45	-0.88	-0.99	-1.56	-12.85	0.00	-0.44	-0.45	-0.88	-0.99	-1.56	-12.86
Canton-Massillon, OH	-	x	-	100	0.00	-3.37	-3.74	-4.69	-5.17	-6.65	-36.72	0.00	-3.38	-3.76	-4.71	-5.19	-6.67	-36.74
Charleston, WV	-	x	-	100	0.00	-0.12	-0.12	-0.23	-0.26	-0.42	-3.44	0.00	-0.12	-0.12	-0.24	-0.26	-0.42	-3.44
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-0.64	-0.65	-1.32	-1.49	-2.39	-20.10	0.00	-0.64	-0.65	-1.33	-1.50	-2.40	-20.11
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.21	-0.21	-0.41	-0.47	-0.74	-6.12	0.00	-0.21	-0.21	-0.42	-0.47	-0.74	-6.12
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-38.92	-43.11	-55.12	-60.81	-79.07	-450.03	0.00	-39.13	-43.32	-55.34	-61.04	-79.30	-450.26
Chico, CA	x	-	100	-	0.00	-0.08	-0.08	-0.15	-0.17	-0.27	-2.22	0.00	-0.08	-0.08	-0.15	-0.17	-0.27	-2.22
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-0.71	-0.73	-1.44	-1.62	-2.56	-21.19	0.00	-0.72	-0.73	-1.44	-1.63	-2.57	-21.19
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.07	-0.07	-0.14	-0.15	-0.24	-2.01	0.00	-0.07	-0.07	-0.14	-0.16	-0.24	-2.01
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-1.04	-1.07	-2.09	-2.35	-3.72	-30.66	0.00	-1.05	-1.07	-2.10	-2.36	-3.73	-30.67
Columbus, OH	x	x	100	100	0.00	-0.67	-0.69	-1.35	-1.52	-2.40	-19.81	0.00	-0.68	-0.69	-1.35	-1.53	-2.41	-19.82
Dallas-Fort Worth, TX	x	-	100	-	0.00	-2.73	-2.79	-5.47	-6.16	-9.73	-80.28	0.00	-2.75	-2.81	-5.49	-6.18	-9.75	-80.30
Dayton-Springfield, OH	-	x	-	100	0.00	-0.32	-0.32	-0.63	-0.71	-1.13	-9.30	0.00	-0.32	-0.33	-0.64	-0.72	-1.13	-9.30
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-5.44	-5.94	-8.26	-9.15	-12.50	-79.75	0.00	-5.47	-5.97	-8.29	-9.19	-12.53	-79.78
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-6.34	-6.89	-9.90	-11.00	-15.29	-101.26	0.00	-6.38	-6.93	-9.94	-11.04	-15.33	-101.30
Door Co., WI	x	-	100	-	0.00	-0.01	-0.01	-0.03	-0.03	-0.05	-0.38	0.00	-0.01	-0.01	-0.03	-0.03	-0.05	-0.38
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.02
Evansville, IN	-	x	-	100	0.00	-0.13	-0.13	-0.26	-0.29	-0.46	-3.88	0.00	-0.13	-0.13	-0.26	-0.29	-0.47	-3.89
Greater Connecticut, CT	x	-	100	-	0.00	-0.69	-0.71	-1.39	-1.56	-2.47	-20.36	0.00	-0.70	-0.71	-1.39	-1.57	-2.48	-20.36
Greene Co., PA	x	-	100	-	0.00	-0.02	-0.02	-0.03	-0.04	-0.06	-0.47	0.00	-0.02	-0.02	-0.03	-0.04	-0.06	-0.47
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-0.31	-0.32	-0.63	-0.71	-1.11	-9.19	0.00	-0.31	-0.32	-0.63	-0.71	-1.12	-9.19
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-0.28	-0.29	-0.57	-0.64	-1.01	-8.33	0.00	-0.29	-0.29	-0.57	-0.64	-1.01	-8.33

Table B2-37
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.06	0.00	0.00	0.00	0.00	0.00	-0.01	-0.06
Hickory, NC	-	x	-	100	0.00	-0.07	-0.08	-0.15	-0.17	-0.26	-2.16	0.00	-0.07	-0.08	-0.15	-0.17	-0.26	-2.16
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-104.32	-116.03	-144.30	-158.95	-203.00	-1,102.47	0.00	-104.87	-116.59	-144.88	-159.55	-203.62	-1,103.08
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-9.99	-11.11	-13.81	-15.21	-19.41	-105.17	0.00	-10.04	-11.17	-13.86	-15.26	-19.46	-105.23
Imperial Co., CA	x	-	100	-	0.00	-0.09	-0.09	-0.17	-0.20	-0.31	-2.56	0.00	-0.09	-0.09	-0.18	-0.20	-0.31	-2.56
Indianapolis, IN	-	x	-	100	0.00	-0.63	-0.64	-1.26	-1.42	-2.24	-18.50	0.00	-0.63	-0.65	-1.27	-1.42	-2.25	-18.50
Jamestown, NY	x	-	100	-	0.00	-0.06	-0.06	-0.12	-0.13	-0.21	-1.71	0.00	-0.06	-0.06	-0.12	-0.13	-0.21	-1.71
Jefferson Co., NY	x	-	100	-	0.00	-0.05	-0.06	-0.11	-0.12	-0.19	-1.59	0.00	-0.05	-0.06	-0.11	-0.12	-0.19	-1.59
Johnstown, PA	-	x	-	100	0.00	-0.05	-0.05	-0.10	-0.11	-0.17	-1.40	0.00	-0.05	-0.05	-0.10	-0.11	-0.17	-1.40
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.05	-0.05	-0.10	-0.11	-0.17	-1.38	0.00	-0.05	-0.05	-0.10	-0.11	-0.17	-1.38
Knoxville, TN	x	x	100	100	0.00	-0.43	-0.44	-0.86	-0.96	-1.52	-12.56	0.00	-0.43	-0.44	-0.86	-0.97	-1.53	-12.57
Lancaster, PA	-	x	-	100	0.00	-0.17	-0.17	-0.33	-0.38	-0.60	-4.91	0.00	-0.17	-0.17	-0.34	-0.38	-0.60	-4.91
Las Vegas, NV	x	-	100	-	0.00	-0.55	-0.56	-1.11	-1.25	-1.97	-16.25	0.00	-0.55	-0.57	-1.11	-1.25	-1.97	-16.26
Libby, MT	-	x	-	100	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.08	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.08
Liberty-Clairton, PA	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.16	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.16
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-60.85	-67.26	-87.10	-96.17	-126.04	-731.74	0.00	-61.18	-67.59	-87.45	-96.53	-126.41	-732.10
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-0.29	-0.29	-0.57	-0.65	-1.02	-8.41	0.00	-0.29	-0.30	-0.58	-0.65	-1.02	-8.41
Louisville, KY-IN	-	x	-	100	0.00	-0.43	-0.44	-0.87	-0.98	-1.55	-12.80	0.00	-0.43	-0.44	-0.87	-0.98	-1.55	-12.81
Macon, GA	-	x	-	100	0.00	-0.08	-0.08	-0.16	-0.18	-0.29	-2.38	0.00	-0.08	-0.08	-0.16	-0.18	-0.29	-2.38
Manitowoc Co., WI	x	-		-	0.00	-0.04	-0.04	-0.08	-0.10	-0.15	-1.24	0.00	-0.04	-0.04	-0.08	-0.10	-0.15	-1.24
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.04	-0.04	-0.08	-0.09	-0.15	-1.20	0.00	-0.04	-0.04	-0.08	-0.09	-0.15	-1.20
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.16	-0.16	-0.32	-0.36	-0.57	-4.71	0.00	-0.16	-0.16	-0.32	-0.36	-0.57	-4.71
Memphis, TN-AR	x	-	100	-	0.00	-8.38	-9.30	-11.74	-12.94	-16.69	-92.94	0.00	-8.43	-9.35	-11.78	-12.99	-16.73	-92.98
Milwaukee-Racine, WI	x	-	100	-	0.00	-0.69	-0.70	-1.38	-1.56	-2.46	-20.25	0.00	-0.69	-0.71	-1.39	-1.56	-2.46	-20.26
Nevada (Western Part), CA	x	-	100	-	0.00	-0.04	-0.04	-0.08	-0.09	-0.14	-1.15	0.00	-0.04	-0.04	-0.08	-0.09	-0.14	-1.15
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-19.79	-21.53	-30.73	-34.11	-47.25	-310.73	0.00	-19.90	-21.64	-30.85	-34.24	-47.37	-310.85
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.06	-0.06	-0.12	-0.14	-0.22	-1.82	0.00	-0.06	-0.06	-0.12	-0.14	-0.22	-1.82
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-55.34	-61.40	-77.59	-85.55	-110.41	-616.37	0.00	-55.64	-61.70	-77.90	-85.88	-110.73	-616.69
Phoenix-Mesa, AZ	x	-	100	-	0.00	-1.51	-1.54	-3.04	-3.42	-5.42	-44.91	0.00	-1.52	-1.55	-3.05	-3.44	-5.44	-44.93
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-0.77	-0.78	-1.54	-1.73	-2.74	-22.61	0.00	-0.77	-0.79	-1.55	-1.74	-2.75	-22.62
Poughkeepsie, NY	x	x	100	100	0.00	-0.50	-0.51	-1.00	-1.13	-1.78	-14.67	0.00	-0.50	-0.51	-1.00	-1.13	-1.78	-14.67

Table B2-37
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-0.36	-0.37	-0.72	-0.81	-1.29	-10.61	0.00	-0.36	-0.37	-0.73	-0.82	-1.29	-10.62
Reading, PA	-	x	-	100	0.00	-0.15	-0.15	-0.29	-0.33	-0.52	-4.31	0.00	-0.15	-0.15	-0.29	-0.33	-0.52	-4.31
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-0.29	-0.30	-0.58	-0.66	-1.04	-8.57	0.00	-0.29	-0.30	-0.59	-0.66	-1.04	-8.57
Rochester, NY	x	-	100	-	0.00	-0.51	-0.52	-1.01	-1.14	-1.80	-14.86	0.00	-0.51	-0.52	-1.02	-1.14	-1.81	-14.87
Rome, GA	-	x	-	100	0.00	-0.04	-0.05	-0.09	-0.10	-0.16	-1.30	0.00	-0.04	-0.05	-0.09	-0.10	-0.16	-1.30
Sacramento Metro, CA	x	-	50	-	0.00	-0.85	-0.87	-1.70	-1.91	-3.03	-24.96	0.00	-0.85	-0.87	-1.71	-1.92	-3.03	-24.97
San Diego, CA	x	-	100	-	0.00	-1.19	-1.21	-2.38	-2.68	-4.24	-34.95	0.00	-1.20	-1.22	-2.39	-2.69	-4.25	-34.96
San Francisco Bay Area, CA	x	-	100	-	0.00	-31.90	-35.30	-45.39	-50.10	-65.37	-375.40	0.00	-32.07	-35.47	-45.57	-50.28	-65.56	-375.59
San Joaquin Valley, CA	x	x	50	100	0.00	-6.65	-7.25	-10.22	-11.34	-15.60	-101.15	0.00	-6.69	-7.29	-10.26	-11.38	-15.64	-101.19
Sheboygan, WI	x	-	100	-	0.00	-0.05	-0.05	-0.09	-0.11	-0.17	-1.38	0.00	-0.05	-0.05	-0.09	-0.11	-0.17	-1.38
Springfield (Western MA), MA	x	-	100	-	0.00	-0.36	-0.37	-0.73	-0.82	-1.29	-10.67	0.00	-0.36	-0.37	-0.73	-0.82	-1.30	-10.67
St. Louis, MO-IL	x	x	100	100	0.00	-14.80	-16.38	-21.05	-23.23	-30.31	-173.97	0.00	-14.88	-16.46	-21.13	-23.32	-30.40	-174.06
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.93	-1.03	-1.30	-1.44	-1.85	-10.30	0.00	-0.94	-1.04	-1.31	-1.44	-1.86	-10.30
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-0.37	-0.39	-0.67	-0.75	-1.13	-8.60	0.00	-0.38	-0.40	-0.67	-0.75	-1.13	-8.60
Washington, DC-MD-VA	x	x	100	100	0.00	-1.92	-1.96	-3.84	-4.33	-6.83	-56.27	0.00	-1.93	-1.98	-3.86	-4.34	-6.84	-56.29
Wheeling, WV-OH	-	x	-	100	0.00	-0.07	-0.07	-0.13	-0.15	-0.24	-1.96	0.00	-0.07	-0.07	-0.13	-0.15	-0.24	-1.96
York, PA	-	x	-	100	0.00	-0.15	-0.16	-0.31	-0.35	-0.55	-4.56	0.00	-0.16	-0.16	-0.31	-0.35	-0.55	-4.56

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-38
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-1.63	-1.66	-3.08	-3.50	-4.67	-38.53	0.00	-3.72	-3.79	-5.43	-5.94	-7.19	-40.22
Allegan Co., MI	x	-	100	-	0.00	-0.18	-0.18	-0.34	-0.38	-0.51	-4.21	0.00	-0.41	-0.41	-0.59	-0.65	-0.79	-4.40
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.17	-0.18	-0.33	-0.37	-0.49	-4.08	0.00	-0.39	-0.40	-0.58	-0.63	-0.76	-4.26
Atlanta, GA	x	x	100	100	0.00	-9.42	-9.60	-17.83	-20.26	-27.05	-223.28	0.00	-21.57	-21.95	-31.46	-34.40	-41.64	-233.06
Baltimore, MD	x	x	100	100	0.00	-3.58	-3.65	-6.78	-7.70	-10.28	-84.78	0.00	-8.21	-8.35	-11.96	-13.08	-15.83	-88.50
Baton Rouge, LA	x	-	100	-	0.00	-75.03	-82.77	-98.45	-110.80	-131.94	-649.88	0.00	-175.15	-185.45	-205.99	-222.21	-246.13	-759.18
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-149.87	-165.43	-195.95	-220.52	-262.22	-1,280.17	0.00	-349.92	-370.61	-410.76	-443.04	-490.28	-1,499.00
Birmingham, AL	-	x	-	100	0.00	-1.27	-1.30	-2.41	-2.74	-3.66	-30.22	0.00	-2.91	-2.96	-4.25	-4.65	-5.63	-31.54
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-5.61	-5.72	-10.61	-12.06	-16.10	-132.83	0.00	-12.85	-13.07	-18.73	-20.48	-24.78	-138.65
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.76	-0.77	-1.45	-1.65	-2.20	-18.34	0.00	-1.73	-1.76	-2.54	-2.78	-3.38	-19.12
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-1.34	-1.37	-2.54	-2.88	-3.85	-31.75	0.00	-3.07	-3.12	-4.48	-4.89	-5.92	-33.14
Canton-Massillon, OH	-	x	-	100	0.00	-10.07	-11.09	-13.37	-15.06	-18.01	-91.34	0.00	-23.50	-24.85	-27.81	-30.02	-33.35	-105.90
Charleston, WV	-	x	-	100	0.00	-0.35	-0.36	-0.67	-0.76	-1.01	-8.33	0.00	-0.81	-0.82	-1.17	-1.28	-1.55	-8.69
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-2.26	-2.29	-4.38	-4.98	-6.69	-56.27	0.00	-5.17	-5.24	-7.65	-8.37	-10.19	-58.54
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.65	-0.66	-1.23	-1.39	-1.86	-15.38	0.00	-1.48	-1.51	-2.16	-2.37	-2.87	-16.05
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-116.83	-128.24	-157.70	-177.65	-213.90	-1,126.18	0.00	-272.40	-287.70	-325.27	-351.25	-391.91	-1,293.20
Chico, CA	x	-	100	-	0.00	-0.24	-0.25	-0.46	-0.52	-0.69	-5.71	0.00	-0.55	-0.56	-0.81	-0.88	-1.07	-5.96
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-2.25	-2.29	-4.28	-4.86	-6.50	-53.78	0.00	-5.16	-5.25	-7.54	-8.24	-9.99	-56.11
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.21	-0.21	-0.39	-0.44	-0.59	-4.87	0.00	-0.47	-0.48	-0.69	-0.75	-0.91	-5.08
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-3.18	-3.25	-6.02	-6.85	-9.14	-75.43	0.00	-7.29	-7.42	-10.64	-11.63	-14.07	-78.74
Columbus, OH	x	x	100	100	0.00	-2.20	-2.24	-4.16	-4.73	-6.32	-52.13	0.00	-5.04	-5.13	-7.35	-8.03	-9.72	-54.41
Dallas-Fort Worth, TX	x	-	100	-	0.00	-9.34	-9.52	-17.68	-20.09	-26.82	-221.36	0.00	-21.40	-21.77	-31.20	-34.11	-41.29	-231.06
Dayton-Springfield, OH	-	x	-	100	0.00	-0.97	-0.99	-1.83	-2.08	-2.78	-22.94	0.00	-2.22	-2.26	-3.23	-3.53	-4.28	-23.94
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-16.66	-18.04	-24.21	-27.33	-33.80	-205.17	0.00	-38.72	-40.61	-48.15	-52.14	-59.27	-227.75
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-19.18	-20.67	-28.50	-32.20	-40.13	-252.63	0.00	-44.52	-46.59	-56.08	-60.77	-69.47	-278.16
Door Co., WI	x	-	100	-	0.00	-0.04	-0.04	-0.07	-0.08	-0.11	-0.93	0.00	-0.09	-0.09	-0.13	-0.14	-0.17	-0.97
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.04
Evansville, IN	-	x	-	100	0.00	-0.40	-0.40	-0.77	-0.88	-1.18	-9.86	0.00	-0.91	-0.93	-1.35	-1.48	-1.79	-10.26
Greater Connecticut, CT	x	-	100	-	0.00	-2.19	-2.24	-4.15	-4.72	-6.29	-51.88	0.00	-5.03	-5.12	-7.33	-8.01	-9.69	-54.17
Greene Co., PA	x	-	100	-	0.00	-0.05	-0.05	-0.09	-0.10	-0.13	-1.11	0.00	-0.11	-0.11	-0.16	-0.17	-0.21	-1.16
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-0.99	-1.01	-1.88	-2.13	-2.85	-23.49	0.00	-2.27	-2.31	-3.31	-3.62	-4.38	-24.52
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-0.88	-0.90	-1.67	-1.90	-2.54	-20.97	0.00	-2.03	-2.06	-2.96	-3.23	-3.91	-21.89

Table B2-38
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.14	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.15
Hickory, NC	-	x	-	100	0.00	-0.24	-0.24	-0.45	-0.51	-0.68	-5.62	0.00	-0.54	-0.55	-0.79	-0.87	-1.05	-5.87
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-312.25	-344.20	-411.45	-463.16	-552.46	-2,749.96	0.00	-728.79	-771.36	-859.07	-926.85	-1,027.75	-3,203.58
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-29.88	-32.94	-39.31	-44.25	-52.75	-261.69	0.00	-69.74	-73.82	-82.14	-88.62	-98.23	-305.13
Imperial Co., CA	x	-	100	-	0.00	-0.31	-0.31	-0.58	-0.66	-0.88	-7.23	0.00	-0.70	-0.71	-1.02	-1.11	-1.35	-7.55
Indianapolis, IN	-	x	-	100	0.00	-2.05	-2.09	-3.88	-4.41	-5.88	-48.55	0.00	-4.69	-4.78	-6.84	-7.48	-9.06	-50.68
Jamestown, NY	x	-	100	-	0.00	-0.18	-0.18	-0.34	-0.38	-0.51	-4.22	0.00	-0.41	-0.42	-0.59	-0.65	-0.79	-4.40
Jefferson Co., NY	x	-	100	-	0.00	-0.18	-0.18	-0.34	-0.38	-0.51	-4.20	0.00	-0.41	-0.41	-0.59	-0.65	-0.78	-4.39
Johnstown, PA	-	x	-	100	0.00	-0.14	-0.15	-0.27	-0.31	-0.41	-3.38	0.00	-0.33	-0.33	-0.48	-0.52	-0.63	-3.53
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.18	-0.18	-0.33	-0.37	-0.49	-3.94	0.00	-0.41	-0.42	-0.59	-0.64	-0.77	-4.14
Knoxville, TN	x	x	100	100	0.00	-1.37	-1.40	-2.59	-2.95	-3.93	-32.48	0.00	-3.14	-3.19	-4.57	-5.00	-6.05	-33.90
Lancaster, PA	-	x	-	100	0.00	-0.52	-0.53	-0.99	-1.13	-1.50	-12.41	0.00	-1.20	-1.22	-1.75	-1.91	-2.32	-12.96
Las Vegas, NV	x	-	100	-	0.00	-2.00	-2.03	-3.78	-4.30	-5.74	-47.47	0.00	-4.57	-4.65	-6.68	-7.30	-8.84	-49.54
Libby, MT	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.20	0.00	-0.02	-0.02	-0.03	-0.03	-0.04	-0.21
Liberty-Clairton, PA	-	x	-	100	0.00	-0.02	-0.02	-0.03	-0.03	-0.05	-0.37	0.00	-0.04	-0.04	-0.05	-0.06	-0.07	-0.39
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-183.61	-201.11	-250.88	-282.72	-341.99	-1,848.53	0.00	-427.87	-451.41	-514.31	-555.64	-621.89	-2,108.83
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-0.97	-0.99	-1.83	-2.08	-2.78	-22.89	0.00	-2.23	-2.27	-3.24	-3.54	-4.29	-23.90
Louisville, KY-IN	-	x	-	100	0.00	-1.32	-1.34	-2.51	-2.86	-3.82	-31.69	0.00	-3.02	-3.07	-4.42	-4.84	-5.86	-33.05
Macon, GA	-	x	-	100	0.00	-0.25	-0.25	-0.47	-0.53	-0.71	-5.92	0.00	-0.56	-0.57	-0.82	-0.90	-1.09	-6.17
Manitowoc Co., WI	x	-		-	0.00	-0.13	-0.13	-0.24	-0.28	-0.37	-3.05	0.00	-0.30	-0.30	-0.43	-0.47	-0.57	-3.18
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.14	-0.15	-0.27	-0.31	-0.41	-3.37	0.00	-0.33	-0.33	-0.48	-0.52	-0.63	-3.52
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.57	-0.58	-1.07	-1.22	-1.63	-13.45	0.00	-1.30	-1.32	-1.90	-2.07	-2.51	-14.04
Memphis, TN-AR	x	-	100	-	0.00	-25.09	-27.60	-33.46	-37.67	-45.15	-231.25	0.00	-58.52	-61.88	-69.43	-74.94	-83.36	-267.41
Milwaukee-Racine, WI	x	-	100	-	0.00	-2.13	-2.18	-4.04	-4.59	-6.13	-50.55	0.00	-4.89	-4.98	-7.13	-7.79	-9.43	-52.77
Nevada (Western Part), CA	x	-	100	-	0.00	-0.13	-0.13	-0.24	-0.27	-0.37	-3.02	0.00	-0.29	-0.30	-0.43	-0.47	-0.56	-3.16
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-59.82	-64.55	-88.42	-99.88	-124.24	-775.54	0.00	-138.90	-145.45	-174.42	-188.98	-215.74	-855.53
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.19	-0.19	-0.35	-0.40	-0.53	-4.42	0.00	-0.42	-0.43	-0.62	-0.68	-0.82	-4.61
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-165.97	-182.51	-221.75	-249.73	-299.50	-1,540.77	0.00	-387.14	-409.25	-459.74	-496.27	-552.27	-1,779.68
Phoenix-Mesa, AZ	x	-	100	-	0.00	-5.36	-5.46	-10.20	-11.60	-15.51	-128.59	0.00	-12.28	-12.48	-17.97	-19.65	-23.81	-134.12
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-2.30	-2.34	-4.35	-4.95	-6.60	-54.54	0.00	-5.27	-5.36	-7.68	-8.40	-10.17	-56.93
Poughkeepsie, NY	x	x	100	100	0.00	-1.61	-1.65	-3.05	-3.47	-4.63	-38.25	0.00	-3.70	-3.76	-5.39	-5.89	-7.13	-39.93

Table B2-38
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-1.12	-1.14	-2.11	-2.40	-3.20	-26.42	0.00	-2.55	-2.60	-3.73	-4.07	-4.93	-27.58
Reading, PA	-	x	-	100	0.00	-0.47	-0.48	-0.90	-1.02	-1.36	-11.26	0.00	-1.09	-1.11	-1.59	-1.73	-2.10	-11.75
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-1.13	-1.16	-2.14	-2.43	-3.25	-26.77	0.00	-2.60	-2.64	-3.78	-4.14	-5.00	-27.95
Rochester, NY	x	-	100	-	0.00	-1.57	-1.60	-2.98	-3.38	-4.52	-37.29	0.00	-3.60	-3.67	-5.26	-5.75	-6.96	-38.92
Rome, GA	-	x	-	100	0.00	-0.14	-0.14	-0.26	-0.29	-0.39	-3.23	0.00	-0.31	-0.32	-0.45	-0.50	-0.60	-3.37
Sacramento Metro, CA	x	-	50	-	0.00	-2.84	-2.89	-5.37	-6.11	-8.15	-67.29	0.00	-6.50	-6.62	-9.48	-10.37	-12.55	-70.24
San Diego, CA	x	-	100	-	0.00	-3.66	-3.73	-6.92	-7.87	-10.50	-86.70	0.00	-8.38	-8.53	-12.22	-13.36	-16.17	-90.49
San Francisco Bay Area, CA	x	-	100	-	0.00	-95.69	-104.96	-129.70	-146.12	-176.21	-936.11	0.00	-223.07	-235.52	-266.96	-288.33	-322.04	-1,072.53
San Joaquin Valley, CA	x	x	50	100	0.00	-20.71	-22.36	-30.56	-34.52	-42.92	-267.22	0.00	-48.09	-50.37	-60.34	-65.37	-74.60	-294.95
Sheboygan, WI	x	-	100	-	0.00	-0.15	-0.15	-0.28	-0.32	-0.42	-3.49	0.00	-0.34	-0.34	-0.49	-0.54	-0.65	-3.64
Springfield (Western MA), MA	x	-	100	-	0.00	-1.14	-1.16	-2.16	-2.45	-3.27	-27.00	0.00	-2.61	-2.66	-3.81	-4.16	-5.04	-28.19
St. Louis, MO-IL	x	x	100	100	0.00	-44.38	-48.68	-60.12	-67.74	-81.68	-433.58	0.00	-103.45	-109.22	-123.78	-133.68	-149.30	-496.86
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-2.78	-3.06	-3.70	-4.17	-4.99	-25.50	0.00	-6.48	-6.86	-7.69	-8.30	-9.22	-29.50
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-1.15	-1.20	-1.95	-2.21	-2.87	-21.52	0.00	-2.64	-2.73	-3.61	-3.93	-4.64	-22.87
Washington, DC-MD-VA	x	x	100	100	0.00	-6.22	-6.35	-11.76	-13.36	-17.83	-147.02	0.00	-14.26	-14.51	-20.77	-22.71	-27.47	-153.49
Wheeling, WV-OH	-	x	-	100	0.00	-0.20	-0.20	-0.38	-0.43	-0.57	-4.74	0.00	-0.46	-0.47	-0.67	-0.73	-0.88	-4.95
York, PA	-	x	-	100	0.00	-0.51	-0.52	-0.97	-1.11	-1.48	-12.18	0.00	-1.18	-1.20	-1.72	-1.88	-2.27	-12.72

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.

b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.

c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)

EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-39
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-2.56	-2.61	-4.77	-5.43	-6.99	-57.66	0.00	-8.13	-8.26	-11.02	-11.91	-13.68	-61.88
Allegan Co., MI	x	-	100	-	0.00	-0.28	-0.28	-0.52	-0.59	-0.76	-6.30	0.00	-0.89	-0.90	-1.20	-1.30	-1.49	-6.76
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.29	-0.29	-0.54	-0.61	-0.79	-6.50	0.00	-0.92	-0.93	-1.24	-1.34	-1.54	-6.98
Atlanta, GA	x	x	100	100	0.00	-16.33	-16.65	-30.45	-34.67	-44.64	-368.13	0.00	-51.87	-52.71	-70.36	-76.01	-87.29	-395.07
Baltimore, MD	x	x	100	100	0.00	-5.61	-5.72	-10.45	-11.90	-15.32	-126.27	0.00	-17.83	-18.12	-24.17	-26.11	-29.98	-135.54
Baton Rouge, LA	x	-	100	-	0.00	-117.45	-129.27	-152.28	-172.17	-201.87	-972.26	0.00	-387.63	-406.16	-442.40	-472.53	-509.54	-1,261.78
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-234.54	-258.30	-303.00	-342.53	-401.15	-1,913.85	0.00	-774.31	-811.52	-882.37	-942.38	-1,015.54	-2,493.56
Birmingham, AL	-	x	-	100	0.00	-1.96	-1.99	-3.65	-4.15	-5.35	-44.16	0.00	-6.21	-6.31	-8.43	-9.10	-10.46	-47.38
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-8.48	-8.65	-15.81	-18.00	-23.17	-191.02	0.00	-26.94	-27.38	-36.54	-39.47	-45.32	-205.02
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-1.18	-1.20	-2.23	-2.54	-3.27	-27.20	0.00	-3.75	-3.81	-5.11	-5.53	-6.36	-29.12
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-2.01	-2.05	-3.74	-4.26	-5.49	-45.23	0.00	-6.38	-6.48	-8.65	-9.35	-10.73	-48.55
Canton-Massillon, OH	-	x	-	100	0.00	-15.74	-17.29	-20.63	-23.33	-27.46	-135.99	0.00	-51.89	-54.33	-59.50	-63.57	-68.68	-174.46
Charleston, WV	-	x	-	100	0.00	-0.52	-0.53	-0.96	-1.10	-1.41	-11.64	0.00	-1.64	-1.67	-2.23	-2.40	-2.76	-12.50
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-3.88	-3.94	-7.38	-8.40	-10.86	-91.01	0.00	-12.29	-12.47	-16.85	-18.22	-20.99	-97.21
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-1.00	-1.02	-1.85	-2.11	-2.72	-22.34	0.00	-3.17	-3.22	-4.29	-4.64	-5.32	-23.99
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-182.79	-200.22	-243.79	-275.80	-326.29	-1,683.48	0.00	-601.80	-629.37	-694.98	-742.95	-805.02	-2,124.32
Chico, CA	x	-	100	-	0.00	-0.38	-0.38	-0.70	-0.80	-1.03	-8.48	0.00	-1.19	-1.21	-1.62	-1.75	-2.01	-9.10
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-3.52	-3.58	-6.58	-7.49	-9.65	-79.84	0.00	-11.17	-11.34	-15.18	-16.40	-18.84	-85.62
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.30	-0.31	-0.56	-0.64	-0.82	-6.80	0.00	-0.96	-0.97	-1.30	-1.40	-1.61	-7.29
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-4.76	-4.85	-8.87	-10.09	-13.00	-107.14	0.00	-15.11	-15.35	-20.49	-22.14	-25.42	-115.00
Columbus, OH	x	x	100	100	0.00	-3.53	-3.60	-6.58	-7.49	-9.65	-79.54	0.00	-11.21	-11.39	-15.20	-16.43	-18.86	-85.36
Dallas-Fort Worth, TX	x	-	100	-	0.00	-15.74	-16.05	-29.35	-33.42	-43.03	-354.82	0.00	-50.02	-50.82	-67.84	-73.29	-84.15	-380.81
Dayton-Springfield, OH	-	x	-	100	0.00	-1.45	-1.48	-2.70	-3.08	-3.96	-32.65	0.00	-4.60	-4.68	-6.24	-6.74	-7.74	-35.04
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-26.34	-28.46	-37.90	-42.95	-51.97	-312.15	0.00	-86.12	-89.58	-102.80	-110.15	-120.92	-371.71
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-29.74	-32.03	-43.52	-49.33	-59.97	-370.61	0.00	-97.07	-100.84	-116.75	-125.16	-137.80	-436.81
Door Co., WI	x	-	100	-	0.00	-0.06	-0.06	-0.11	-0.12	-0.16	-1.32	0.00	-0.19	-0.19	-0.25	-0.27	-0.31	-1.42
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.06	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.06
Evansville, IN	-	x	-	100	0.00	-0.62	-0.62	-1.17	-1.33	-1.72	-14.44	0.00	-1.95	-1.98	-2.68	-2.89	-3.33	-15.42
Greater Connecticut, CT	x	-	100	-	0.00	-3.39	-3.46	-6.32	-7.19	-9.26	-76.28	0.00	-10.78	-10.96	-14.61	-15.79	-18.12	-81.89
Greene Co., PA	x	-	100	-	0.00	-0.07	-0.07	-0.13	-0.14	-0.18	-1.52	0.00	-0.21	-0.22	-0.29	-0.31	-0.36	-1.63
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-1.54	-1.57	-2.86	-3.26	-4.20	-34.61	0.00	-4.88	-4.96	-6.62	-7.15	-8.21	-37.15
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-1.35	-1.38	-2.52	-2.87	-3.69	-30.45	0.00	-4.29	-4.36	-5.82	-6.29	-7.22	-32.68

Table B2-39
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.21	0.00	-0.03	-0.03	-0.04	-0.04	-0.05	-0.22
Hickory, NC	-	x	-	100	0.00	-0.37	-0.38	-0.70	-0.80	-1.02	-8.44	0.00	-1.19	-1.21	-1.61	-1.74	-2.00	-9.06
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-488.87	-537.68	-636.58	-719.78	-845.12	-4,115.32	0.00	-1,612.86	-1,689.48	-1,843.99	-1,969.86	-2,125.68	-5,316.45
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-46.73	-51.42	-60.74	-68.68	-80.59	-390.57	0.00	-154.21	-161.55	-176.17	-188.18	-203.01	-505.55
Imperial Co., CA	x	-	100	-	0.00	-0.52	-0.53	-0.97	-1.11	-1.43	-11.77	0.00	-1.66	-1.69	-2.25	-2.43	-2.79	-12.64
Indianapolis, IN	-	x	-	100	0.00	-3.28	-3.35	-6.12	-6.97	-8.98	-74.02	0.00	-10.43	-10.60	-14.15	-15.29	-17.56	-79.44
Jamestown, NY	x	-	100	-	0.00	-0.27	-0.27	-0.50	-0.56	-0.73	-6.00	0.00	-0.85	-0.86	-1.15	-1.24	-1.42	-6.43
Jefferson Co., NY	x	-	100	-	0.00	-0.28	-0.29	-0.53	-0.60	-0.78	-6.41	0.00	-0.90	-0.92	-1.23	-1.32	-1.52	-6.88
Johnstown, PA	-	x	-	100	0.00	-0.21	-0.21	-0.39	-0.44	-0.57	-4.68	0.00	-0.66	-0.67	-0.90	-0.97	-1.11	-5.03
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.32	-0.33	-0.57	-0.64	-0.82	-6.49	0.00	-1.02	-1.04	-1.34	-1.45	-1.65	-7.05
Knoxville, TN	x	x	100	100	0.00	-2.15	-2.19	-4.01	-4.56	-5.88	-48.47	0.00	-6.83	-6.94	-9.26	-10.00	-11.49	-52.01
Lancaster, PA	-	x	-	100	0.00	-0.80	-0.82	-1.50	-1.70	-2.19	-18.09	0.00	-2.55	-2.59	-3.46	-3.74	-4.29	-19.41
Las Vegas, NV	x	-	100	-	0.00	-3.53	-3.60	-6.60	-7.52	-9.68	-79.96	0.00	-11.22	-11.40	-15.23	-16.46	-18.91	-85.77
Libby, MT	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.03	-0.04	-0.30	0.00	-0.04	-0.04	-0.06	-0.06	-0.07	-0.32
Liberty-Clairton, PA	-	x	-	100	0.00	-0.02	-0.02	-0.04	-0.05	-0.06	-0.50	0.00	-0.07	-0.07	-0.10	-0.11	-0.12	-0.53
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-288.41	-315.18	-389.78	-441.10	-524.00	-2,785.11	0.00	-948.42	-990.96	-1,101.46	-1,177.95	-1,279.28	-3,473.32
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-1.62	-1.65	-3.00	-3.42	-4.39	-36.04	0.00	-5.14	-5.23	-6.96	-7.51	-8.62	-38.74
Louisville, KY-IN	-	x	-	100	0.00	-1.98	-2.02	-3.72	-4.23	-5.46	-45.26	0.00	-6.29	-6.38	-8.56	-9.25	-10.63	-48.49
Macon, GA	-	x	-	100	0.00	-0.37	-0.38	-0.69	-0.79	-1.02	-8.47	0.00	-1.17	-1.19	-1.60	-1.73	-1.98	-9.07
Manitowoc Co., WI	x	-		-	0.00	-0.19	-0.20	-0.36	-0.41	-0.53	-4.33	0.00	-0.61	-0.62	-0.83	-0.90	-1.03	-4.65
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.24	-0.25	-0.45	-0.51	-0.66	-5.46	0.00	-0.77	-0.78	-1.04	-1.13	-1.30	-5.86
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.98	-1.00	-1.84	-2.09	-2.69	-22.20	0.00	-3.13	-3.18	-4.24	-4.58	-5.26	-23.82
Memphis, TN-AR	x	-	100	-	0.00	-39.20	-43.03	-51.60	-58.36	-68.77	-344.11	0.00	-129.19	-135.23	-148.39	-158.57	-171.43	-439.60
Milwaukee-Racine, WI	x	-	100	-	0.00	-3.24	-3.30	-6.03	-6.87	-8.84	-72.86	0.00	-10.28	-10.45	-13.94	-15.06	-17.29	-78.21
Nevada (Western Part), CA	x	-	100	-	0.00	-0.20	-0.21	-0.38	-0.43	-0.56	-4.61	0.00	-0.65	-0.66	-0.88	-0.95	-1.09	-4.95
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-92.80	-100.03	-135.06	-153.08	-185.83	-1,138.29	0.00	-303.06	-314.94	-363.61	-389.74	-428.71	-1,345.89
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.27	-0.28	-0.51	-0.58	-0.75	-6.19	0.00	-0.87	-0.88	-1.18	-1.27	-1.46	-6.64
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-259.75	-285.03	-342.86	-387.79	-457.30	-2,302.76	0.00	-855.96	-895.80	-984.19	-1,051.80	-1,137.65	-2,934.32
Phoenix-Mesa, AZ	x	-	100	-	0.00	-9.31	-9.48	-17.46	-19.88	-25.62	-212.30	0.00	-29.55	-30.01	-40.21	-43.45	-49.94	-227.52
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-3.37	-3.43	-6.28	-7.15	-9.21	-75.94	0.00	-10.69	-10.86	-14.51	-15.67	-18.00	-81.49
Poughkeepsie, NY	x	x	100	100	0.00	-2.55	-2.60	-4.76	-5.42	-6.98	-57.54	0.00	-8.11	-8.24	-11.00	-11.89	-13.65	-61.75

Table B2-39
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-1.68	-1.72	-3.14	-3.57	-4.60	-37.94	0.00	-5.35	-5.44	-7.26	-7.84	-9.00	-40.73
Reading, PA	-	x	-	100	0.00	-0.75	-0.77	-1.40	-1.60	-2.06	-16.95	0.00	-2.39	-2.43	-3.24	-3.50	-4.02	-18.19
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-2.15	-2.20	-4.00	-4.56	-5.86	-48.22	0.00	-6.84	-6.95	-9.26	-10.01	-11.48	-51.79
Rochester, NY	x	-	100	-	0.00	-2.40	-2.44	-4.47	-5.08	-6.55	-53.98	0.00	-7.61	-7.73	-10.32	-11.15	-12.80	-57.93
Rome, GA	-	x	-	100	0.00	-0.21	-0.21	-0.38	-0.44	-0.56	-4.62	0.00	-0.65	-0.66	-0.88	-0.96	-1.10	-4.96
Sacramento Metro, CA	x	-	50	-	0.00	-4.67	-4.76	-8.70	-9.90	-12.75	-105.08	0.00	-14.82	-15.06	-20.10	-21.71	-24.93	-112.79
San Diego, CA	x	-	100	-	0.00	-5.50	-5.61	-10.26	-11.68	-15.04	-124.03	0.00	-17.48	-17.76	-23.71	-25.62	-29.41	-133.11
San Francisco Bay Area, CA	x	-	100	-	0.00	-149.47	-163.64	-199.93	-226.20	-267.86	-1,391.39	0.00	-491.97	-514.40	-568.85	-608.17	-659.32	-1,751.02
San Joaquin Valley, CA	x	x	50	100	0.00	-33.19	-35.72	-48.67	-55.17	-67.12	-416.35	0.00	-108.30	-112.48	-130.39	-139.79	-153.97	-490.07
Sheboygan, WI	x	-	100	-	0.00	-0.23	-0.23	-0.42	-0.48	-0.62	-5.08	0.00	-0.72	-0.73	-0.97	-1.05	-1.21	-5.45
Springfield (Western MA), MA	x	-	100	-	0.00	-1.75	-1.78	-3.26	-3.71	-4.78	-39.43	0.00	-5.56	-5.65	-7.54	-8.14	-9.35	-42.32
St. Louis, MO-IL	x	x	100	100	0.00	-69.30	-75.88	-92.68	-104.85	-124.15	-644.46	0.00	-228.12	-238.52	-263.73	-281.96	-305.65	-811.25
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-4.33	-4.76	-5.70	-6.44	-7.59	-37.78	0.00	-14.29	-14.96	-16.40	-17.52	-18.94	-48.35
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-1.76	-1.84	-2.95	-3.35	-4.21	-31.26	0.00	-5.66	-5.81	-7.26	-7.82	-8.81	-34.64
Washington, DC-MD-VA	x	x	100	100	0.00	-9.98	-10.18	-18.57	-21.15	-27.22	-224.12	0.00	-31.70	-32.22	-42.96	-46.41	-53.28	-240.63
Wheeling, WV-OH	-	x	-	100	0.00	-0.29	-0.30	-0.55	-0.62	-0.80	-6.62	0.00	-0.93	-0.95	-1.27	-1.37	-1.57	-7.10
York, PA	-	x	-	100	0.00	-0.83	-0.85	-1.55	-1.77	-2.28	-18.79	0.00	-2.65	-2.69	-3.59	-3.88	-4.46	-20.17

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-40
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-3.47	-3.53	-6.51	-7.43	-9.31	-76.66	0.00	-13.43	-13.64	-17.71	-19.02	-21.27	-84.05
Allegan Co., MI	x	-	100	-	0.00	-0.38	-0.38	-0.71	-0.81	-1.01	-8.34	0.00	-1.46	-1.48	-1.93	-2.07	-2.31	-9.14
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.44	-0.45	-0.83	-0.95	-1.19	-9.79	0.00	-1.72	-1.74	-2.26	-2.43	-2.72	-10.74
Atlanta, GA	x	x	100	100	0.00	-27.58	-28.11	-51.82	-59.13	-74.09	-609.92	0.00	-106.82	-108.48	-140.83	-151.32	-169.17	-668.69
Baltimore, MD	x	x	100	100	0.00	-7.54	-7.68	-14.15	-16.14	-20.23	-166.39	0.00	-29.20	-29.65	-38.48	-41.34	-46.21	-182.47
Baton Rouge, LA	x	-	100	-	0.00	-164.05	-180.70	-212.54	-241.40	-280.54	-1,327.22	0.00	-666.90	-695.90	-752.42	-800.25	-852.86	-1,862.42
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-327.45	-360.91	-422.58	-479.94	-557.19	-2,609.28	0.00	-1,331.71	-1,389.95	-1,500.39	-1,595.62	-1,699.71	-3,680.79
Birmingham, AL	-	x	-	100	0.00	-2.57	-2.62	-4.84	-5.52	-6.92	-57.00	0.00	-9.96	-10.12	-13.14	-14.12	-15.79	-62.48
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-10.67	-10.88	-20.04	-22.87	-28.65	-235.79	0.00	-41.33	-41.97	-54.48	-58.54	-65.44	-258.54
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-1.57	-1.60	-2.98	-3.40	-4.27	-35.44	0.00	-6.08	-6.17	-8.06	-8.66	-9.69	-38.74
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-2.46	-2.51	-4.62	-5.28	-6.61	-54.39	0.00	-9.54	-9.68	-12.57	-13.50	-15.10	-59.64
Canton-Massillon, OH	-	x	-	100	0.00	-21.89	-24.07	-28.63	-32.52	-37.88	-183.56	0.00	-88.88	-92.70	-100.62	-107.05	-114.22	-254.44
Charleston, WV	-	x	-	100	0.00	-0.61	-0.62	-1.15	-1.31	-1.64	-13.53	0.00	-2.37	-2.41	-3.12	-3.36	-3.75	-14.83
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-6.28	-6.38	-11.95	-13.63	-17.12	-142.38	0.00	-24.29	-24.63	-32.21	-34.62	-38.76	-155.49
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-1.30	-1.33	-2.41	-2.76	-3.45	-28.12	0.00	-5.04	-5.12	-6.61	-7.10	-7.93	-30.93
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-254.70	-279.18	-339.74	-386.04	-451.88	-2,295.03	0.00	-1,032.22	-1,075.31	-1,176.90	-1,252.65	-1,339.79	-3,107.07
Chico, CA	x	-	100	-	0.00	-0.50	-0.51	-0.94	-1.07	-1.34	-11.05	0.00	-1.94	-1.97	-2.55	-2.74	-3.07	-12.12
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-4.87	-4.96	-9.17	-10.47	-13.12	-108.35	0.00	-18.84	-19.12	-24.88	-26.73	-29.90	-118.66
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.35	-0.36	-0.67	-0.76	-0.95	-7.84	0.00	-1.37	-1.40	-1.81	-1.95	-2.18	-8.60
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-5.81	-5.92	-10.92	-12.46	-15.61	-128.44	0.00	-22.51	-22.86	-29.67	-31.88	-35.64	-140.84
Columbus, OH	x	x	100	100	0.00	-5.05	-5.15	-9.49	-10.83	-13.57	-111.75	0.00	-19.57	-19.88	-25.81	-27.73	-31.00	-122.52
Dallas-Fort Worth, TX	x	-	100	-	0.00	-25.05	-25.53	-47.06	-53.70	-67.29	-553.90	0.00	-97.03	-98.53	-127.92	-137.44	-153.65	-607.29
Dayton-Springfield, OH	-	x	-	100	0.00	-1.77	-1.81	-3.33	-3.80	-4.76	-39.19	0.00	-6.87	-6.97	-9.05	-9.73	-10.87	-42.97
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-37.35	-40.33	-54.09	-61.53	-73.41	-439.25	0.00	-149.94	-155.40	-176.37	-188.12	-203.29	-550.02
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-40.36	-43.55	-58.71	-66.79	-79.76	-480.85	0.00	-161.95	-167.80	-190.83	-203.57	-220.10	-600.06
Door Co., WI	x	-	100	-	0.00	-0.07	-0.07	-0.13	-0.15	-0.19	-1.59	0.00	-0.28	-0.28	-0.37	-0.39	-0.44	-1.74
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.07	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.08
Evansville, IN	-	x	-	100	0.00	-0.80	-0.81	-1.53	-1.75	-2.20	-18.37	0.00	-3.10	-3.14	-4.12	-4.43	-4.96	-20.03
Greater Connecticut, CT	x	-	100	-	0.00	-4.43	-4.52	-8.31	-9.49	-11.88	-97.72	0.00	-17.17	-17.44	-22.62	-24.30	-27.16	-107.18
Greene Co., PA	x	-	100	-	0.00	-0.08	-0.08	-0.14	-0.16	-0.21	-1.70	0.00	-0.30	-0.30	-0.39	-0.42	-0.47	-1.86
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-2.01	-2.05	-3.79	-4.32	-5.41	-44.55	0.00	-7.80	-7.92	-10.29	-11.05	-12.36	-48.84
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-1.72	-1.76	-3.24	-3.69	-4.63	-38.10	0.00	-6.68	-6.78	-8.80	-9.45	-10.57	-41.77

Table B2-40
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.27	0.00	-0.04	-0.04	-0.06	-0.06	-0.07	-0.29
Hickory, NC	-	x	-	100	0.00	-0.51	-0.52	-0.96	-1.09	-1.37	-11.25	0.00	-1.97	-2.01	-2.60	-2.80	-3.13	-12.34
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-683.09	-751.84	-889.07	-1,009.88	-1,174.94	-5,624.23	0.00	-2,775.59	-2,895.56	-3,136.65	-3,336.45	-3,557.80	-7,844.88
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-65.16	-71.76	-84.56	-96.04	-111.66	-530.40	0.00	-264.86	-276.36	-299.00	-318.02	-338.99	-742.73
Imperial Co., CA	x	-	100	-	0.00	-0.84	-0.85	-1.57	-1.79	-2.24	-18.48	0.00	-3.24	-3.29	-4.27	-4.58	-5.13	-20.26
Indianapolis, IN	-	x	-	100	0.00	-4.71	-4.80	-8.86	-10.10	-12.66	-104.22	0.00	-18.26	-18.54	-24.07	-25.86	-28.91	-114.27
Jamestown, NY	x	-	100	-	0.00	-0.32	-0.33	-0.61	-0.70	-0.87	-7.18	0.00	-1.26	-1.28	-1.66	-1.78	-1.99	-7.87
Jefferson Co., NY	x	-	100	-	0.00	-0.40	-0.41	-0.75	-0.86	-1.07	-8.83	0.00	-1.55	-1.57	-2.04	-2.19	-2.45	-9.68
Johnstown, PA	-	x	-	100	0.00	-0.24	-0.25	-0.45	-0.52	-0.65	-5.34	0.00	-0.94	-0.95	-1.24	-1.33	-1.49	-5.85
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.55	-0.57	-0.96	-1.09	-1.35	-10.44	0.00	-2.14	-2.19	-2.73	-2.93	-3.25	-11.74
Knoxville, TN	x	x	100	100	0.00	-2.90	-2.96	-5.45	-6.22	-7.79	-64.16	0.00	-11.23	-11.40	-14.81	-15.91	-17.79	-70.33
Lancaster, PA	-	x	-	100	0.00	-1.03	-1.05	-1.93	-2.21	-2.76	-22.75	0.00	-3.99	-4.05	-5.25	-5.65	-6.31	-24.94
Las Vegas, NV	x	-	100	-	0.00	-6.04	-6.15	-11.38	-12.99	-16.28	-134.39	0.00	-23.37	-23.73	-30.86	-33.16	-37.09	-147.19
Libby, MT	-	x	-	100	0.00	-0.02	-0.02	-0.03	-0.04	-0.05	-0.38	0.00	-0.07	-0.07	-0.09	-0.09	-0.11	-0.42
Liberty-Clairton, PA	-	x	-	100	0.00	-0.03	-0.03	-0.05	-0.05	-0.07	-0.52	0.00	-0.10	-0.10	-0.13	-0.14	-0.15	-0.58
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-405.12	-442.83	-548.97	-623.92	-733.11	-3,856.97	0.00	-1,638.97	-1,705.77	-1,879.57	-2,001.35	-2,144.77	-5,131.89
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-2.47	-2.53	-4.59	-5.24	-6.55	-53.37	0.00	-9.60	-9.75	-12.58	-13.51	-15.08	-58.74
Louisville, KY-IN	-	x	-	100	0.00	-2.44	-2.49	-4.62	-5.27	-6.62	-54.78	0.00	-9.46	-9.60	-12.51	-13.44	-15.04	-59.93
Macon, GA	-	x	-	100	0.00	-0.46	-0.46	-0.87	-0.99	-1.24	-10.29	0.00	-1.76	-1.79	-2.34	-2.51	-2.81	-11.25
Manitowoc Co., WI	x	-		-	0.00	-0.24	-0.24	-0.44	-0.50	-0.63	-5.19	0.00	-0.91	-0.93	-1.20	-1.29	-1.44	-5.69
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.38	-0.39	-0.72	-0.82	-1.03	-8.49	0.00	-1.49	-1.51	-1.96	-2.11	-2.36	-9.31
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-1.63	-1.66	-3.07	-3.50	-4.39	-36.10	0.00	-6.32	-6.42	-8.34	-8.96	-10.01	-39.58
Memphis, TN-AR	x	-	100	-	0.00	-54.46	-59.86	-71.52	-81.25	-94.74	-463.63	0.00	-221.09	-230.53	-250.65	-266.68	-284.68	-639.46
Milwaukee-Racine, WI	x	-	100	-	0.00	-4.07	-4.15	-7.65	-8.73	-10.94	-90.00	0.00	-15.78	-16.03	-20.80	-22.35	-24.98	-98.69
Nevada (Western Part), CA	x	-	100	-	0.00	-0.29	-0.29	-0.54	-0.61	-0.77	-6.33	0.00	-1.11	-1.13	-1.47	-1.57	-1.76	-6.95
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-125.96	-136.07	-182.21	-207.27	-247.23	-1,476.25	0.00	-505.81	-524.28	-594.68	-634.30	-685.34	-1,850.31
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.32	-0.33	-0.61	-0.70	-0.87	-7.20	0.00	-1.25	-1.27	-1.66	-1.78	-1.99	-7.89
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-362.08	-397.65	-477.39	-542.37	-633.05	-3,128.63	0.00	-1,469.21	-1,531.57	-1,668.08	-1,774.91	-1,895.68	-4,293.81
Phoenix-Mesa, AZ	x	-	100	-	0.00	-15.32	-15.60	-28.95	-33.04	-41.43	-342.75	0.00	-59.30	-60.18	-78.39	-84.24	-94.25	-375.08
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-3.95	-4.03	-7.43	-8.48	-10.62	-87.48	0.00	-15.31	-15.54	-20.18	-21.69	-24.25	-95.89
Poughkeepsie, NY	x	x	100	100	0.00	-3.49	-3.56	-6.56	-7.48	-9.38	-77.18	0.00	-13.52	-13.73	-17.83	-19.15	-21.41	-84.62

Table B2-40
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-2.10	-2.14	-3.94	-4.50	-5.64	-46.39	0.00	-8.13	-8.26	-10.72	-11.51	-12.87	-50.86
Reading, PA	-	x	-	100	0.00	-1.03	-1.05	-1.94	-2.21	-2.77	-22.78	0.00	-3.99	-4.05	-5.26	-5.65	-6.32	-24.98
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-4.23	-4.32	-7.92	-9.03	-11.31	-92.73	0.00	-16.40	-16.66	-21.58	-23.18	-25.90	-101.81
Rochester, NY	x	-	100	-	0.00	-3.04	-3.09	-5.70	-6.51	-8.15	-67.10	0.00	-11.76	-11.94	-15.50	-16.65	-18.62	-73.57
Rome, GA	-	x	-	100	0.00	-0.25	-0.26	-0.48	-0.55	-0.68	-5.62	0.00	-0.98	-1.00	-1.30	-1.39	-1.56	-6.16
Sacramento Metro, CA	x	-	50	-	0.00	-6.97	-7.11	-13.09	-14.93	-18.71	-153.89	0.00	-27.01	-27.43	-35.60	-38.24	-42.75	-168.77
San Diego, CA	x	-	100	-	0.00	-6.80	-6.93	-12.78	-14.58	-18.27	-150.38	0.00	-26.34	-26.75	-34.73	-37.31	-41.71	-164.87
San Francisco Bay Area, CA	x	-	100	-	0.00	-207.30	-227.23	-276.47	-314.15	-367.71	-1,866.85	0.00	-840.14	-875.22	-957.84	-1,019.49	-1,090.39	-2,527.86
San Joaquin Valley, CA	x	x	50	100	0.00	-48.14	-51.73	-71.55	-81.42	-97.68	-610.15	0.00	-192.67	-199.34	-228.97	-244.40	-264.97	-749.38
Sheboygan, WI	x	-	100	-	0.00	-0.29	-0.30	-0.54	-0.62	-0.78	-6.38	0.00	-1.12	-1.14	-1.48	-1.59	-1.78	-7.00
Springfield (Western MA), MA	x	-	100	-	0.00	-2.25	-2.30	-4.23	-4.83	-6.05	-49.81	0.00	-8.73	-8.86	-11.50	-12.36	-13.82	-54.61
St. Louis, MO-IL	x	x	100	100	0.00	-96.15	-105.39	-128.23	-145.71	-170.55	-865.96	0.00	-389.66	-405.92	-444.25	-472.84	-505.73	-1,172.53
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-6.01	-6.61	-7.87	-8.94	-10.41	-50.56	0.00	-24.40	-25.45	-27.63	-29.39	-31.37	-70.01
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-2.30	-2.41	-3.84	-4.37	-5.37	-39.27	0.00	-9.06	-9.29	-11.30	-12.10	-13.32	-45.10
Washington, DC-MD-VA	x	x	100	100	0.00	-14.52	-14.80	-27.23	-31.06	-38.91	-319.87	0.00	-56.24	-57.12	-74.08	-79.59	-88.96	-350.89
Wheeling, WV-OH	-	x	-	100	0.00	-0.35	-0.35	-0.65	-0.74	-0.93	-7.66	0.00	-1.34	-1.36	-1.77	-1.90	-2.12	-8.40
York, PA	-	x	-	100	0.00	-1.20	-1.22	-2.25	-2.57	-3.22	-26.48	0.00	-4.64	-4.71	-6.12	-6.57	-7.35	-29.03

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-41
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-6.54	-6.62	-15.02	-17.23	-29.56	-285.24	0.00	-6.59	-6.67	-15.07	-17.28	-29.61	-285.29
Allegan Co., MI	x	-	100	-	0.00	-0.72	-0.72	-1.64	-1.88	-3.23	-31.20	0.00	-0.72	-0.73	-1.65	-1.89	-3.24	-31.21
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.65	-0.66	-1.49	-1.71	-2.94	-28.37	0.00	-0.66	-0.66	-1.50	-1.72	-2.95	-28.38
Atlanta, GA	x	x	100	100	0.00	-34.78	-35.17	-79.83	-91.56	-157.12	-1,516.42	0.00	-35.03	-35.43	-80.09	-91.82	-157.39	-1,516.66
Baltimore, MD	x	x	100	100	0.00	-14.50	-14.66	-33.25	-38.14	-65.42	-631.15	0.00	-14.60	-14.77	-33.36	-38.25	-65.53	-631.25
Baton Rouge, LA	x	-	100	-	0.00	-8.60	-9.03	-16.70	-19.05	-29.98	-263.03	0.00	-8.65	-9.08	-16.75	-19.11	-30.03	-263.08
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-12.62	-13.43	-22.86	-26.02	-39.19	-325.27	0.00	-12.70	-13.51	-22.94	-26.10	-39.27	-325.34
Birmingham, AL	-	x	-	100	0.00	-5.27	-5.33	-12.11	-13.89	-23.84	-230.14	0.00	-5.31	-5.37	-12.15	-13.93	-23.88	-230.17
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-23.56	-23.83	-54.05	-61.99	-106.36	-1,026.27	0.00	-23.73	-24.00	-54.23	-62.17	-106.54	-1,026.43
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-3.06	-3.09	-7.10	-8.14	-14.03	-136.05	0.00	-3.08	-3.11	-7.12	-8.17	-14.06	-136.07
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-5.66	-5.73	-13.00	-14.91	-25.57	-246.77	0.00	-5.71	-5.77	-13.04	-14.95	-25.62	-246.80
Canton-Massillon, OH	-	x	-	100	0.00	-2.30	-2.37	-4.87	-5.58	-9.21	-85.49	0.00	-2.31	-2.38	-4.89	-5.59	-9.23	-85.50
Charleston, WV	-	x	-	100	0.00	-1.52	-1.53	-3.48	-3.99	-6.84	-66.04	0.00	-1.53	-1.54	-3.49	-4.00	-6.86	-66.05
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-8.30	-8.34	-19.54	-22.43	-38.93	-379.97	0.00	-8.36	-8.40	-19.60	-22.49	-38.99	-380.03
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-2.67	-2.69	-6.14	-7.05	-12.11	-117.13	0.00	-2.68	-2.71	-6.16	-7.07	-12.13	-117.15
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-42.70	-43.62	-94.00	-107.68	-181.18	-1,713.81	0.00	-42.99	-43.92	-94.30	-107.99	-181.50	-1,714.09
Chico, CA	x	-	100	-	0.00	-0.98	-0.99	-2.25	-2.58	-4.42	-42.65	0.00	-0.99	-1.00	-2.25	-2.58	-4.43	-42.66
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-9.26	-9.36	-21.32	-24.45	-42.01	-405.98	0.00	-9.33	-9.43	-21.38	-24.52	-42.08	-406.05
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.89	-0.90	-2.03	-2.33	-4.00	-38.64	0.00	-0.89	-0.90	-2.04	-2.34	-4.01	-38.65
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-13.51	-13.66	-31.00	-35.56	-61.00	-588.66	0.00	-13.61	-13.76	-31.10	-35.66	-61.11	-588.75
Columbus, OH	x	x	100	100	0.00	-8.72	-8.82	-20.02	-22.96	-39.41	-380.31	0.00	-8.79	-8.89	-20.09	-23.03	-39.47	-380.37
Dallas-Fort Worth, TX	x	-	100	-	0.00	-35.36	-35.76	-81.15	-93.07	-159.71	-1,541.21	0.00	-35.61	-36.02	-81.41	-93.34	-159.98	-1,541.46
Dayton-Springfield, OH	-	x	-	100	0.00	-4.09	-4.14	-9.40	-10.78	-18.49	-178.45	0.00	-4.12	-4.17	-9.43	-10.81	-18.52	-178.48
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-17.25	-17.50	-39.09	-44.81	-76.44	-733.31	0.00	-17.37	-17.63	-39.21	-44.94	-76.57	-733.43
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-25.60	-25.95	-58.20	-66.73	-114.01	-1,095.53	0.00	-25.78	-26.13	-58.38	-66.92	-114.21	-1,095.70
Door Co., WI	x	-	100	-	0.00	-0.17	-0.17	-0.38	-0.44	-0.75	-7.24	0.00	-0.17	-0.17	-0.38	-0.44	-0.75	-7.25
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.30	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.30
Evansville, IN	-	x	-	100	0.00	-1.63	-1.64	-3.81	-4.38	-7.57	-73.72	0.00	-1.64	-1.65	-3.83	-4.39	-7.59	-73.73
Greater Connecticut, CT	x	-	100	-	0.00	-8.99	-9.10	-20.62	-23.65	-40.55	-391.13	0.00	-9.06	-9.16	-20.68	-23.71	-40.62	-391.19
Greene Co., PA	x	-	100	-	0.00	-0.21	-0.21	-0.47	-0.54	-0.93	-8.96	0.00	-0.21	-0.21	-0.47	-0.54	-0.93	-8.96
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-4.05	-4.09	-9.29	-10.66	-18.29	-176.47	0.00	-4.08	-4.12	-9.32	-10.69	-18.32	-176.50
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-3.67	-3.71	-8.42	-9.66	-16.57	-159.89	0.00	-3.70	-3.74	-8.45	-9.68	-16.60	-159.91

Table B2-41
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.02	-0.02	-0.06	-0.07	-0.11	-1.09	0.00	-0.02	-0.03	-0.06	-0.07	-0.11	-1.09
Hickory, NC	-	x	-	100	0.00	-0.95	-0.96	-2.19	-2.51	-4.30	-41.51	0.00	-0.96	-0.97	-2.19	-2.52	-4.31	-41.51
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-47.61	-49.52	-96.78	-110.59	-178.60	-1,615.32	0.00	-47.92	-49.83	-97.10	-110.92	-178.93	-1,615.61
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-3.80	-3.94	-7.80	-8.92	-14.49	-131.88	0.00	-3.82	-3.97	-7.83	-8.94	-14.51	-131.90
Imperial Co., CA	x	-	100	-	0.00	-1.13	-1.14	-2.59	-2.97	-5.10	-49.21	0.00	-1.14	-1.15	-2.60	-2.98	-5.11	-49.21
Indianapolis, IN	-	x	-	100	0.00	-8.15	-8.24	-18.70	-21.44	-36.80	-355.10	0.00	-8.21	-8.30	-18.76	-21.51	-36.86	-355.16
Jamestown, NY	x	-	100	-	0.00	-0.75	-0.76	-1.73	-1.98	-3.40	-32.85	0.00	-0.76	-0.77	-1.74	-1.99	-3.41	-32.85
Jefferson Co., NY	x	-	100	-	0.00	-0.70	-0.71	-1.61	-1.84	-3.16	-30.52	0.00	-0.71	-0.71	-1.61	-1.85	-3.17	-30.52
Johnstown, PA	-	x	-	100	0.00	-0.62	-0.63	-1.42	-1.63	-2.80	-26.97	0.00	-0.62	-0.63	-1.43	-1.63	-2.80	-26.98
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.64	-0.65	-1.44	-1.65	-2.81	-26.86	0.00	-0.64	-0.65	-1.44	-1.66	-2.81	-26.86
Knoxville, TN	x	x	100	100	0.00	-5.53	-5.59	-12.69	-14.55	-24.98	-241.09	0.00	-5.57	-5.63	-12.73	-14.60	-25.02	-241.13
Lancaster, PA	-	x	-	100	0.00	-2.16	-2.19	-4.97	-5.70	-9.77	-94.31	0.00	-2.18	-2.20	-4.98	-5.71	-9.79	-94.33
Las Vegas, NV	x	-	100	-	0.00	-7.14	-7.22	-16.41	-18.82	-32.30	-311.87	0.00	-7.19	-7.28	-16.46	-18.87	-32.36	-311.92
Libby, MT	-	x	-	100	0.00	-0.04	-0.04	-0.08	-0.09	-0.16	-1.55	0.00	-0.04	-0.04	-0.08	-0.09	-0.16	-1.55
Liberty-Clairton, PA	-	x	-	100	0.00	-0.07	-0.07	-0.16	-0.19	-0.32	-3.09	0.00	-0.07	-0.07	-0.16	-0.19	-0.32	-3.09
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-86.51	-88.23	-191.84	-219.81	-371.18	-3,523.91	0.00	-87.11	-88.85	-192.46	-220.45	-371.83	-3,524.48
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-3.72	-3.76	-8.52	-9.77	-16.75	-161.54	0.00	-3.74	-3.79	-8.55	-9.80	-16.78	-161.57
Louisville, KY-IN	-	x	-	100	0.00	-5.56	-5.61	-12.83	-14.71	-25.31	-244.92	0.00	-5.60	-5.65	-12.87	-14.76	-25.36	-244.96
Macon, GA	-	x	-	100	0.00	-1.03	-1.04	-2.38	-2.73	-4.70	-45.54	0.00	-1.04	-1.05	-2.39	-2.74	-4.71	-45.55
Manitowoc Co., WI	x	-		-	0.00	-0.55	-0.55	-1.25	-1.44	-2.46	-23.76	0.00	-0.55	-0.56	-1.26	-1.44	-2.47	-23.76
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.53	-0.54	-1.22	-1.40	-2.40	-23.12	0.00	-0.53	-0.54	-1.22	-1.40	-2.40	-23.12
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-2.07	-2.10	-4.76	-5.46	-9.37	-90.41	0.00	-2.09	-2.11	-4.78	-5.48	-9.38	-90.42
Memphis, TN-AR	x	-	100	-	0.00	-6.72	-6.90	-14.44	-16.53	-27.48	-256.77	0.00	-6.76	-6.95	-14.48	-16.57	-27.53	-256.81
Milwaukee-Racine, WI	x	-	100	-	0.00	-8.93	-9.03	-20.48	-23.49	-40.30	-388.86	0.00	-8.99	-9.10	-20.55	-23.56	-40.37	-388.92
Nevada (Western Part), CA	x	-	100	-	0.00	-0.50	-0.51	-1.16	-1.33	-2.28	-21.99	0.00	-0.51	-0.51	-1.16	-1.33	-2.28	-21.99
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-76.46	-77.52	-173.70	-199.17	-340.17	-3,267.36	0.00	-77.00	-78.08	-174.26	-199.74	-340.76	-3,267.88
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.80	-0.80	-1.83	-2.10	-3.61	-34.85	0.00	-0.80	-0.81	-1.84	-2.11	-3.61	-34.86
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-46.24	-47.47	-99.63	-114.06	-189.92	-1,776.61	0.00	-46.55	-47.79	-99.96	-114.39	-190.26	-1,776.91
Phoenix-Mesa, AZ	x	-	100	-	0.00	-19.52	-19.72	-45.04	-51.66	-88.86	-859.49	0.00	-19.67	-19.87	-45.18	-51.81	-89.01	-859.62
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-9.95	-10.06	-22.84	-26.20	-44.96	-433.97	0.00	-10.02	-10.13	-22.91	-26.27	-45.04	-434.04
Poughkeepsie, NY	x	x	100	100	0.00	-6.46	-6.53	-14.83	-17.01	-29.18	-281.60	0.00	-6.51	-6.58	-14.88	-17.06	-29.23	-281.65

Table B2-41
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-4.68	-4.73	-10.73	-12.31	-21.12	-203.76	0.00	-4.71	-4.76	-10.76	-12.34	-21.15	-203.79
Reading, PA	-	x	-	100	0.00	-1.90	-1.92	-4.36	-5.00	-8.57	-82.74	0.00	-1.91	-1.93	-4.37	-5.01	-8.59	-82.76
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-3.78	-3.83	-8.68	-9.95	-17.06	-164.60	0.00	-3.81	-3.86	-8.70	-9.98	-17.09	-164.63
Rochester, NY	x	-	100	-	0.00	-6.55	-6.62	-15.03	-17.23	-29.57	-285.36	0.00	-6.59	-6.67	-15.07	-17.28	-29.62	-285.40
Rome, GA	-	x	-	100	0.00	-0.57	-0.58	-1.31	-1.51	-2.59	-24.95	0.00	-0.58	-0.58	-1.32	-1.51	-2.59	-24.95
Sacramento Metro, CA	x	-	50	-	0.00	-10.98	-11.11	-25.22	-28.92	-49.63	-479.05	0.00	-11.06	-11.19	-25.30	-29.01	-49.72	-479.13
San Diego, CA	x	-	100	-	0.00	-15.39	-15.57	-35.33	-40.52	-69.53	-670.96	0.00	-15.50	-15.68	-35.44	-40.64	-69.65	-671.06
San Francisco Bay Area, CA	x	-	100	-	0.00	-38.24	-38.96	-85.18	-97.61	-165.18	-1,571.56	0.00	-38.51	-39.24	-85.46	-97.90	-165.47	-1,571.81
San Joaquin Valley, CA	x	x	50	100	0.00	-23.41	-23.73	-53.16	-60.95	-104.07	-999.47	0.00	-23.57	-23.90	-53.33	-61.12	-104.25	-999.63
Sheboygan, WI	x	-	100	-	0.00	-0.61	-0.62	-1.40	-1.61	-2.75	-26.55	0.00	-0.62	-0.62	-1.40	-1.61	-2.76	-26.55
Springfield (Western MA), MA	x	-	100	-	0.00	-4.70	-4.75	-10.78	-12.37	-21.22	-204.80	0.00	-4.73	-4.79	-10.82	-12.40	-21.26	-204.83
St. Louis, MO-IL	x	x	100	100	0.00	-18.54	-18.94	-40.82	-46.76	-78.68	-744.28	0.00	-18.67	-19.07	-40.95	-46.90	-78.82	-744.40
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.73	-0.75	-1.57	-1.80	-2.99	-27.95	0.00	-0.74	-0.76	-1.58	-1.81	-3.00	-27.96
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-3.25	-3.29	-7.45	-8.55	-14.66	-141.30	0.00	-3.28	-3.32	-7.48	-8.57	-14.68	-141.32
Washington, DC-MD-VA	x	x	100	100	0.00	-24.87	-25.16	-57.00	-65.37	-112.10	-1,081.18	0.00	-25.05	-25.34	-57.18	-65.56	-112.30	-1,081.35
Wheeling, WV-OH	-	x	-	100	0.00	-0.86	-0.87	-1.98	-2.27	-3.89	-37.57	0.00	-0.87	-0.88	-1.98	-2.28	-3.90	-37.57
York, PA	-	x	-	100	0.00	-2.01	-2.03	-4.61	-5.28	-9.06	-87.46	0.00	-2.02	-2.04	-4.62	-5.30	-9.08	-87.47

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.

b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.

c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)

EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-42
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-21.05	-20.40	-47.90	-55.70	-85.04	-852.00	0.00	-50.54	-50.59	-78.75	-87.79	-118.38	-869.01
Allegan Co., MI	x	-	100	-	0.00	-2.30	-2.23	-5.24	-6.09	-9.30	-93.17	0.00	-5.53	-5.53	-8.61	-9.60	-12.94	-95.03
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-2.23	-2.16	-5.07	-5.90	-9.01	-90.23	0.00	-5.36	-5.36	-8.34	-9.30	-12.54	-92.04
Atlanta, GA	x	x	100	100	0.00	-121.92	-118.14	-277.49	-322.72	-492.74	-4,937.14	0.00	-292.74	-293.01	-456.23	-508.60	-685.82	-5,035.58
Baltimore, MD	x	x	100	100	0.00	-46.39	-44.96	-105.48	-122.67	-187.24	-1,875.28	0.00	-111.37	-111.49	-173.47	-193.38	-260.69	-1,912.79
Baton Rouge, LA	x	-	100	-	0.00	-27.52	-28.27	-50.95	-59.00	-83.65	-743.47	0.00	-65.10	-66.88	-89.78	-99.36	-125.32	-771.80
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-39.96	-41.95	-67.41	-77.87	-105.95	-870.95	0.00	-93.96	-97.50	-122.92	-135.56	-165.36	-915.51
Birmingham, AL	-	x	-	100	0.00	-16.47	-15.95	-37.51	-43.63	-66.63	-667.94	0.00	-39.54	-39.57	-61.66	-68.73	-92.71	-681.21
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-72.61	-70.37	-165.17	-192.10	-293.25	-2,937.60	0.00	-174.34	-174.51	-271.62	-302.79	-408.23	-2,996.28
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-9.78	-9.44	-22.51	-26.19	-40.13	-404.09	0.00	-23.51	-23.49	-36.89	-41.14	-55.66	-411.86
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-17.36	-16.82	-39.48	-45.91	-70.09	-702.11	0.00	-41.67	-41.71	-64.92	-72.37	-97.57	-716.14
Canton-Massillon, OH	-	x	-	100	0.00	-7.13	-7.12	-14.70	-17.06	-25.20	-240.17	0.00	-16.99	-17.23	-24.95	-27.72	-36.24	-246.72
Charleston, WV	-	x	-	100	0.00	-4.55	-4.41	-10.35	-12.04	-18.38	-184.18	0.00	-10.92	-10.93	-17.02	-18.98	-25.59	-187.85
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-29.13	-27.99	-68.00	-79.13	-121.75	-1,233.76	0.00	-70.09	-69.90	-110.93	-123.77	-168.17	-1,256.39
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-8.38	-8.12	-19.10	-22.21	-33.92	-339.96	0.00	-20.13	-20.15	-31.39	-34.99	-47.20	-346.72
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-135.27	-133.10	-293.03	-340.46	-511.68	-5,006.77	0.00	-323.53	-326.01	-489.40	-544.65	-723.45	-5,123.73
Chico, CA	x	-	100	-	0.00	-3.12	-3.03	-7.10	-8.26	-12.61	-126.37	0.00	-7.50	-7.50	-11.68	-13.02	-17.56	-128.89
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-29.15	-28.21	-66.58	-77.43	-118.36	-1,187.82	0.00	-70.01	-70.04	-109.34	-121.91	-164.56	-1,211.23
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-2.66	-2.58	-6.06	-7.04	-10.75	-107.70	0.00	-6.39	-6.40	-9.96	-11.10	-14.97	-109.85
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-41.23	-39.95	-93.79	-109.08	-166.52	-1,668.22	0.00	-98.99	-99.09	-154.23	-171.93	-231.81	-1,701.53
Columbus, OH	x	x	100	100	0.00	-28.47	-27.59	-64.79	-75.35	-115.04	-1,152.67	0.00	-68.35	-68.42	-106.53	-118.75	-160.13	-1,175.67
Dallas-Fort Worth, TX	x	-	100	-	0.00	-120.92	-117.17	-275.16	-320.01	-488.57	-4,894.95	0.00	-290.33	-290.61	-452.43	-504.36	-680.06	-4,992.62
Dayton-Springfield, OH	-	x	-	100	0.00	-12.53	-12.14	-28.51	-33.16	-50.63	-507.23	0.00	-30.09	-30.11	-46.88	-52.26	-70.47	-517.35
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-56.98	-55.48	-127.73	-148.51	-225.67	-2,245.22	0.00	-136.66	-137.07	-211.01	-235.11	-315.59	-2,292.26
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-79.44	-77.27	-178.66	-207.73	-315.99	-3,148.79	0.00	-190.56	-191.05	-294.84	-328.55	-441.44	-3,214.06
Door Co., WI	x	-	100	-	0.00	-0.51	-0.49	-1.16	-1.35	-2.05	-20.58	0.00	-1.22	-1.22	-1.90	-2.12	-2.86	-20.99
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.02	-0.02	-0.05	-0.06	-0.09	-0.86	0.00	-0.05	-0.05	-0.08	-0.09	-0.12	-0.88
Evansville, IN	-	x	-	100	0.00	-5.15	-4.95	-11.97	-13.93	-21.40	-216.51	0.00	-12.38	-12.36	-19.55	-21.81	-29.60	-220.54
Greater Connecticut, CT	x	-	100	-	0.00	-28.43	-27.56	-64.60	-75.13	-114.65	-1,147.89	0.00	-68.25	-68.33	-106.26	-118.45	-159.65	-1,170.90
Greene Co., PA	x	-	100	-	0.00	-0.61	-0.59	-1.38	-1.60	-2.45	-24.55	0.00	-1.46	-1.46	-2.27	-2.53	-3.41	-25.04
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-12.83	-12.43	-29.19	-33.95	-51.84	-519.36	0.00	-30.80	-30.83	-48.00	-53.51	-72.16	-529.73
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-11.46	-11.10	-26.07	-30.31	-46.28	-463.65	0.00	-27.51	-27.53	-42.86	-47.78	-64.42	-472.91

Table B2-42
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.08	-0.07	-0.18	-0.20	-0.31	-3.16	0.00	-0.18	-0.18	-0.29	-0.32	-0.43	-3.22
Hickory, NC	-	x	-	100	0.00	-3.08	-2.98	-7.00	-8.14	-12.42	-124.37	0.00	-7.39	-7.39	-11.51	-12.83	-17.29	-126.86
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-152.49	-154.36	-298.88	-346.51	-502.58	-4,645.37	0.00	-362.07	-369.47	-516.13	-572.38	-736.13	-4,793.66
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-11.89	-12.01	-23.49	-27.24	-39.63	-368.16	0.00	-28.24	-28.79	-40.45	-44.87	-57.87	-379.62
Imperial Co., CA	x	-	100	-	0.00	-3.95	-3.83	-8.99	-10.46	-15.97	-159.96	0.00	-9.49	-9.50	-14.78	-16.48	-22.22	-163.15
Indianapolis, IN	-	x	-	100	0.00	-26.52	-25.70	-60.35	-70.19	-107.16	-1,073.65	0.00	-63.68	-63.74	-99.23	-110.62	-149.16	-1,095.07
Jamestown, NY	x	-	100	-	0.00	-2.30	-2.23	-5.24	-6.10	-9.31	-93.26	0.00	-5.53	-5.54	-8.62	-9.61	-12.96	-95.13
Jefferson Co., NY	x	-	100	-	0.00	-2.30	-2.23	-5.23	-6.08	-9.28	-92.94	0.00	-5.52	-5.52	-8.60	-9.58	-12.92	-94.80
Johnstown, PA	-	x	-	100	0.00	-1.85	-1.79	-4.20	-4.89	-7.46	-74.71	0.00	-4.44	-4.45	-6.92	-7.71	-10.39	-76.21
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-2.33	-2.28	-5.11	-5.94	-8.97	-88.33	0.00	-5.58	-5.61	-8.50	-9.47	-12.63	-90.31
Knoxville, TN	x	x	100	100	0.00	-17.72	-17.17	-40.35	-46.93	-71.65	-718.04	0.00	-42.56	-42.59	-66.33	-73.95	-99.72	-732.34
Lancaster, PA	-	x	-	100	0.00	-6.78	-6.57	-15.43	-17.94	-27.40	-274.47	0.00	-16.28	-16.30	-25.37	-28.28	-38.14	-279.95
Las Vegas, NV	x	-	100	-	0.00	-25.84	-25.03	-58.90	-68.51	-104.64	-1,049.18	0.00	-62.06	-62.10	-96.80	-107.92	-145.58	-1,070.00
Libby, MT	-	x	-	100	0.00	-0.11	-0.11	-0.25	-0.30	-0.45	-4.53	0.00	-0.27	-0.27	-0.42	-0.47	-0.63	-4.62
Liberty-Clairton, PA	-	x	-	100	0.00	-0.21	-0.20	-0.47	-0.55	-0.83	-8.24	0.00	-0.50	-0.50	-0.78	-0.86	-1.16	-8.42
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-283.09	-277.84	-618.42	-718.65	-1,083.04	-10,642.28	0.00	-677.52	-681.94	-1,030.06	-1,146.69	-1,527.09	-10,884.37
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-12.60	-12.23	-28.57	-33.22	-50.67	-506.76	0.00	-30.25	-30.29	-47.03	-52.42	-70.60	-517.00
Louisville, KY-IN	-	x	-	100	0.00	-17.06	-16.49	-39.09	-45.46	-69.56	-699.15	0.00	-40.98	-40.97	-64.13	-71.50	-96.62	-712.78
Macon, GA	-	x	-	100	0.00	-3.17	-3.07	-7.28	-8.47	-12.97	-130.45	0.00	-7.62	-7.62	-11.94	-13.32	-18.00	-132.98
Manitowoc Co., WI	x	-		-	0.00	-1.67	-1.62	-3.80	-4.42	-6.74	-67.44	0.00	-4.02	-4.02	-6.25	-6.97	-9.39	-68.79
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-1.84	-1.79	-4.20	-4.88	-7.45	-74.62	0.00	-4.43	-4.43	-6.90	-7.69	-10.37	-76.11
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-7.35	-7.12	-16.71	-19.44	-29.68	-297.35	0.00	-17.64	-17.65	-27.48	-30.64	-41.31	-303.29
Memphis, TN-AR	x	-	100	-	0.00	-20.88	-20.74	-43.74	-50.79	-75.47	-725.70	0.00	-49.81	-50.40	-73.85	-82.10	-107.91	-744.52
Milwaukee-Racine, WI	x	-	100	-	0.00	-27.64	-26.79	-62.87	-73.12	-111.62	-1,118.04	0.00	-66.36	-66.43	-103.39	-115.25	-155.38	-1,140.38
Nevada (Western Part), CA	x	-	100	-	0.00	-1.65	-1.60	-3.76	-4.37	-6.68	-66.89	0.00	-3.97	-3.98	-6.19	-6.90	-9.30	-68.23
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-237.53	-231.10	-533.67	-620.51	-943.60	-9,398.61	0.00	-569.73	-571.28	-881.00	-981.69	-1,318.63	-9,594.03
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-2.40	-2.32	-5.47	-6.37	-9.73	-97.58	0.00	-5.76	-5.77	-8.99	-10.03	-13.53	-99.51
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-147.54	-146.39	-310.76	-360.85	-537.19	-5,179.68	0.00	-352.14	-356.14	-523.78	-582.35	-766.72	-5,311.88
Phoenix-Mesa, AZ	x	-	100	-	0.00	-69.35	-67.06	-158.76	-184.66	-282.46	-2,837.76	0.00	-166.58	-166.60	-260.55	-290.51	-392.43	-2,893.27
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-29.76	-28.83	-67.75	-78.79	-120.32	-1,205.81	0.00	-71.45	-71.51	-111.38	-124.16	-167.45	-1,229.83
Poughkeepsie, NY	x	x	100	100	0.00	-20.90	-20.25	-47.55	-55.30	-84.43	-845.85	0.00	-50.18	-50.22	-78.19	-87.16	-117.52	-862.73

Table B2-42
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-14.44	-13.99	-32.85	-38.20	-58.33	-584.30	0.00	-34.67	-34.70	-54.02	-60.22	-81.19	-595.97
Reading, PA	-	x	-	100	0.00	-6.15	-5.96	-13.99	-16.27	-24.84	-248.91	0.00	-14.76	-14.78	-23.01	-25.65	-34.58	-253.87
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-14.69	-14.24	-33.35	-38.79	-59.18	-592.31	0.00	-35.26	-35.31	-54.88	-61.17	-82.43	-604.21
Rochester, NY	x	-	100	-	0.00	-20.37	-19.74	-46.36	-53.91	-82.31	-824.60	0.00	-48.92	-48.96	-76.22	-84.97	-114.57	-841.06
Rome, GA	-	x	-	100	0.00	-1.76	-1.71	-4.01	-4.67	-7.12	-71.38	0.00	-4.23	-4.24	-6.60	-7.35	-9.92	-72.80
Sacramento Metro, CA	x	-	50	-	0.00	-36.76	-35.62	-83.65	-97.28	-148.52	-1,488.04	0.00	-88.26	-88.34	-137.53	-153.32	-206.73	-1,517.73
San Diego, CA	x	-	100	-	0.00	-47.36	-45.89	-107.77	-125.33	-191.35	-1,917.13	0.00	-113.71	-113.82	-177.19	-197.53	-266.35	-1,955.38
San Francisco Bay Area, CA	x	-	100	-	0.00	-119.69	-117.38	-262.19	-304.70	-459.61	-4,522.42	0.00	-286.53	-288.29	-436.33	-485.78	-647.48	-4,624.41
San Joaquin Valley, CA	x	x	50	100	0.00	-80.70	-78.48	-181.58	-211.13	-321.21	-3,201.53	0.00	-193.59	-194.07	-299.62	-333.88	-448.67	-3,267.78
Sheboygan, WI	x	-	100	-	0.00	-1.91	-1.85	-4.35	-5.05	-7.71	-77.19	0.00	-4.59	-4.60	-7.15	-7.97	-10.74	-78.74
Springfield (Western MA), MA	x	-	100	-	0.00	-14.75	-14.29	-33.57	-39.04	-59.60	-597.17	0.00	-35.42	-35.45	-55.19	-61.53	-82.97	-609.08
St. Louis, MO-IL	x	x	100	100	0.00	-57.86	-56.99	-124.98	-145.20	-218.00	-2,129.98	0.00	-138.36	-139.48	-208.93	-232.49	-308.53	-2,180.21
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-2.21	-2.20	-4.61	-5.35	-7.95	-76.22	0.00	-5.27	-5.34	-7.80	-8.67	-11.38	-78.23
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-10.12	-9.81	-22.96	-26.70	-40.74	-407.65	0.00	-24.28	-24.32	-37.78	-42.12	-56.75	-415.85
Washington, DC-MD-VA	x	x	100	100	0.00	-80.60	-78.14	-183.09	-212.93	-324.92	-3,252.86	0.00	-193.48	-193.71	-301.20	-335.76	-452.50	-3,318.11
Wheeling, WV-OH	-	x	-	100	0.00	-2.59	-2.51	-5.89	-6.85	-10.46	-104.79	0.00	-6.22	-6.22	-9.69	-10.80	-14.56	-106.88
York, PA	-	x	-	100	0.00	-6.66	-6.45	-15.15	-17.61	-26.89	-269.39	0.00	-15.98	-16.00	-24.90	-27.76	-37.43	-274.77

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-43
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-31.79	-29.40	-80.42	-93.83	-141.34	-1,506.76	0.00	-105.40	-104.45	-158.64	-175.22	-226.22	-1,540.20
Allegan Co., MI	x	-	100	-	0.00	-3.47	-3.21	-8.79	-10.25	-15.44	-164.60	0.00	-11.51	-11.41	-17.33	-19.14	-24.71	-168.25
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-3.59	-3.32	-9.07	-10.58	-15.94	-169.88	0.00	-11.89	-11.78	-17.89	-19.76	-25.51	-173.66
Atlanta, GA	x	x	100	100	0.00	-202.84	-187.59	-513.34	-598.96	-902.25	-9,619.70	0.00	-672.58	-666.48	-1,012.51	-1,118.34	-1,443.96	-9,832.95
Baltimore, MD	x	x	100	100	0.00	-69.72	-64.51	-176.23	-205.62	-309.65	-3,299.90	0.00	-231.18	-229.11	-347.78	-384.11	-495.81	-3,373.40
Baton Rouge, LA	x	-	100	-	0.00	-43.02	-43.43	-82.82	-96.21	-134.60	-1,248.03	0.00	-141.87	-144.78	-185.54	-202.98	-244.94	-1,317.49
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-62.52	-65.17	-105.78	-122.58	-163.86	-1,370.37	0.00	-205.77	-212.36	-253.33	-275.87	-321.69	-1,484.90
Birmingham, AL	-	x	-	100	0.00	-24.28	-22.44	-61.52	-71.78	-108.17	-1,153.86	0.00	-80.50	-79.76	-121.28	-133.96	-173.02	-1,179.31
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-105.37	-97.47	-266.49	-310.94	-468.32	-4,991.91	0.00	-349.38	-346.24	-525.78	-580.72	-749.69	-5,102.85
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-14.63	-13.46	-37.56	-43.83	-66.23	-709.90	0.00	-48.54	-48.01	-73.63	-81.37	-105.40	-724.80
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-24.95	-23.08	-63.10	-73.63	-110.89	-1,182.00	0.00	-82.73	-81.99	-124.50	-137.51	-177.52	-1,208.28
Canton-Massillon, OH	-	x	-	100	0.00	-10.59	-10.27	-23.40	-27.25	-39.70	-398.84	0.00	-35.02	-35.26	-49.06	-53.93	-67.40	-413.15
Charleston, WV	-	x	-	100	0.00	-6.42	-5.94	-16.24	-18.95	-28.54	-304.26	0.00	-21.28	-21.09	-32.03	-35.38	-45.68	-311.01
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-47.87	-43.80	-124.49	-145.31	-220.22	-2,372.03	0.00	-158.83	-156.84	-242.70	-268.32	-348.65	-2,419.24
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-12.40	-11.49	-31.25	-36.45	-54.86	-583.99	0.00	-41.11	-40.76	-61.74	-68.18	-87.95	-597.15
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-204.02	-193.03	-485.24	-565.66	-839.78	-8,730.46	0.00	-675.56	-674.44	-983.55	-1,084.02	-1,379.21	-8,973.86
Chico, CA	x	-	100	-	0.00	-4.67	-4.32	-11.82	-13.79	-20.78	-221.52	0.00	-15.49	-15.35	-23.32	-25.76	-33.26	-226.43
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-43.64	-40.29	-110.96	-129.48	-195.25	-2,085.46	0.00	-144.72	-143.32	-218.42	-241.29	-311.89	-2,130.85
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-3.75	-3.47	-9.48	-11.06	-16.66	-177.61	0.00	-12.43	-12.32	-18.70	-20.66	-26.67	-181.55
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-59.09	-54.66	-149.46	-174.39	-262.67	-2,799.95	0.00	-195.93	-194.16	-294.87	-325.68	-420.46	-2,862.15
Columbus, OH	x	x	100	100	0.00	-43.83	-40.54	-110.92	-129.42	-194.95	-2,078.43	0.00	-145.34	-144.02	-218.78	-241.65	-312.00	-2,124.52
Dallas-Fort Worth, TX	x	-	100	-	0.00	-195.58	-180.90	-494.86	-577.39	-869.73	-9,272.18	0.00	-648.51	-642.64	-976.15	-1,078.18	-1,392.03	-9,477.89
Dayton-Springfield, OH	-	x	-	100	0.00	-18.00	-16.64	-45.53	-53.13	-80.03	-853.14	0.00	-59.67	-59.13	-89.82	-99.21	-128.08	-872.07
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-89.11	-83.02	-221.18	-258.00	-386.93	-4,094.35	0.00	-295.34	-293.36	-439.95	-485.61	-624.16	-4,192.06
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-116.14	-108.07	-289.15	-337.30	-506.22	-5,363.07	0.00	-384.95	-382.22	-574.38	-634.06	-815.55	-5,489.60
Door Co., WI	x	-	100	-	0.00	-0.73	-0.67	-1.85	-2.15	-3.24	-34.58	0.00	-2.42	-2.40	-3.64	-4.02	-5.19	-35.35
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.03	-0.03	-0.08	-0.09	-0.14	-1.47	0.00	-0.10	-0.10	-0.15	-0.17	-0.22	-1.50
Evansville, IN	-	x	-	100	0.00	-7.60	-6.96	-19.76	-23.06	-34.94	-376.31	0.00	-25.22	-24.90	-38.52	-42.59	-55.33	-383.82
Greater Connecticut, CT	x	-	100	-	0.00	-42.18	-39.04	-106.52	-124.29	-187.14	-1,993.64	0.00	-139.85	-138.62	-210.29	-232.26	-299.74	-2,038.19
Greene Co., PA	x	-	100	-	0.00	-0.84	-0.78	-2.12	-2.48	-3.73	-39.78	0.00	-2.78	-2.76	-4.19	-4.63	-5.97	-40.66
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-19.08	-17.65	-48.27	-56.32	-84.84	-904.49	0.00	-63.26	-62.69	-95.22	-105.17	-135.79	-924.55
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-16.79	-15.53	-42.48	-49.56	-74.65	-795.79	0.00	-55.67	-55.17	-83.79	-92.55	-119.49	-813.46

Table B2-43
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.11	-0.10	-0.29	-0.33	-0.51	-5.46	0.00	-0.37	-0.36	-0.56	-0.62	-0.80	-5.57
Hickory, NC	-	x	-	100	0.00	-4.66	-4.31	-11.78	-13.74	-20.69	-220.49	0.00	-15.45	-15.31	-23.24	-25.67	-33.13	-225.40
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-236.89	-234.13	-492.16	-572.50	-819.86	-7,970.18	0.00	-782.32	-792.54	-1,062.19	-1,165.15	-1,433.78	-8,319.11
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-17.97	-17.75	-37.43	-43.54	-62.40	-607.44	0.00	-59.36	-60.12	-80.69	-88.52	-108.99	-633.83
Imperial Co., CA	x	-	100	-	0.00	-6.49	-6.00	-16.42	-19.16	-28.86	-307.66	0.00	-21.52	-21.32	-32.39	-35.78	-46.19	-314.49
Indianapolis, IN	-	x	-	100	0.00	-40.80	-37.74	-103.24	-120.45	-181.44	-1,934.32	0.00	-135.29	-134.06	-203.64	-224.92	-290.40	-1,977.23
Jamestown, NY	x	-	100	-	0.00	-3.31	-3.06	-8.36	-9.76	-14.70	-156.68	0.00	-10.96	-10.87	-16.50	-18.22	-23.53	-160.16
Jefferson Co., NY	x	-	100	-	0.00	-3.54	-3.27	-8.94	-10.43	-15.71	-167.50	0.00	-11.73	-11.62	-17.65	-19.49	-25.16	-171.22
Johnstown, PA	-	x	-	100	0.00	-2.59	-2.40	-6.54	-7.63	-11.49	-122.41	0.00	-8.60	-8.52	-12.92	-14.27	-18.41	-125.15
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-4.01	-3.80	-9.51	-11.09	-16.45	-170.82	0.00	-13.27	-13.26	-19.30	-21.27	-27.04	-175.63
Knoxville, TN	x	x	100	100	0.00	-26.69	-24.68	-67.57	-78.84	-118.78	-1,266.54	0.00	-88.51	-87.70	-133.26	-147.19	-190.06	-1,294.58
Lancaster, PA	-	x	-	100	0.00	-9.97	-9.22	-25.23	-29.43	-44.33	-472.62	0.00	-33.06	-32.76	-49.76	-54.96	-70.96	-483.11
Las Vegas, NV	x	-	100	-	0.00	-43.85	-40.51	-111.28	-129.85	-195.72	-2,088.91	0.00	-145.41	-144.04	-219.23	-242.17	-312.88	-2,134.73
Libby, MT	-	x	-	100	0.00	-0.17	-0.15	-0.42	-0.49	-0.73	-7.83	0.00	-0.55	-0.54	-0.82	-0.91	-1.18	-8.00
Liberty-Clairton, PA	-	x	-	100	0.00	-0.29	-0.27	-0.71	-0.82	-1.23	-12.98	0.00	-0.95	-0.95	-1.41	-1.56	-1.99	-13.30
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-441.17	-416.03	-1,059.19	-1,234.91	-1,837.54	-19,180.03	0.00	-1,461.14	-1,457.12	-2,137.94	-2,357.11	-3,005.73	-19,697.15
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-20.14	-18.69	-50.56	-58.98	-88.69	-942.57	0.00	-66.78	-66.24	-100.08	-110.51	-142.41	-964.13
Louisville, KY-IN	-	x	-	100	0.00	-24.55	-22.63	-62.70	-73.17	-110.44	-1,181.59	0.00	-81.43	-80.60	-123.19	-136.11	-176.11	-1,206.88
Macon, GA	-	x	-	100	0.00	-4.57	-4.21	-11.71	-13.67	-20.65	-221.13	0.00	-15.17	-15.01	-22.98	-25.40	-32.88	-225.81
Manitowoc Co., WI	x	-		-	0.00	-2.40	-2.22	-6.06	-7.07	-10.64	-113.25	0.00	-7.97	-7.90	-11.97	-13.22	-17.05	-115.79
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-3.01	-2.79	-7.62	-8.89	-13.39	-142.67	0.00	-9.99	-9.90	-15.03	-16.60	-21.43	-145.84
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-12.24	-11.32	-30.96	-36.12	-54.41	-580.05	0.00	-40.57	-40.20	-61.07	-67.45	-87.08	-592.92
Memphis, TN-AR	x	-	100	-	0.00	-30.96	-29.81	-69.95	-81.48	-119.42	-1,212.89	0.00	-102.40	-102.83	-145.12	-159.66	-200.63	-1,253.25
Milwaukee-Racine, WI	x	-	100	-	0.00	-40.20	-37.19	-101.66	-118.62	-178.65	-1,904.19	0.00	-133.30	-132.11	-200.59	-221.55	-286.01	-1,946.53
Nevada (Western Part), CA	x	-	100	-	0.00	-2.54	-2.35	-6.43	-7.50	-11.30	-120.40	0.00	-8.43	-8.36	-12.69	-14.01	-18.09	-123.08
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-347.29	-323.33	-863.53	-1,007.30	-1,511.29	-16,002.78	0.00	-1,151.08	-1,143.11	-1,716.31	-1,894.55	-2,436.08	-16,382.19
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-3.39	-3.13	-8.61	-10.05	-15.14	-161.67	0.00	-11.24	-11.14	-16.96	-18.73	-24.21	-165.21
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-224.56	-215.49	-512.54	-597.11	-877.37	-8,953.86	0.00	-742.95	-745.20	-1,058.43	-1,164.87	-1,467.36	-9,241.84
Phoenix-Mesa, AZ	x	-	100	-	0.00	-115.43	-106.43	-294.39	-343.53	-518.38	-5,543.30	0.00	-382.80	-378.96	-578.72	-639.38	-827.04	-5,662.53
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-41.80	-38.65	-105.85	-123.51	-186.07	-1,984.30	0.00	-138.61	-137.34	-208.73	-230.55	-297.72	-2,028.19
Poughkeepsie, NY	x	x	100	100	0.00	-31.72	-29.34	-80.25	-93.64	-141.04	-1,503.58	0.00	-105.18	-104.23	-158.31	-174.85	-225.75	-1,536.95

Table B2-43
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-20.92	-19.36	-52.93	-61.76	-93.02	-991.58	0.00	-69.38	-68.76	-104.42	-115.33	-148.90	-1,013.61
Reading, PA	-	x	-	100	0.00	-9.35	-8.64	-23.64	-27.59	-41.56	-443.01	0.00	-30.99	-30.71	-46.64	-51.52	-66.51	-452.84
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-26.76	-24.79	-67.45	-78.69	-118.43	-1,260.63	0.00	-88.73	-87.96	-133.27	-147.18	-189.84	-1,289.02
Rochester, NY	x	-	100	-	0.00	-29.76	-27.52	-75.29	-87.84	-132.31	-1,410.53	0.00	-98.67	-97.78	-148.51	-164.03	-211.78	-1,441.84
Rome, GA	-	x	-	100	0.00	-2.55	-2.36	-6.45	-7.52	-11.33	-120.83	0.00	-8.45	-8.38	-12.72	-14.05	-18.14	-123.51
Sacramento Metro, CA	x	-	50	-	0.00	-57.96	-53.62	-146.60	-171.05	-257.63	-2,746.13	0.00	-192.19	-190.46	-289.23	-319.45	-412.41	-2,807.15
San Diego, CA	x	-	100	-	0.00	-68.36	-63.23	-172.98	-201.82	-304.01	-3,241.07	0.00	-226.68	-224.62	-341.20	-376.86	-486.57	-3,312.97
San Francisco Bay Area, CA	x	-	100	-	0.00	-177.32	-167.24	-425.56	-496.16	-738.22	-7,704.16	0.00	-587.28	-585.70	-859.14	-947.20	-1,207.73	-7,912.16
San Joaquin Valley, CA	x	x	50	100	0.00	-131.00	-121.76	-327.21	-381.71	-573.28	-6,081.12	0.00	-434.26	-431.01	-649.07	-716.59	-922.38	-6,222.87
Sheboygan, WI	x	-	100	-	0.00	-2.81	-2.60	-7.10	-8.28	-12.47	-132.79	0.00	-9.32	-9.24	-14.01	-15.48	-19.97	-135.77
Springfield (Western MA), MA	x	-	100	-	0.00	-21.73	-20.10	-54.99	-64.16	-96.65	-1,030.36	0.00	-72.06	-71.41	-108.47	-119.81	-154.69	-1,053.22
St. Louis, MO-IL	x	x	100	100	0.00	-85.85	-81.49	-202.33	-235.83	-349.33	-3,617.24	0.00	-284.22	-284.05	-411.80	-453.72	-576.00	-3,721.40
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-3.19	-3.08	-7.13	-8.31	-12.15	-122.81	0.00	-10.54	-10.60	-14.87	-16.35	-20.50	-127.03
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Ventura Co., CA	x	-	100	-	0.00	-14.76	-13.67	-37.22	-43.42	-65.36	-695.84	0.00	-48.94	-48.52	-73.53	-81.20	-104.76	-711.49
Washington, DC-MD-VA	x	x	100	100	0.00	-124.02	-114.80	-313.09	-365.29	-549.96	-5,858.06	0.00	-411.19	-407.59	-618.18	-682.74	-881.03	-5,989.15
Wheeling, WV-OH	-	x	-	100	0.00	-3.65	-3.37	-9.23	-10.77	-16.23	-172.99	0.00	-12.10	-11.99	-18.21	-20.12	-25.97	-176.83
York, PA	-	x	-	100	0.00	-10.36	-9.58	-26.21	-30.58	-46.06	-490.99	0.00	-34.35	-34.04	-51.70	-57.10	-73.72	-501.89

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.

b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.

c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)

EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-44
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-39.50	-32.11	-130.99	-153.06	-222.87	-2,565.74	0.00	-150.69	-144.33	-254.43	-282.02	-359.47	-2,586.41
Allegan Co., MI	x	-	100	-	0.00	-4.30	-3.49	-14.25	-16.65	-24.25	-279.17	0.00	-16.40	-15.70	-27.68	-30.69	-39.11	-281.42
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-5.05	-4.11	-16.74	-19.56	-28.48	-327.78	0.00	-19.27	-18.46	-32.52	-36.05	-45.94	-330.43
Atlanta, GA	x	x	100	100	0.00	-314.13	-255.32	-1,042.11	-1,217.76	-1,773.22	-20,415.24	0.00	-1,198.46	-1,147.77	-2,023.86	-2,243.38	-2,859.66	-20,579.23
Baltimore, MD	x	x	100	100	0.00	-85.90	-69.89	-284.45	-332.40	-483.91	-5,568.76	0.00	-327.78	-314.01	-552.91	-612.84	-780.96	-5,614.20
Baton Rouge, LA	x	-	100	-	0.00	-58.60	-56.90	-128.80	-150.04	-205.86	-2,035.69	0.00	-231.53	-233.60	-311.14	-339.82	-403.03	-2,143.00
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-85.57	-88.21	-151.74	-176.38	-231.42	-1,991.03	0.00	-342.47	-351.89	-417.55	-452.63	-516.27	-2,190.19
Birmingham, AL	-	x	-	100	0.00	-29.28	-23.77	-97.33	-113.74	-165.66	-1,908.26	0.00	-111.68	-106.93	-188.84	-209.34	-266.94	-1,923.31
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-121.57	-98.86	-402.97	-470.89	-685.61	-7,891.78	0.00	-463.85	-444.29	-782.90	-867.80	-1,106.03	-7,955.64
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-17.81	-14.32	-60.20	-70.35	-102.66	-1,187.60	0.00	-67.81	-64.74	-115.87	-128.53	-164.35	-1,195.59
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-28.05	-22.81	-92.96	-108.63	-158.17	-1,820.55	0.00	-107.02	-102.51	-180.62	-200.21	-255.17	-1,835.30
Canton-Massillon, OH	-	x	-	100	0.00	-12.93	-11.72	-34.32	-40.04	-56.66	-608.60	0.00	-50.37	-49.79	-74.62	-82.05	-100.65	-625.38
Charleston, WV	-	x	-	100	0.00	-6.97	-5.67	-23.12	-27.02	-39.34	-452.86	0.00	-26.59	-25.47	-44.90	-49.77	-63.44	-456.51
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-70.96	-56.83	-241.40	-282.13	-411.96	-4,773.46	0.00	-270.01	-257.51	-463.25	-513.96	-657.90	-4,803.51
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-14.89	-12.25	-48.37	-56.51	-82.09	-939.75	0.00	-56.95	-54.73	-94.90	-105.12	-133.51	-948.75
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-257.09	-217.81	-790.19	-922.93	-1,331.85	-15,014.20	0.00	-988.43	-957.97	-1,592.89	-1,760.83	-2,215.74	-15,221.71
Chico, CA	x	-	100	-	0.00	-5.69	-4.63	-18.88	-22.06	-32.13	-369.86	0.00	-21.72	-20.80	-36.67	-40.65	-51.82	-372.84
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-55.30	-44.77	-184.73	-215.88	-314.59	-3,628.38	0.00	-210.84	-201.70	-357.59	-396.48	-505.97	-3,655.77
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-4.04	-3.29	-13.40	-15.66	-22.80	-262.47	0.00	-15.42	-14.77	-26.04	-28.86	-36.78	-264.59
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-66.21	-53.83	-219.51	-256.50	-373.47	-4,299.11	0.00	-252.62	-241.96	-426.43	-472.67	-602.45	-4,333.84
Columbus, OH	x	x	100	100	0.00	-57.56	-46.79	-190.94	-223.13	-324.90	-3,740.57	0.00	-219.61	-210.32	-370.84	-411.07	-523.98	-3,770.64
Dallas-Fort Worth, TX	x	-	100	-	0.00	-285.36	-231.96	-946.45	-1,105.97	-1,610.40	-18,539.72	0.00	-1,088.70	-1,042.69	-1,838.27	-2,037.65	-2,597.31	-18,688.92
Dayton-Springfield, OH	-	x	-	100	0.00	-20.19	-16.41	-66.97	-78.26	-113.95	-1,311.85	0.00	-77.04	-73.78	-130.08	-144.18	-183.79	-1,322.41
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-120.97	-99.83	-390.70	-456.48	-662.65	-7,575.01	0.00	-462.82	-445.17	-768.65	-851.20	-1,080.15	-7,650.58
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-135.92	-112.16	-439.00	-512.91	-744.57	-8,511.70	0.00	-520.00	-500.16	-863.64	-956.40	-1,213.66	-8,596.57
Door Co., WI	x	-	100	-	0.00	-0.82	-0.66	-2.71	-3.17	-4.61	-53.06	0.00	-3.12	-2.99	-5.26	-5.83	-7.44	-53.49
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.03	-0.03	-0.12	-0.14	-0.20	-2.33	0.00	-0.13	-0.12	-0.22	-0.25	-0.32	-2.34
Evansville, IN	-	x	-	100	0.00	-9.03	-7.18	-31.05	-36.29	-53.05	-616.39	0.00	-34.31	-32.66	-59.28	-65.79	-84.37	-619.82
Greater Connecticut, CT	x	-	100	-	0.00	-50.52	-41.13	-167.11	-195.28	-284.25	-3,270.18	0.00	-192.80	-184.73	-325.00	-360.21	-458.94	-3,297.12
Greene Co., PA	x	-	100	-	0.00	-0.87	-0.71	-2.90	-3.39	-4.93	-56.78	0.00	-3.33	-3.19	-5.63	-6.24	-7.95	-57.24
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-22.95	-18.66	-76.12	-88.95	-129.52	-1,491.05	0.00	-87.56	-83.86	-147.84	-163.88	-208.89	-1,503.05
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-19.63	-15.96	-65.10	-76.07	-110.77	-1,275.14	0.00	-74.90	-71.74	-126.46	-140.17	-178.67	-1,285.43

Table B2-44
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.12	-0.10	-0.44	-0.52	-0.76	-8.94	0.00	-0.47	-0.44	-0.83	-0.93	-1.19	-8.96
Hickory, NC	-	x	-	100	0.00	-5.81	-4.73	-19.24	-22.48	-32.73	-376.62	0.00	-22.17	-21.24	-37.39	-41.45	-52.82	-379.69
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-320.92	-299.03	-794.19	-926.13	-1,296.56	-13,549.29	0.00	-1,257.11	-1,252.86	-1,793.83	-1,967.49	-2,383.74	-14,033.02
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-22.92	-21.58	-55.17	-64.32	-89.65	-925.72	0.00	-89.98	-89.95	-126.55	-138.67	-167.17	-962.10
Imperial Co., CA	x	-	100	-	0.00	-9.52	-7.74	-31.57	-36.89	-53.72	-618.47	0.00	-36.32	-34.78	-61.32	-67.98	-86.65	-623.45
Indianapolis, IN	-	x	-	100	0.00	-53.69	-43.65	-178.09	-208.10	-303.02	-3,488.52	0.00	-204.85	-196.19	-345.89	-383.41	-488.72	-3,516.59
Jamestown, NY	x	-	100	-	0.00	-3.70	-3.01	-12.27	-14.34	-20.87	-240.27	0.00	-14.12	-13.52	-23.83	-26.42	-33.67	-242.21
Jefferson Co., NY	x	-	100	-	0.00	-4.56	-3.70	-15.10	-17.64	-25.68	-295.60	0.00	-17.38	-16.65	-29.33	-32.51	-41.44	-298.00
Johnstown, PA	-	x	-	100	0.00	-2.77	-2.26	-9.13	-10.67	-15.53	-178.53	0.00	-10.57	-10.13	-17.78	-19.71	-25.10	-180.03
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-6.53	-5.71	-18.74	-21.88	-31.30	-345.60	0.00	-25.25	-24.70	-39.10	-43.12	-53.63	-352.40
Knoxville, TN	x	x	100	100	0.00	-33.02	-26.83	-109.60	-128.07	-186.50	-2,147.48	0.00	-125.97	-120.63	-212.80	-235.88	-300.71	-2,164.65
Lancaster, PA	-	x	-	100	0.00	-11.72	-9.53	-38.87	-45.43	-66.14	-761.45	0.00	-44.72	-42.83	-75.51	-83.70	-106.68	-767.58
Las Vegas, NV	x	-	100	-	0.00	-68.62	-55.56	-229.15	-267.78	-390.22	-4,500.37	0.00	-261.60	-250.26	-443.62	-491.85	-627.66	-4,534.42
Libby, MT	-	x	-	100	0.00	-0.20	-0.16	-0.65	-0.76	-1.11	-12.74	0.00	-0.75	-0.72	-1.26	-1.40	-1.78	-12.84
Liberty-Clairton, PA	-	x	-	100	0.00	-0.29	-0.25	-0.91	-1.07	-1.54	-17.44	0.00	-1.13	-1.09	-1.83	-2.03	-2.56	-17.67
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-598.49	-506.48	-1,843.56	-2,153.29	-3,108.18	-35,061.74	0.00	-2,300.51	-2,228.88	-3,712.26	-4,103.96	-5,166.16	-35,540.07
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-28.39	-23.39	-91.90	-107.38	-155.92	-1,783.52	0.00	-108.58	-104.40	-180.60	-200.01	-253.91	-1,801.00
Louisville, KY-IN	-	x	-	100	0.00	-27.71	-22.35	-93.21	-108.92	-158.85	-1,835.32	0.00	-105.58	-100.88	-179.83	-199.44	-254.81	-1,848.31
Macon, GA	-	x	-	100	0.00	-5.16	-4.15	-17.47	-20.42	-29.80	-344.90	0.00	-19.65	-18.76	-33.61	-37.28	-47.69	-347.19
Manitowoc Co., WI	x	-		-	0.00	-2.69	-2.19	-8.88	-10.38	-15.10	-173.62	0.00	-10.27	-9.85	-17.29	-19.16	-24.40	-175.08
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-4.38	-3.56	-14.51	-16.96	-24.69	-284.19	0.00	-16.71	-16.01	-28.20	-31.26	-39.84	-286.49
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-18.60	-15.12	-61.69	-72.08	-104.96	-1,208.36	0.00	-70.96	-67.96	-119.81	-132.81	-169.28	-1,218.08
Memphis, TN-AR	x	-	100	-	0.00	-37.55	-33.50	-103.43	-120.71	-171.70	-1,869.10	0.00	-145.81	-143.47	-220.52	-242.80	-299.79	-1,913.42
Milwaukee-Racine, WI	x	-	100	-	0.00	-46.42	-37.75	-153.82	-179.75	-261.71	-3,012.22	0.00	-177.10	-169.64	-298.88	-331.29	-422.23	-3,036.64
Nevada (Western Part), CA	x	-	100	-	0.00	-3.27	-2.66	-10.83	-12.65	-18.42	-211.93	0.00	-12.49	-11.97	-21.06	-23.34	-29.74	-213.67
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-405.22	-334.78	-1,305.89	-1,525.73	-2,214.27	-25,297.56	0.00	-1,550.61	-1,491.97	-2,571.83	-2,847.83	-3,612.51	-25,553.98
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-3.68	-2.99	-12.28	-14.35	-20.91	-241.04	0.00	-14.05	-13.44	-23.79	-26.38	-33.65	-242.89
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-286.80	-252.93	-811.06	-946.77	-1,351.63	-14,846.09	0.00	-1,111.18	-1,089.58	-1,705.67	-1,879.82	-2,331.74	-15,159.94
Phoenix-Mesa, AZ	x	-	100	-	0.00	-173.87	-140.37	-583.50	-681.90	-994.23	-11,480.86	0.00	-662.52	-633.28	-1,126.97	-1,249.73	-1,596.12	-11,563.78
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-45.00	-36.56	-149.42	-174.61	-254.28	-2,928.27	0.00	-171.66	-164.38	-290.06	-321.54	-409.93	-2,951.60
Poughkeepsie, NY	x	x	100	100	0.00	-39.77	-32.33	-131.89	-154.11	-224.40	-2,583.34	0.00	-151.73	-145.32	-256.17	-283.96	-361.94	-2,604.15

Table B2-44
Reference Case Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Providence (All RI), RI	x	-	100	-	0.00	-23.91	-19.44	-79.28	-92.64	-134.88	-1,552.71	0.00	-91.23	-87.38	-154.00	-170.70	-217.58	-1,565.24
Reading, PA	-	x	-	100	0.00	-11.74	-9.54	-38.93	-45.49	-66.24	-762.56	0.00	-44.79	-42.89	-75.62	-83.82	-106.84	-768.70
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-48.35	-39.50	-158.90	-185.67	-270.08	-3,101.92	0.00	-184.62	-177.08	-309.98	-343.48	-437.16	-3,128.89
Rochester, NY	x	-	100	-	0.00	-34.58	-28.11	-114.67	-133.99	-195.10	-2,246.03	0.00	-131.92	-126.35	-222.73	-246.88	-314.69	-2,264.13
Rome, GA	-	x	-	100	0.00	-2.90	-2.35	-9.61	-11.22	-16.34	-188.16	0.00	-11.05	-10.58	-18.66	-20.68	-26.36	-189.67
Sacramento Metro, CA	x	-	50	-	0.00	-79.48	-64.67	-263.10	-307.45	-447.58	-5,150.23	0.00	-303.27	-290.55	-511.48	-566.92	-722.40	-5,192.36
San Diego, CA	x	-	100	-	0.00	-77.47	-62.97	-256.95	-300.25	-437.20	-5,033.34	0.00	-295.55	-283.05	-499.05	-553.17	-705.12	-5,073.83
San Francisco Bay Area, CA	x	-	100	-	0.00	-213.85	-182.39	-648.67	-757.57	-1,091.43	-12,256.20	0.00	-823.20	-799.38	-1,316.24	-1,454.31	-1,825.92	-12,438.86
San Joaquin Valley, CA	x	x	50	100	0.00	-188.48	-154.44	-616.45	-720.30	-1,047.15	-12,011.02	0.00	-720.15	-691.28	-1,205.40	-1,335.47	-1,698.28	-12,119.72
Sheboygan, WI	x	-	100	-	0.00	-3.30	-2.69	-10.92	-12.76	-18.57	-213.60	0.00	-12.61	-12.09	-21.25	-23.55	-30.00	-215.37
Springfield (Western MA), MA	x	-	100	-	0.00	-25.66	-20.86	-85.11	-99.46	-144.82	-1,667.26	0.00	-97.91	-93.77	-165.31	-183.24	-233.57	-1,680.68
St. Louis, MO-IL	x	x	100	100	0.00	-104.52	-90.25	-309.24	-361.10	-518.59	-5,779.47	0.00	-403.31	-393.04	-635.44	-701.46	-876.93	-5,877.88
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-3.68	-3.32	-9.86	-11.51	-16.31	-175.81	0.00	-14.33	-14.15	-21.34	-23.48	-28.85	-180.48
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Ventura Co., CA	x	-	100	-	0.00	-17.10	-13.95	-56.39	-65.89	-95.88	-1,102.14	0.00	-65.28	-62.58	-109.83	-121.71	-154.99	-1,111.46
Washington, DC-MD-VA	x	x	100	100	0.00	-165.54	-134.83	-547.15	-639.36	-930.61	-10,704.01	0.00	-631.79	-605.44	-1,064.48	-1,179.79	-1,502.96	-10,792.77
Wheeling, WV-OH	-	x	-	100	0.00	-3.95	-3.21	-13.09	-15.29	-22.27	-256.34	0.00	-15.05	-14.42	-25.42	-28.17	-35.91	-258.40
York, PA	-	x	-	100	0.00	-13.65	-11.09	-45.25	-52.87	-76.98	-886.21	0.00	-52.06	-49.87	-87.89	-97.43	-124.18	-893.36

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-45
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.08	0.11	0.12	0.15	0.22	0.62	0.00	0.08	0.11	0.12	0.15	0.22	0.62
Allegan Co., MI	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.01	0.02	0.02	0.07
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.01	0.01	0.02	0.06
Atlanta, GA	x	x	100	100	0.00	0.45	0.56	0.65	0.79	1.17	3.30	0.00	0.45	0.56	0.65	0.79	1.17	3.30
Baltimore, MD	x	x	100	100	0.00	0.19	0.23	0.27	0.33	0.49	1.37	0.00	0.19	0.23	0.27	0.33	0.49	1.37
Baton Rouge, LA	x	-	100	-	0.00	-0.34	-0.42	-0.56	-0.63	-0.72	-1.34	0.00	-0.34	-0.42	-0.56	-0.63	-0.72	-1.35
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-0.74	-0.92	-1.21	-1.38	-1.60	-3.15	0.00	-0.74	-0.92	-1.21	-1.38	-1.60	-3.15
Birmingham, AL	-	x	-	100	0.00	0.07	0.09	0.10	0.12	0.18	0.50	0.00	0.07	0.09	0.10	0.12	0.18	0.50
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.30	0.38	0.44	0.53	0.79	2.23	0.00	0.30	0.38	0.44	0.53	0.79	2.23
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.04	0.05	0.06	0.07	0.11	0.30	0.00	0.04	0.05	0.06	0.07	0.11	0.30
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.07	0.09	0.11	0.13	0.19	0.54	0.00	0.07	0.09	0.11	0.13	0.19	0.54
Canton-Massillon, OH	-	x	-	100	0.00	-0.03	-0.04	-0.05	-0.06	-0.05	-0.06	0.00	-0.03	-0.04	-0.05	-0.06	-0.05	-0.06
Charleston, WV	-	x	-	100	0.00	0.02	0.02	0.03	0.03	0.05	0.14	0.00	0.02	0.02	0.03	0.03	0.05	0.14
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.12	0.15	0.17	0.21	0.31	0.87	0.00	0.12	0.15	0.17	0.21	0.31	0.87
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.03	0.04	0.05	0.06	0.09	0.26	0.00	0.03	0.04	0.05	0.06	0.09	0.26
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.09	-0.11	-0.23	-0.22	0.00	0.97	0.00	-0.10	-0.11	-0.23	-0.22	0.00	0.97
Chico, CA	x	-	100	-	0.00	0.01	0.02	0.02	0.02	0.03	0.09	0.00	0.01	0.02	0.02	0.02	0.03	0.09
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.12	0.15	0.18	0.21	0.32	0.89	0.00	0.12	0.15	0.18	0.21	0.32	0.89
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.08	0.00	0.01	0.01	0.02	0.02	0.03	0.08
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.17	0.22	0.25	0.31	0.46	1.28	0.00	0.17	0.22	0.25	0.31	0.46	1.28
Columbus, OH	x	x	100	100	0.00	0.11	0.14	0.16	0.20	0.29	0.83	0.00	0.11	0.14	0.16	0.20	0.29	0.83
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.45	0.57	0.66	0.80	1.19	3.35	0.00	0.45	0.57	0.66	0.80	1.19	3.35
Dayton-Springfield, OH	-	x	-	100	0.00	0.05	0.07	0.08	0.09	0.14	0.39	0.00	0.05	0.07	0.08	0.09	0.14	0.39
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.15	0.19	0.20	0.25	0.41	1.27	0.00	0.15	0.19	0.20	0.25	0.41	1.27
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.25	0.31	0.35	0.43	0.68	2.04	0.00	0.25	0.31	0.35	0.43	0.68	2.04
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.02	0.03	0.03	0.04	0.06	0.17	0.00	0.02	0.03	0.03	0.04	0.06	0.17
Greater Connecticut, CT	x	-	100	-	0.00	0.11	0.15	0.17	0.20	0.30	0.85	0.00	0.11	0.15	0.17	0.20	0.30	0.85
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.05	0.07	0.08	0.09	0.14	0.38	0.00	0.05	0.07	0.08	0.09	0.14	0.38

Table B2-45
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.05	0.06	0.07	0.08	0.12	0.35	0.00	0.05	0.06	0.07	0.08	0.12	0.35
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.01	0.02	0.02	0.02	0.03	0.09	0.00	0.01	0.02	0.02	0.02	0.03	0.09
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-1.23	-1.54	-2.06	-2.32	-2.54	-4.38	0.00	-1.23	-1.54	-2.07	-2.33	-2.54	-4.39
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.12	-0.15	-0.20	-0.23	-0.25	-0.45	0.00	-0.12	-0.15	-0.20	-0.23	-0.25	-0.45
Imperial Co., CA	x	-	100	-	0.00	0.01	0.02	0.02	0.03	0.04	0.11	0.00	0.01	0.02	0.02	0.03	0.04	0.11
Indianapolis, IN	-	x	-	100	0.00	0.10	0.13	0.15	0.18	0.27	0.77	0.00	0.10	0.13	0.15	0.18	0.27	0.77
Jamestown, NY	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.03	0.07	0.00	0.01	0.01	0.01	0.02	0.03	0.07
Jefferson Co., NY	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.01	0.02	0.02	0.07
Johnstown, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.01	0.01	0.02	0.06
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.01	0.01	0.02	0.06
Knoxville, TN	x	x	100	100	0.00	0.07	0.09	0.10	0.13	0.19	0.53	0.00	0.07	0.09	0.10	0.13	0.19	0.53
Lancaster, PA	-	x	-	100	0.00	0.03	0.04	0.04	0.05	0.07	0.21	0.00	0.03	0.04	0.04	0.05	0.07	0.21
Las Vegas, NV	x	-	100	-	0.00	0.09	0.12	0.13	0.16	0.24	0.68	0.00	0.09	0.12	0.13	0.16	0.24	0.68
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	0.12	0.16	0.03	0.13	0.69	3.42	0.00	0.12	0.16	0.03	0.13	0.69	3.42
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.05	0.06	0.07	0.08	0.12	0.35	0.00	0.05	0.06	0.07	0.08	0.12	0.35
Louisville, KY-IN	-	x	-	100	0.00	0.07	0.09	0.11	0.13	0.19	0.54	0.00	0.07	0.09	0.11	0.13	0.19	0.54
Macon, GA	-	x	-	100	0.00	0.01	0.02	0.02	0.02	0.04	0.10	0.00	0.01	0.02	0.02	0.02	0.04	0.10
Manitowoc Co., WI	x	-		-	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.03	0.03	0.04	0.05	0.07	0.20	0.00	0.03	0.03	0.04	0.05	0.07	0.20
Memphis, TN-AR	x	-	100	-	0.00	-0.06	-0.07	-0.10	-0.11	-0.10	-0.06	0.00	-0.06	-0.07	-0.11	-0.11	-0.10	-0.06
Milwaukee-Racine, WI	x	-	100	-	0.00	0.11	0.14	0.17	0.20	0.30	0.85	0.00	0.11	0.14	0.17	0.20	0.30	0.85
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.73	0.92	1.02	1.26	2.00	6.02	0.00	0.72	0.92	1.02	1.26	2.00	6.02
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.08	0.00	0.01	0.01	0.02	0.02	0.03	0.08
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-0.35	-0.44	-0.66	-0.71	-0.57	-0.20	0.00	-0.36	-0.44	-0.66	-0.71	-0.58	-0.20

Table B2-45
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.26	0.32	0.37	0.45	0.67	1.89	0.00	0.26	0.32	0.37	0.45	0.67	1.89
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.13	0.16	0.19	0.23	0.34	0.95	0.00	0.13	0.16	0.19	0.23	0.34	0.95
Poughkeepsie, NY	x	x	100	100	0.00	0.08	0.10	0.12	0.15	0.22	0.61	0.00	0.08	0.10	0.12	0.15	0.22	0.61
Providence (All RI), RI	x	-	100	-	0.00	0.06	0.08	0.09	0.11	0.16	0.44	0.00	0.06	0.08	0.09	0.11	0.16	0.44
Reading, PA	-	x	-	100	0.00	0.02	0.03	0.04	0.04	0.06	0.18	0.00	0.02	0.03	0.04	0.04	0.06	0.18
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.05	0.06	0.07	0.09	0.13	0.36	0.00	0.05	0.06	0.07	0.09	0.13	0.36
Rochester, NY	x	-	100	-	0.00	0.08	0.11	0.12	0.15	0.22	0.62	0.00	0.08	0.11	0.12	0.15	0.22	0.62
Rome, GA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Sacramento Metro, CA	x	-	50	-	0.00	0.14	0.18	0.21	0.25	0.37	1.04	0.00	0.14	0.18	0.21	0.25	0.37	1.04
San Diego, CA	x	-	100	-	0.00	0.20	0.25	0.29	0.35	0.52	1.46	0.00	0.20	0.25	0.29	0.35	0.52	1.46
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.02	-0.02	-0.10	-0.07	0.16	1.23	0.00	-0.02	-0.02	-0.10	-0.07	0.16	1.23
San Joaquin Valley, CA	x	x	50	100	0.00	0.21	0.27	0.30	0.37	0.59	1.80	0.00	0.21	0.27	0.30	0.37	0.59	1.80
Sheboygan, WI	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.01	0.01	0.02	0.06
Springfield (Western MA), MA	x	-	100	-	0.00	0.06	0.08	0.09	0.11	0.16	0.45	0.00	0.06	0.08	0.09	0.11	0.16	0.45
St. Louis, MO-IL	x	x	100	100	0.00	-0.01	-0.01	-0.05	-0.04	0.07	0.56	0.00	-0.01	-0.01	-0.05	-0.04	0.07	0.56
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.04	0.05	0.06	0.07	0.10	0.30	0.00	0.04	0.05	0.06	0.07	0.10	0.30
Washington, DC-MD-VA	x	x	100	100	0.00	0.32	0.40	0.46	0.56	0.83	2.35	0.00	0.32	0.40	0.46	0.56	0.83	2.35
Wheeling, WV-OH	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.08	0.00	0.01	0.01	0.02	0.02	0.03	0.08
York, PA	-	x	-	100	0.00	0.03	0.03	0.04	0.05	0.07	0.19	0.00	0.03	0.03	0.04	0.05	0.07	0.19

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-46
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.22	0.23	0.20	0.28	0.36	1.12	0.00	0.31	0.33	0.30	0.40	0.51	1.28
Allegan Co., MI	x	-	100	-	0.00	0.02	0.03	0.02	0.03	0.04	0.12	0.00	0.03	0.04	0.03	0.04	0.06	0.14
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.02	0.02	0.03	0.04	0.12	0.00	0.03	0.04	0.03	0.04	0.05	0.14
Atlanta, GA	x	x	100	100	0.00	1.25	1.35	1.14	1.61	2.10	6.46	0.00	1.78	1.94	1.77	2.34	2.94	7.43
Baltimore, MD	x	x	100	100	0.00	0.48	0.51	0.43	0.61	0.80	2.45	0.00	0.67	0.73	0.67	0.89	1.12	2.82
Baton Rouge, LA	x	-	100	-	0.00	-1.08	-1.26	-1.58	-1.74	-1.93	-3.54	0.00	-1.78	-2.02	-2.36	-2.55	-2.74	-4.04
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-2.33	-2.71	-3.33	-3.70	-4.15	-7.94	0.00	-3.82	-4.30	-4.98	-5.43	-5.89	-9.08
Birmingham, AL	-	x	-	100	0.00	0.17	0.18	0.15	0.22	0.28	0.88	0.00	0.24	0.26	0.24	0.32	0.40	1.01
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.75	0.80	0.68	0.96	1.25	3.84	0.00	1.06	1.15	1.05	1.39	1.75	4.42
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.10	0.11	0.09	0.13	0.17	0.54	0.00	0.15	0.16	0.15	0.19	0.24	0.62
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.18	0.19	0.16	0.23	0.30	0.92	0.00	0.25	0.28	0.25	0.33	0.42	1.06
Canton-Massillon, OH	-	x	-	100	0.00	-0.10	-0.13	-0.17	-0.18	-0.19	-0.27	0.00	-0.18	-0.21	-0.26	-0.27	-0.27	-0.31
Charleston, WV	-	x	-	100	0.00	0.05	0.05	0.04	0.06	0.08	0.24	0.00	0.07	0.07	0.07	0.09	0.11	0.28
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.32	0.35	0.30	0.42	0.54	1.67	0.00	0.46	0.50	0.46	0.61	0.76	1.92
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.09	0.09	0.08	0.11	0.14	0.45	0.00	0.12	0.13	0.12	0.16	0.20	0.51
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.56	-0.75	-1.39	-1.24	-1.12	0.05	0.00	-1.17	-1.38	-2.02	-1.83	-1.63	0.09
Chico, CA	x	-	100	-	0.00	0.03	0.03	0.03	0.04	0.05	0.17	0.00	0.05	0.05	0.05	0.06	0.08	0.19
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.30	0.33	0.28	0.39	0.51	1.56	0.00	0.43	0.47	0.43	0.57	0.71	1.80
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.03	0.03	0.02	0.04	0.05	0.14	0.00	0.04	0.04	0.04	0.05	0.06	0.16
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.42	0.46	0.38	0.54	0.71	2.18	0.00	0.60	0.65	0.60	0.79	0.99	2.51
Columbus, OH	x	x	100	100	0.00	0.29	0.32	0.27	0.38	0.49	1.51	0.00	0.41	0.45	0.41	0.55	0.69	1.73
Dallas-Fort Worth, TX	x	-	100	-	0.00	1.24	1.34	1.13	1.60	2.08	6.41	0.00	1.76	1.92	1.75	2.32	2.92	7.36
Dayton-Springfield, OH	-	x	-	100	0.00	0.13	0.14	0.12	0.17	0.22	0.66	0.00	0.18	0.20	0.18	0.24	0.30	0.76
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.36	0.37	0.22	0.40	0.58	2.18	0.00	0.46	0.49	0.36	0.58	0.80	2.51
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.57	0.60	0.41	0.67	0.94	3.31	0.00	0.77	0.82	0.66	0.97	1.31	3.81
Door Co., WI	x	-	100	-	0.00	0.01	0.01	0.00	0.01	0.01	0.03	0.00	0.01	0.01	0.01	0.01	0.01	0.03
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.06	0.06	0.05	0.07	0.09	0.29	0.00	0.08	0.09	0.08	0.11	0.13	0.34
Greater Connecticut, CT	x	-	100	-	0.00	0.29	0.31	0.26	0.37	0.49	1.50	0.00	0.41	0.45	0.41	0.54	0.68	1.72
Greene Co., PA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	0.03	0.00	0.01	0.01	0.01	0.01	0.01	0.04
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.13	0.14	0.12	0.17	0.22	0.68	0.00	0.19	0.20	0.19	0.25	0.31	0.78

Table B2-46
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.12	0.13	0.11	0.15	0.20	0.61	0.00	0.17	0.18	0.17	0.22	0.28	0.70
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.03	0.03	0.03	0.04	0.05	0.16	0.00	0.04	0.05	0.04	0.06	0.07	0.19
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-4.03	-4.76	-6.15	-6.64	-7.28	-12.50	0.00	-6.78	-7.69	-9.17	-9.76	-10.36	-14.28
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.40	-0.47	-0.60	-0.66	-0.72	-1.27	0.00	-0.67	-0.76	-0.90	-0.97	-1.03	-1.45
Imperial Co., CA	x	-	100	-	0.00	0.04	0.04	0.04	0.05	0.07	0.21	0.00	0.06	0.06	0.06	0.08	0.10	0.24
Indianapolis, IN	-	x	-	100	0.00	0.27	0.29	0.25	0.35	0.46	1.41	0.00	0.39	0.42	0.38	0.51	0.64	1.61
Jamestown, NY	x	-	100	-	0.00	0.02	0.03	0.02	0.03	0.04	0.12	0.00	0.03	0.04	0.03	0.04	0.06	0.14
Jefferson Co., NY	x	-	100	-	0.00	0.02	0.03	0.02	0.03	0.04	0.12	0.00	0.03	0.04	0.03	0.04	0.06	0.14
Johnstown, PA	-	x	-	100	0.00	0.02	0.02	0.02	0.02	0.03	0.10	0.00	0.03	0.03	0.03	0.04	0.04	0.11
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.02	0.02	0.02	0.03	0.04	0.11	0.00	0.03	0.03	0.03	0.04	0.05	0.13
Knoxville, TN	x	x	100	100	0.00	0.18	0.20	0.17	0.23	0.31	0.94	0.00	0.26	0.28	0.26	0.34	0.43	1.08
Lancaster, PA	-	x	-	100	0.00	0.07	0.08	0.06	0.09	0.12	0.36	0.00	0.10	0.11	0.10	0.13	0.16	0.41
Las Vegas, NV	x	-	100	-	0.00	0.27	0.29	0.24	0.34	0.45	1.38	0.00	0.38	0.41	0.38	0.50	0.63	1.58
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-0.10	-0.33	-1.43	-0.92	-0.45	3.93	0.00	-0.72	-0.95	-2.02	-1.39	-0.72	4.57
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.13	0.14	0.12	0.16	0.21	0.66	0.00	0.18	0.20	0.18	0.24	0.30	0.76
Louisville, KY-IN	-	x	-	100	0.00	0.18	0.19	0.16	0.23	0.30	0.92	0.00	0.25	0.28	0.25	0.33	0.42	1.06
Macon, GA	-	x	-	100	0.00	0.03	0.04	0.03	0.04	0.06	0.17	0.00	0.05	0.05	0.05	0.06	0.08	0.20
Manitowoc Co., WI	x	-		-	0.00	0.02	0.02	0.02	0.02	0.03	0.09	0.00	0.02	0.03	0.02	0.03	0.04	0.10
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.02	0.02	0.02	0.03	0.10	0.00	0.03	0.03	0.03	0.04	0.04	0.11
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.08	0.08	0.07	0.10	0.13	0.39	0.00	0.11	0.12	0.11	0.14	0.18	0.45
Memphis, TN-AR	x	-	100	-	0.00	-0.22	-0.27	-0.40	-0.40	-0.41	-0.50	0.00	-0.40	-0.46	-0.59	-0.59	-0.59	-0.57
Milwaukee-Racine, WI	x	-	100	-	0.00	0.28	0.31	0.26	0.36	0.48	1.46	0.00	0.40	0.44	0.40	0.53	0.67	1.68
Nevada (Western Part), CA	x	-	100	-	0.00	0.02	0.02	0.02	0.02	0.03	0.09	0.00	0.02	0.03	0.02	0.03	0.04	0.10
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	1.67	1.74	1.17	1.94	2.72	9.73	0.00	2.21	2.37	1.87	2.80	3.79	11.19
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.02	0.03	0.02	0.03	0.04	0.13	0.00	0.04	0.04	0.04	0.05	0.06	0.15
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-1.37	-1.68	-2.52	-2.51	-2.56	-2.79	0.00	-2.49	-2.86	-3.72	-3.70	-3.67	-3.16

Table B2-46
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.73	0.78	0.66	0.93	1.22	3.75	0.00	1.03	1.12	1.02	1.36	1.71	4.31
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.31	0.33	0.28	0.39	0.51	1.58	0.00	0.43	0.47	0.43	0.57	0.72	1.82
Poughkeepsie, NY	x	x	100	100	0.00	0.21	0.23	0.20	0.28	0.36	1.11	0.00	0.30	0.33	0.30	0.40	0.50	1.27
Providence (All RI), RI	x	-	100	-	0.00	0.15	0.16	0.13	0.19	0.25	0.76	0.00	0.21	0.23	0.21	0.28	0.35	0.88
Reading, PA	-	x	-	100	0.00	0.06	0.07	0.06	0.08	0.11	0.33	0.00	0.09	0.10	0.09	0.12	0.15	0.37
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.15	0.16	0.14	0.19	0.25	0.77	0.00	0.21	0.23	0.21	0.28	0.35	0.89
Rochester, NY	x	-	100	-	0.00	0.21	0.23	0.19	0.27	0.35	1.08	0.00	0.30	0.32	0.30	0.39	0.49	1.24
Rome, GA	-	x	-	100	0.00	0.02	0.02	0.02	0.02	0.03	0.09	0.00	0.03	0.03	0.03	0.03	0.04	0.11
Sacramento Metro, CA	x	-	50	-	0.00	0.38	0.41	0.34	0.49	0.63	1.95	0.00	0.54	0.58	0.53	0.71	0.89	2.24
San Diego, CA	x	-	100	-	0.00	0.49	0.52	0.44	0.63	0.82	2.51	0.00	0.69	0.75	0.69	0.91	1.14	2.88
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.33	-0.47	-1.01	-0.84	-0.70	0.70	0.00	-0.77	-0.93	-1.46	-1.25	-1.02	0.83
San Joaquin Valley, CA	x	x	50	100	0.00	0.56	0.59	0.39	0.65	0.92	3.30	0.00	0.75	0.80	0.63	0.95	1.28	3.80
Sheboygan, WI	x	-	100	-	0.00	0.02	0.02	0.02	0.03	0.03	0.10	0.00	0.03	0.03	0.03	0.04	0.05	0.12
Springfield (Western MA), MA	x	-	100	-	0.00	0.15	0.16	0.14	0.19	0.25	0.78	0.00	0.21	0.23	0.21	0.28	0.36	0.90
St. Louis, MO-IL	x	x	100	100	0.00	-0.15	-0.22	-0.47	-0.39	-0.33	0.31	0.00	-0.36	-0.43	-0.68	-0.58	-0.48	0.37
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.03	-0.03	-0.05	-0.05	-0.05	-0.06	0.00	-0.05	-0.05	-0.07	-0.07	-0.07	-0.07
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.10	0.10	0.09	0.12	0.16	0.51	0.00	0.14	0.15	0.13	0.18	0.23	0.59
Washington, DC-MD-VA	x	x	100	100	0.00	0.82	0.89	0.75	1.06	1.38	4.25	0.00	1.17	1.27	1.16	1.54	1.93	4.88
Wheeling, WV-OH	-	x	-	100	0.00	0.03	0.03	0.02	0.03	0.04	0.14	0.00	0.04	0.04	0.04	0.05	0.06	0.16
York, PA	-	x	-	100	0.00	0.07	0.07	0.06	0.09	0.11	0.35	0.00	0.10	0.11	0.10	0.13	0.16	0.41

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-47
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.23	0.27	0.13	0.21	0.26	0.66	0.00	0.51	0.58	0.45	0.57	0.65	1.19
Allegan Co., MI	x	-	100	-	0.00	0.03	0.03	0.01	0.02	0.03	0.07	0.00	0.06	0.06	0.05	0.06	0.07	0.13
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.03	0.03	0.01	0.02	0.03	0.07	0.00	0.06	0.06	0.05	0.06	0.07	0.13
Atlanta, GA	x	x	100	100	0.00	1.48	1.70	0.85	1.36	1.65	4.20	0.00	3.24	3.68	2.89	3.64	4.16	7.61
Baltimore, MD	x	x	100	100	0.00	0.51	0.58	0.29	0.47	0.56	1.44	0.00	1.11	1.26	0.99	1.25	1.42	2.61
Baton Rouge, LA	x	-	100	-	0.00	-1.74	-1.99	-2.49	-2.73	-3.03	-5.75	0.00	-3.60	-3.97	-4.54	-4.88	-5.18	-7.02
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-3.68	-4.21	-5.12	-5.66	-6.31	-12.08	0.00	-7.63	-8.44	-9.49	-10.25	-10.93	-15.05
Birmingham, AL	-	x	-	100	0.00	0.18	0.20	0.10	0.16	0.20	0.50	0.00	0.39	0.44	0.35	0.44	0.50	0.91
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.77	0.88	0.44	0.70	0.85	2.18	0.00	1.68	1.91	1.50	1.89	2.16	3.95
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.11	0.13	0.06	0.10	0.12	0.31	0.00	0.24	0.28	0.22	0.27	0.31	0.57
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.18	0.21	0.10	0.17	0.20	0.52	0.00	0.40	0.45	0.36	0.45	0.51	0.93
Canton-Massillon, OH	-	x	-	100	0.00	-0.19	-0.22	-0.30	-0.32	-0.36	-0.65	0.00	-0.39	-0.43	-0.52	-0.55	-0.57	-0.73
Charleston, WV	-	x	-	100	0.00	0.05	0.05	0.03	0.04	0.05	0.13	0.00	0.10	0.12	0.09	0.12	0.13	0.24
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.37	0.43	0.21	0.34	0.42	1.06	0.00	0.82	0.93	0.73	0.92	1.05	1.92
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.09	0.10	0.05	0.08	0.10	0.25	0.00	0.20	0.22	0.17	0.22	0.25	0.46
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-1.46	-1.66	-3.02	-2.99	-3.23	-5.33	0.00	-2.89	-3.11	-4.52	-4.45	-4.52	-4.69
Chico, CA	x	-	100	-	0.00	0.03	0.04	0.02	0.03	0.04	0.10	0.00	0.07	0.08	0.07	0.08	0.10	0.18
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.32	0.37	0.18	0.30	0.36	0.91	0.00	0.71	0.80	0.63	0.79	0.91	1.66
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.03	0.03	0.02	0.03	0.03	0.08	0.00	0.06	0.07	0.05	0.07	0.08	0.14
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.43	0.49	0.25	0.40	0.48	1.22	0.00	0.94	1.07	0.84	1.06	1.21	2.21
Columbus, OH	x	x	100	100	0.00	0.32	0.37	0.18	0.29	0.36	0.91	0.00	0.70	0.79	0.62	0.79	0.90	1.64
Dallas-Fort Worth, TX	x	-	100	-	0.00	1.43	1.63	0.82	1.31	1.59	4.05	0.00	3.12	3.55	2.79	3.51	4.01	7.33
Dayton-Springfield, OH	-	x	-	100	0.00	0.13	0.15	0.08	0.12	0.15	0.37	0.00	0.29	0.33	0.26	0.32	0.37	0.67
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.31	0.35	-0.08	0.09	0.15	0.73	0.00	0.70	0.82	0.40	0.65	0.81	1.89
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.48	0.55	0.01	0.24	0.34	1.21	0.00	1.09	1.25	0.73	1.07	1.29	2.81
Door Co., WI	x	-	100	-	0.00	0.01	0.01	0.00	0.00	0.01	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.03
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.06	0.07	0.03	0.05	0.07	0.17	0.00	0.13	0.15	0.12	0.15	0.17	0.30
Greater Connecticut, CT	x	-	100	-	0.00	0.31	0.35	0.18	0.28	0.34	0.87	0.00	0.67	0.76	0.60	0.75	0.86	1.57
Greene Co., PA	x	-	100	-	0.00	0.01	0.01	0.00	0.01	0.01	0.02	0.00	0.01	0.02	0.01	0.02	0.02	0.03
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.14	0.16	0.08	0.13	0.15	0.39	0.00	0.30	0.35	0.27	0.34	0.39	0.72

Table B2-47
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.12	0.14	0.07	0.11	0.14	0.35	0.00	0.27	0.30	0.24	0.30	0.34	0.63
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.03	0.04	0.02	0.03	0.04	0.10	0.00	0.07	0.08	0.07	0.08	0.10	0.17
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-6.74	-7.70	-10.02	-10.86	-12.03	-22.48	0.00	-13.89	-15.30	-17.88	-19.03	-20.13	-26.72
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.67	-0.76	-0.98	-1.06	-1.18	-2.22	0.00	-1.38	-1.52	-1.76	-1.88	-1.99	-2.67
Imperial Co., CA	x	-	100	-	0.00	0.05	0.05	0.03	0.04	0.05	0.13	0.00	0.10	0.12	0.09	0.12	0.13	0.24
Indianapolis, IN	-	x	-	100	0.00	0.30	0.34	0.17	0.27	0.33	0.84	0.00	0.65	0.74	0.58	0.73	0.84	1.53
Jamestown, NY	x	-	100	-	0.00	0.02	0.03	0.01	0.02	0.03	0.07	0.00	0.05	0.06	0.05	0.06	0.07	0.12
Jefferson Co., NY	x	-	100	-	0.00	0.03	0.03	0.01	0.02	0.03	0.07	0.00	0.06	0.06	0.05	0.06	0.07	0.13
Johnstown, PA	-	x	-	100	0.00	0.02	0.02	0.01	0.02	0.02	0.05	0.00	0.04	0.05	0.04	0.05	0.05	0.10
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.02	0.03	0.01	0.02	0.03	0.07	0.00	0.05	0.06	0.05	0.06	0.07	0.13
Knoxville, TN	x	x	100	100	0.00	0.19	0.22	0.11	0.18	0.22	0.55	0.00	0.43	0.48	0.38	0.48	0.55	1.00
Lancaster, PA	-	x	-	100	0.00	0.07	0.08	0.04	0.07	0.08	0.21	0.00	0.16	0.18	0.14	0.18	0.20	0.37
Las Vegas, NV	x	-	100	-	0.00	0.32	0.37	0.18	0.30	0.36	0.91	0.00	0.71	0.80	0.63	0.79	0.91	1.66
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-1.34	-1.52	-4.08	-3.74	-3.93	-5.60	0.00	-2.46	-2.54	-5.15	-4.61	-4.40	-2.60
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.14	0.16	0.08	0.13	0.16	0.41	0.00	0.31	0.36	0.28	0.35	0.40	0.74
Louisville, KY-IN	-	x	-	100	0.00	0.18	0.21	0.10	0.17	0.20	0.52	0.00	0.40	0.46	0.36	0.45	0.51	0.94
Macon, GA	-	x	-	100	0.00	0.03	0.04	0.02	0.03	0.04	0.10	0.00	0.08	0.09	0.07	0.08	0.10	0.18
Manitowoc Co., WI	x	-		-	0.00	0.02	0.02	0.01	0.02	0.02	0.05	0.00	0.04	0.04	0.03	0.04	0.05	0.09
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.03	0.01	0.02	0.02	0.06	0.00	0.05	0.05	0.04	0.05	0.06	0.11
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.09	0.10	0.05	0.08	0.10	0.25	0.00	0.20	0.22	0.17	0.22	0.25	0.46
Memphis, TN-AR	x	-	100	-	0.00	-0.44	-0.50	-0.73	-0.77	-0.84	-1.50	0.00	-0.89	-0.97	-1.22	-1.26	-1.32	-1.62
Milwaukee-Racine, WI	x	-	100	-	0.00	0.29	0.34	0.17	0.27	0.33	0.83	0.00	0.64	0.73	0.57	0.72	0.82	1.50
Nevada (Western Part), CA	x	-	100	-	0.00	0.02	0.02	0.01	0.02	0.02	0.05	0.00	0.04	0.05	0.04	0.05	0.05	0.10
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	1.36	1.56	-0.07	0.60	0.89	3.40	0.00	3.10	3.58	2.01	3.01	3.66	8.09
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.02	0.03	0.01	0.02	0.03	0.07	0.00	0.05	0.06	0.05	0.06	0.07	0.13
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-2.72	-3.11	-4.73	-4.90	-5.36	-9.45	0.00	-5.51	-6.02	-7.74	-7.96	-8.26	-9.91

Table B2-47
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.86	0.98	0.49	0.79	0.95	2.44	0.00	1.88	2.14	1.68	2.11	2.41	4.42
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.31	0.35	0.17	0.28	0.34	0.87	0.00	0.67	0.76	0.60	0.75	0.86	1.57
Poughkeepsie, NY	x	x	100	100	0.00	0.23	0.27	0.13	0.21	0.26	0.66	0.00	0.51	0.57	0.45	0.57	0.65	1.19
Providence (All RI), RI	x	-	100	-	0.00	0.15	0.17	0.09	0.14	0.17	0.43	0.00	0.33	0.38	0.30	0.37	0.43	0.78
Reading, PA	-	x	-	100	0.00	0.07	0.08	0.04	0.06	0.08	0.19	0.00	0.15	0.17	0.13	0.17	0.19	0.35
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.19	0.22	0.11	0.18	0.21	0.55	0.00	0.42	0.48	0.38	0.48	0.54	0.99
Rochester, NY	x	-	100	-	0.00	0.22	0.25	0.12	0.20	0.24	0.62	0.00	0.47	0.54	0.42	0.53	0.61	1.12
Rome, GA	-	x	-	100	0.00	0.02	0.02	0.01	0.02	0.02	0.05	0.00	0.04	0.05	0.04	0.05	0.05	0.10
Sacramento Metro, CA	x	-	50	-	0.00	0.42	0.48	0.24	0.39	0.47	1.20	0.00	0.92	1.05	0.83	1.04	1.19	2.17
San Diego, CA	x	-	100	-	0.00	0.50	0.57	0.29	0.46	0.55	1.41	0.00	1.09	1.24	0.97	1.23	1.40	2.56
San Francisco Bay Area, CA	x	-	100	-	0.00	-1.09	-1.24	-2.39	-2.34	-2.51	-4.04	0.00	-2.13	-2.28	-3.48	-3.38	-3.39	-3.30
San Joaquin Valley, CA	x	x	50	100	0.00	0.55	0.64	0.02	0.28	0.40	1.41	0.00	1.25	1.45	0.86	1.24	1.50	3.23
Sheboygan, WI	x	-	100	-	0.00	0.02	0.02	0.01	0.02	0.02	0.06	0.00	0.04	0.05	0.04	0.05	0.06	0.10
Springfield (Western MA), MA	x	-	100	-	0.00	0.16	0.18	0.09	0.15	0.18	0.45	0.00	0.35	0.39	0.31	0.39	0.45	0.81
St. Louis, MO-IL	x	x	100	100	0.00	-0.50	-0.57	-1.11	-1.08	-1.16	-1.87	0.00	-0.99	-1.06	-1.61	-1.56	-1.57	-1.53
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.05	-0.06	-0.08	-0.09	-0.10	-0.17	0.00	-0.10	-0.11	-0.14	-0.14	-0.15	-0.19
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.10	0.11	0.05	0.08	0.10	0.27	0.00	0.21	0.24	0.18	0.24	0.27	0.51
Washington, DC-MD-VA	x	x	100	100	0.00	0.90	1.03	0.52	0.83	1.00	2.55	0.00	1.97	2.24	1.76	2.21	2.53	4.62
Wheeling, WV-OH	-	x	-	100	0.00	0.03	0.03	0.02	0.02	0.03	0.08	0.00	0.06	0.07	0.05	0.07	0.07	0.14
York, PA	-	x	-	100	0.00	0.08	0.09	0.04	0.07	0.08	0.21	0.00	0.17	0.19	0.15	0.19	0.21	0.39

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-48
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.14	0.21	-0.03	0.00	-0.06	-0.62	0.00	0.71	0.86	0.61	0.66	0.63	0.54
Allegan Co., MI	x	-	100	-	0.00	0.02	0.02	0.00	0.00	-0.01	-0.07	0.00	0.08	0.09	0.07	0.07	0.07	0.06
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.03	0.00	0.00	-0.01	-0.08	0.00	0.09	0.11	0.08	0.08	0.08	0.07
Atlanta, GA	x	x	100	100	0.00	1.11	1.71	-0.23	-0.04	-0.48	-4.91	0.00	5.64	6.86	4.82	5.26	4.99	4.29
Baltimore, MD	x	x	100	100	0.00	0.30	0.46	-0.06	-0.01	-0.13	-1.34	0.00	1.54	1.87	1.31	1.43	1.36	1.17
Baton Rouge, LA	x	-	100	-	0.00	-2.54	-2.84	-3.53	-3.90	-4.35	-8.60	0.00	-5.91	-6.43	-7.27	-7.82	-8.29	-10.80
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-5.23	-5.89	-7.09	-7.84	-8.70	-16.81	0.00	-12.49	-13.66	-15.14	-16.28	-17.22	-22.20
Birmingham, AL	-	x	-	100	0.00	0.10	0.16	-0.02	0.00	-0.04	-0.46	0.00	0.53	0.64	0.45	0.49	0.47	0.40
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.43	0.66	-0.09	-0.02	-0.19	-1.90	0.00	2.18	2.65	1.86	2.03	1.93	1.66
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.07	0.10	-0.01	0.00	-0.03	-0.29	0.00	0.33	0.40	0.28	0.31	0.29	0.25
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.10	0.15	-0.02	0.00	-0.04	-0.44	0.00	0.50	0.61	0.43	0.47	0.44	0.38
Canton-Massillon, OH	-	x	-	100	0.00	-0.31	-0.34	-0.47	-0.51	-0.58	-1.21	0.00	-0.68	-0.72	-0.87	-0.93	-1.00	-1.34
Charleston, WV	-	x	-	100	0.00	0.02	0.04	-0.01	0.00	-0.01	-0.11	0.00	0.13	0.15	0.11	0.12	0.11	0.10
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.26	0.40	-0.05	-0.01	-0.11	-1.16	0.00	1.34	1.62	1.14	1.24	1.18	1.02
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.05	0.08	-0.01	0.00	-0.02	-0.22	0.00	0.26	0.31	0.22	0.24	0.23	0.20
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-3.03	-3.11	-5.29	-5.71	-6.63	-15.52	0.00	-5.21	-5.23	-7.69	-8.22	-9.08	-13.17
Chico, CA	x	-	100	-	0.00	0.02	0.03	0.00	0.00	-0.01	-0.09	0.00	0.10	0.12	0.09	0.10	0.09	0.08
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.20	0.30	-0.04	-0.01	-0.09	-0.88	0.00	1.01	1.22	0.86	0.94	0.89	0.76
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.01	0.02	0.00	0.00	-0.01	-0.06	0.00	0.07	0.09	0.06	0.07	0.06	0.06
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.23	0.36	-0.05	-0.01	-0.10	-1.03	0.00	1.19	1.45	1.01	1.11	1.05	0.90
Columbus, OH	x	x	100	100	0.00	0.20	0.31	-0.04	-0.01	-0.09	-0.90	0.00	1.03	1.26	0.88	0.96	0.91	0.79
Dallas-Fort Worth, TX	x	-	100	-	0.00	1.01	1.55	-0.21	-0.04	-0.44	-4.46	0.00	5.13	6.23	4.38	4.77	4.53	3.90
Dayton-Springfield, OH	-	x	-	100	0.00	0.07	0.11	-0.01	0.00	-0.03	-0.32	0.00	0.36	0.44	0.31	0.34	0.32	0.28
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.03	0.13	-0.67	-0.67	-0.90	-3.19	0.00	1.01	1.35	0.49	0.55	0.37	-0.30
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.01	0.17	-0.72	-0.71	-0.97	-3.50	0.00	1.19	1.59	0.62	0.70	0.51	-0.22
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.01
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.03	0.05	-0.01	0.00	-0.01	-0.15	0.00	0.17	0.21	0.15	0.16	0.15	0.13
Greater Connecticut, CT	x	-	100	-	0.00	0.18	0.27	-0.04	-0.01	-0.08	-0.79	0.00	0.90	1.10	0.77	0.84	0.80	0.69
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.02	0.02	0.01	0.01	0.01	0.01
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.08	0.12	-0.02	0.00	-0.04	-0.36	0.00	0.41	0.50	0.35	0.38	0.36	0.31

Table B2-48
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.07	0.11	-0.01	0.00	-0.03	-0.31	0.00	0.35	0.43	0.30	0.33	0.31	0.27
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.02	0.03	0.00	0.00	-0.01	-0.09	0.00	0.10	0.13	0.09	0.10	0.09	0.08
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-10.18	-11.27	-14.62	-16.06	-18.03	-36.68	0.00	-22.94	-24.77	-28.75	-30.89	-32.93	-43.45
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-1.00	-1.11	-1.41	-1.55	-1.73	-3.45	0.00	-2.30	-2.50	-2.85	-3.06	-3.25	-4.26
Imperial Co., CA	x	-	100	-	0.00	0.03	0.05	-0.01	0.00	-0.01	-0.15	0.00	0.17	0.21	0.15	0.16	0.15	0.13
Indianapolis, IN	-	x	-	100	0.00	0.19	0.29	-0.04	-0.01	-0.08	-0.84	0.00	0.96	1.17	0.82	0.90	0.85	0.73
Jamestown, NY	x	-	100	-	0.00	0.01	0.02	0.00	0.00	-0.01	-0.06	0.00	0.07	0.08	0.06	0.06	0.06	0.05
Jefferson Co., NY	x	-	100	-	0.00	0.02	0.02	0.00	0.00	-0.01	-0.07	0.00	0.08	0.10	0.07	0.08	0.07	0.06
Johnstown, PA	-	x	-	100	0.00	0.01	0.01	0.00	0.00	0.00	-0.04	0.00	0.05	0.06	0.04	0.05	0.04	0.04
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.02	0.03	0.00	0.00	-0.01	-0.08	0.00	0.09	0.11	0.08	0.08	0.08	0.07
Knoxville, TN	x	x	100	100	0.00	0.12	0.18	-0.02	0.00	-0.05	-0.52	0.00	0.59	0.72	0.51	0.55	0.53	0.45
Lancaster, PA	-	x	-	100	0.00	0.04	0.06	-0.01	0.00	-0.02	-0.18	0.00	0.21	0.26	0.18	0.20	0.19	0.16
Las Vegas, NV	x	-	100	-	0.00	0.25	0.38	-0.05	-0.01	-0.11	-1.09	0.00	1.25	1.52	1.07	1.16	1.10	0.95
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-3.96	-3.75	-8.18	-8.70	-10.36	-26.44	0.00	-4.66	-3.99	-8.91	-9.47	-10.93	-17.54
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.10	0.15	-0.02	0.00	-0.04	-0.42	0.00	0.49	0.59	0.42	0.45	0.43	0.37
Louisville, KY-IN	-	x	-	100	0.00	0.10	0.15	-0.02	0.00	-0.04	-0.44	0.00	0.51	0.62	0.44	0.48	0.45	0.39
Macon, GA	-	x	-	100	0.00	0.02	0.03	0.00	0.00	-0.01	-0.08	0.00	0.10	0.12	0.08	0.09	0.09	0.07
Manitowoc Co., WI	x	-		-	0.00	0.01	0.01	0.00	0.00	0.00	-0.04	0.00	0.05	0.06	0.04	0.04	0.04	0.04
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.02	0.00	0.00	-0.01	-0.07	0.00	0.08	0.10	0.07	0.07	0.07	0.06
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.07	0.10	-0.01	0.00	-0.03	-0.29	0.00	0.33	0.41	0.29	0.31	0.30	0.25
Memphis, TN-AR	x	-	100	-	0.00	-0.75	-0.81	-1.15	-1.26	-1.43	-3.06	0.00	-1.57	-1.66	-2.05	-2.20	-2.37	-3.22
Milwaukee-Racine, WI	x	-	100	-	0.00	0.16	0.25	-0.03	-0.01	-0.07	-0.72	0.00	0.83	1.01	0.71	0.78	0.74	0.63
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.02	0.00	0.00	0.00	-0.05	0.00	0.06	0.07	0.05	0.05	0.05	0.04
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.13	0.40	-2.28	-2.26	-3.04	-10.70	0.00	3.31	4.45	1.56	1.77	1.18	-1.08
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.01	0.02	0.00	0.00	-0.01	-0.06	0.00	0.07	0.08	0.06	0.06	0.06	0.05
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-4.81	-5.14	-7.61	-8.28	-9.46	-20.76	0.00	-9.63	-10.10	-12.93	-13.86	-15.02	-20.70

Table B2-48
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acetaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.63	0.96	-0.13	-0.02	-0.27	-2.78	0.00	3.19	3.88	2.73	2.97	2.82	2.43
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.16	0.24	-0.03	-0.01	-0.07	-0.70	0.00	0.81	0.99	0.69	0.75	0.72	0.62
Poughkeepsie, NY	x	x	100	100	0.00	0.14	0.22	-0.03	0.00	-0.06	-0.62	0.00	0.71	0.87	0.61	0.66	0.63	0.54
Providence (All RI), RI	x	-	100	-	0.00	0.08	0.13	-0.02	0.00	-0.04	-0.37	0.00	0.43	0.52	0.37	0.40	0.38	0.33
Reading, PA	-	x	-	100	0.00	0.04	0.06	-0.01	0.00	-0.02	-0.18	0.00	0.21	0.26	0.18	0.20	0.19	0.16
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.17	0.26	-0.03	-0.01	-0.07	-0.74	0.00	0.85	1.04	0.73	0.79	0.75	0.65
Rochester, NY	x	-	100	-	0.00	0.12	0.19	-0.02	0.00	-0.05	-0.54	0.00	0.62	0.76	0.53	0.58	0.55	0.47
Rome, GA	-	x	-	100	0.00	0.01	0.02	0.00	0.00	0.00	-0.05	0.00	0.05	0.06	0.04	0.05	0.05	0.04
Sacramento Metro, CA	x	-	50	-	0.00	0.28	0.43	-0.06	-0.01	-0.12	-1.24	0.00	1.42	1.73	1.21	1.32	1.26	1.08
San Diego, CA	x	-	100	-	0.00	0.27	0.42	-0.06	-0.01	-0.12	-1.21	0.00	1.39	1.69	1.19	1.30	1.23	1.06
San Francisco Bay Area, CA	x	-	100	-	0.00	-2.46	-2.53	-4.30	-4.64	-5.39	-12.60	0.00	-4.24	-4.26	-6.26	-6.69	-7.39	-10.71
San Joaquin Valley, CA	x	x	50	100	0.00	0.13	0.41	-0.83	-0.80	-1.14	-4.51	0.00	2.05	2.64	1.31	1.45	1.20	0.30
Sheboygan, WI	x	-	100	-	0.00	0.01	0.02	0.00	0.00	-0.01	-0.05	0.00	0.06	0.07	0.05	0.05	0.05	0.04
Springfield (Western MA), MA	x	-	100	-	0.00	0.09	0.14	-0.02	0.00	-0.04	-0.40	0.00	0.46	0.56	0.39	0.43	0.41	0.35
St. Louis, MO-IL	x	x	100	100	0.00	-1.14	-1.17	-1.99	-2.14	-2.49	-5.83	0.00	-1.95	-1.96	-2.88	-3.08	-3.40	-4.94
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.09	-0.09	-0.13	-0.14	-0.16	-0.33	0.00	-0.18	-0.20	-0.24	-0.25	-0.27	-0.36
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.05	0.08	-0.03	-0.02	-0.05	-0.31	0.00	0.27	0.33	0.22	0.24	0.23	0.18
Washington, DC-MD-VA	x	x	100	100	0.00	0.58	0.89	-0.12	-0.02	-0.25	-2.57	0.00	2.95	3.59	2.52	2.75	2.61	2.25
Wheeling, WV-OH	-	x	-	100	0.00	0.01	0.02	0.00	0.00	-0.01	-0.06	0.00	0.07	0.09	0.06	0.07	0.06	0.05
York, PA	-	x	-	100	0.00	0.05	0.07	-0.01	0.00	-0.02	-0.21	0.00	0.24	0.30	0.21	0.23	0.22	0.19

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-49
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.02	0.02	0.04	0.05	0.06	0.21	0.00	0.02	0.02	0.04	0.05	0.06	0.21
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Atlanta, GA	x	x	100	100	0.00	0.10	0.12	0.21	0.25	0.34	1.12	0.00	0.10	0.12	0.21	0.25	0.34	1.12
Baltimore, MD	x	x	100	100	0.00	0.04	0.05	0.09	0.10	0.14	0.47	0.00	0.04	0.05	0.09	0.10	0.14	0.47
Baton Rouge, LA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.11	0.00	0.01	0.01	0.02	0.02	0.03	0.11
Beaumont/Port Arthur, TX	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.07	0.00	0.01	0.01	0.01	0.01	0.02	0.07
Birmingham, AL	-	x	-	100	0.00	0.02	0.02	0.03	0.04	0.05	0.17	0.00	0.02	0.02	0.03	0.04	0.05	0.17
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.07	0.08	0.14	0.17	0.23	0.76	0.00	0.07	0.08	0.14	0.17	0.23	0.76
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.01	0.01	0.02	0.02	0.03	0.10
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.02	0.02	0.03	0.04	0.05	0.18	0.00	0.02	0.02	0.03	0.04	0.05	0.18
Canton-Massillon, OH	-	x	-	100	0.00	0.00	0.01	0.01	0.01	0.02	0.05	0.00	0.00	0.01	0.01	0.01	0.02	0.05
Charleston, WV	-	x	-	100	0.00	0.00	0.01	0.01	0.01	0.01	0.05	0.00	0.00	0.01	0.01	0.01	0.01	0.05
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.03	0.03	0.05	0.06	0.09	0.29	0.00	0.03	0.03	0.05	0.06	0.09	0.29
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.09	0.00	0.01	0.01	0.02	0.02	0.03	0.09
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	0.10	0.12	0.21	0.25	0.35	1.15	0.00	0.10	0.12	0.21	0.25	0.35	1.15
Chico, CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.03	0.03	0.06	0.07	0.09	0.30	0.00	0.03	0.03	0.06	0.07	0.09	0.30
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.04	0.05	0.08	0.10	0.13	0.44	0.00	0.04	0.05	0.08	0.10	0.13	0.44
Columbus, OH	x	x	100	100	0.00	0.02	0.03	0.05	0.06	0.08	0.28	0.00	0.02	0.03	0.05	0.06	0.08	0.28
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.10	0.12	0.21	0.25	0.34	1.14	0.00	0.10	0.12	0.21	0.25	0.34	1.14
Dayton-Springfield, OH	-	x	-	100	0.00	0.01	0.01	0.02	0.03	0.04	0.13	0.00	0.01	0.01	0.02	0.03	0.04	0.13
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.05	0.06	0.10	0.12	0.16	0.53	0.00	0.05	0.06	0.10	0.12	0.16	0.53
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.07	0.09	0.15	0.17	0.24	0.79	0.00	0.07	0.09	0.15	0.17	0.24	0.79
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	0.01	0.01	0.01	0.02	0.06	0.00	0.00	0.01	0.01	0.01	0.02	0.06
Greater Connecticut, CT	x	-	100	-	0.00	0.03	0.03	0.05	0.06	0.09	0.29	0.00	0.03	0.03	0.05	0.06	0.09	0.29
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.01	0.01	0.02	0.03	0.04	0.13	0.00	0.01	0.01	0.02	0.03	0.04	0.13

Table B2-49
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.01	0.01	0.02	0.03	0.04	0.12	0.00	0.01	0.01	0.02	0.03	0.04	0.12
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	0.07	0.09	0.15	0.18	0.25	0.84	0.00	0.07	0.09	0.15	0.18	0.25	0.84
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.01	0.02	0.02	0.07
Imperial Co., CA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.04	0.00	0.00	0.00	0.01	0.01	0.01	0.04
Indianapolis, IN	-	x	-	100	0.00	0.02	0.03	0.05	0.06	0.08	0.26	0.00	0.02	0.03	0.05	0.06	0.08	0.26
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Knoxville, TN	x	x	100	100	0.00	0.02	0.02	0.03	0.04	0.05	0.18	0.00	0.02	0.02	0.03	0.04	0.05	0.18
Lancaster, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.01	0.02	0.02	0.07
Las Vegas, NV	x	-	100	-	0.00	0.02	0.02	0.04	0.05	0.07	0.23	0.00	0.02	0.02	0.04	0.05	0.07	0.23
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	0.21	0.26	0.44	0.53	0.73	2.42	0.00	0.21	0.26	0.44	0.53	0.73	2.42
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.01	0.01	0.02	0.03	0.04	0.12	0.00	0.01	0.01	0.02	0.03	0.04	0.12
Louisville, KY-IN	-	x	-	100	0.00	0.02	0.02	0.03	0.04	0.06	0.18	0.00	0.02	0.02	0.03	0.04	0.06	0.18
Macon, GA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.02	0.07	0.00	0.01	0.01	0.01	0.01	0.02	0.07
Memphis, TN-AR	x	-	100	-	0.00	0.01	0.02	0.03	0.04	0.05	0.16	0.00	0.01	0.02	0.03	0.04	0.05	0.16
Milwaukee-Racine, WI	x	-	100	-	0.00	0.03	0.03	0.05	0.06	0.09	0.29	0.00	0.03	0.03	0.05	0.06	0.09	0.29
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.21	0.26	0.43	0.52	0.71	2.37	0.00	0.21	0.26	0.43	0.52	0.71	2.37
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.03
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	0.10	0.12	0.21	0.25	0.34	1.13	0.00	0.10	0.12	0.21	0.25	0.34	1.13

Table B2-49
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.06	0.07	0.12	0.14	0.19	0.64	0.00	0.06	0.07	0.12	0.14	0.19	0.64
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.03	0.03	0.06	0.07	0.10	0.32	0.00	0.03	0.03	0.06	0.07	0.10	0.32
Poughkeepsie, NY	x	x	100	100	0.00	0.02	0.02	0.04	0.05	0.06	0.21	0.00	0.02	0.02	0.04	0.05	0.06	0.21
Providence (All RI), RI	x	-	100	-	0.00	0.01	0.02	0.03	0.03	0.05	0.15	0.00	0.01	0.02	0.03	0.03	0.05	0.15
Reading, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.01	0.01	0.02	0.06
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.01	0.01	0.02	0.03	0.04	0.12	0.00	0.01	0.01	0.02	0.03	0.04	0.12
Rochester, NY	x	-	100	-	0.00	0.02	0.02	0.04	0.05	0.06	0.21	0.00	0.02	0.02	0.04	0.05	0.06	0.21
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Sacramento Metro, CA	x	-	50	-	0.00	0.03	0.04	0.07	0.08	0.11	0.35	0.00	0.03	0.04	0.07	0.08	0.11	0.35
San Diego, CA	x	-	100	-	0.00	0.04	0.05	0.09	0.11	0.15	0.50	0.00	0.04	0.05	0.09	0.11	0.15	0.50
San Francisco Bay Area, CA	x	-	100	-	0.00	0.10	0.12	0.20	0.24	0.33	1.09	0.00	0.10	0.12	0.20	0.24	0.33	1.09
San Joaquin Valley, CA	x	x	50	100	0.00	0.06	0.08	0.13	0.16	0.22	0.72	0.00	0.06	0.08	0.13	0.16	0.22	0.72
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Springfield (Western MA), MA	x	-	100	-	0.00	0.01	0.02	0.03	0.03	0.05	0.15	0.00	0.01	0.02	0.03	0.03	0.05	0.15
St. Louis, MO-IL	x	x	100	100	0.00	0.04	0.05	0.09	0.11	0.15	0.50	0.00	0.04	0.05	0.09	0.11	0.15	0.50
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.01	0.01	0.02	0.02	0.03	0.10
Washington, DC-MD-VA	x	x	100	100	0.00	0.07	0.09	0.15	0.18	0.24	0.80	0.00	0.07	0.09	0.15	0.18	0.24	0.80
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
York, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.01	0.01	0.02	0.06

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-50
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.07	0.07	0.11	0.14	0.17	0.61	0.00	0.08	0.08	0.13	0.16	0.20	0.63
Allegan Co., MI	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.07	0.00	0.01	0.01	0.01	0.02	0.02	0.07
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.01	0.02	0.02	0.07
Atlanta, GA	x	x	100	100	0.00	0.39	0.39	0.64	0.79	1.01	3.51	0.00	0.45	0.46	0.73	0.90	1.15	3.63
Baltimore, MD	x	x	100	100	0.00	0.15	0.15	0.24	0.30	0.38	1.33	0.00	0.17	0.18	0.28	0.34	0.44	1.38
Baton Rouge, LA	x	-	100	-	0.00	0.03	0.03	0.06	0.07	0.09	0.32	0.00	0.04	0.04	0.07	0.08	0.10	0.33
Beaumont/Port Arthur, TX	x	-	100	-	0.00	0.02	0.02	0.03	0.04	0.05	0.19	0.00	0.02	0.02	0.04	0.05	0.06	0.19
Birmingham, AL	-	x	-	100	0.00	0.05	0.05	0.09	0.11	0.14	0.48	0.00	0.06	0.06	0.10	0.12	0.16	0.49
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.23	0.23	0.38	0.47	0.60	2.09	0.00	0.27	0.27	0.44	0.54	0.69	2.16
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.03	0.03	0.05	0.07	0.08	0.29	0.00	0.04	0.04	0.06	0.08	0.10	0.30
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.06	0.06	0.09	0.11	0.14	0.50	0.00	0.06	0.07	0.10	0.13	0.16	0.52
Canton-Massillon, OH	-	x	-	100	0.00	0.02	0.02	0.03	0.03	0.04	0.14	0.00	0.02	0.02	0.03	0.04	0.05	0.15
Charleston, WV	-	x	-	100	0.00	0.01	0.01	0.02	0.03	0.04	0.13	0.00	0.02	0.02	0.03	0.03	0.04	0.14
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.10	0.10	0.17	0.20	0.26	0.91	0.00	0.12	0.12	0.19	0.23	0.30	0.94
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.03	0.03	0.04	0.05	0.07	0.24	0.00	0.03	0.03	0.05	0.06	0.08	0.25
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	0.36	0.37	0.60	0.74	0.95	3.29	0.00	0.42	0.43	0.69	0.85	1.08	3.40
Chico, CA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.09	0.00	0.01	0.01	0.02	0.02	0.03	0.09
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.09	0.09	0.15	0.19	0.25	0.85	0.00	0.11	0.11	0.18	0.22	0.28	0.88
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.02	0.08	0.00	0.01	0.01	0.02	0.02	0.03	0.08
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.13	0.13	0.22	0.27	0.34	1.19	0.00	0.15	0.16	0.25	0.31	0.39	1.23
Columbus, OH	x	x	100	100	0.00	0.09	0.09	0.15	0.18	0.24	0.82	0.00	0.11	0.11	0.17	0.21	0.27	0.85
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.38	0.39	0.63	0.78	1.00	3.48	0.00	0.45	0.46	0.73	0.90	1.14	3.60
Dayton-Springfield, OH	-	x	-	100	0.00	0.04	0.04	0.07	0.08	0.10	0.36	0.00	0.05	0.05	0.08	0.09	0.12	0.37
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.17	0.17	0.28	0.35	0.45	1.56	0.00	0.20	0.21	0.33	0.40	0.51	1.61
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.24	0.24	0.40	0.50	0.64	2.20	0.00	0.28	0.29	0.46	0.57	0.72	2.27
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.02	0.02	0.03	0.04	0.05	0.16	0.00	0.02	0.02	0.03	0.04	0.05	0.16
Greater Connecticut, CT	x	-	100	-	0.00	0.09	0.09	0.15	0.18	0.24	0.82	0.00	0.11	0.11	0.17	0.21	0.27	0.84
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.04	0.04	0.07	0.08	0.11	0.37	0.00	0.05	0.05	0.08	0.10	0.12	0.38

Table B2-50
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.04	0.04	0.06	0.07	0.10	0.33	0.00	0.04	0.04	0.07	0.08	0.11	0.34
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.09	0.00	0.01	0.01	0.02	0.02	0.03	0.09
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	0.27	0.27	0.44	0.55	0.70	2.42	0.00	0.31	0.32	0.51	0.62	0.80	2.50
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	0.02	0.02	0.04	0.04	0.06	0.20	0.00	0.03	0.03	0.04	0.05	0.06	0.20
Imperial Co., CA	x	-	100	-	0.00	0.01	0.01	0.02	0.03	0.03	0.11	0.00	0.01	0.01	0.02	0.03	0.04	0.12
Indianapolis, IN	-	x	-	100	0.00	0.08	0.08	0.14	0.17	0.22	0.76	0.00	0.10	0.10	0.16	0.20	0.25	0.79
Jamestown, NY	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.07	0.00	0.01	0.01	0.01	0.02	0.02	0.07
Jefferson Co., NY	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.07	0.00	0.01	0.01	0.01	0.02	0.02	0.07
Johnstown, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.01	0.02	0.02	0.06
Knoxville, TN	x	x	100	100	0.00	0.06	0.06	0.09	0.12	0.15	0.51	0.00	0.07	0.07	0.11	0.13	0.17	0.53
Lancaster, PA	-	x	-	100	0.00	0.02	0.02	0.04	0.04	0.06	0.20	0.00	0.03	0.03	0.04	0.05	0.06	0.20
Las Vegas, NV	x	-	100	-	0.00	0.08	0.08	0.14	0.17	0.22	0.75	0.00	0.10	0.10	0.16	0.19	0.25	0.77
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	0.78	0.79	1.29	1.60	2.05	7.10	0.00	0.92	0.93	1.48	1.83	2.33	7.34
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.04	0.04	0.07	0.08	0.10	0.36	0.00	0.05	0.05	0.07	0.09	0.12	0.37
Louisville, KY-IN	-	x	-	100	0.00	0.06	0.06	0.09	0.11	0.14	0.50	0.00	0.06	0.07	0.10	0.13	0.17	0.52
Macon, GA	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.09	0.00	0.01	0.01	0.02	0.02	0.03	0.10
Manitowoc Co., WI	x	-		-	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.02	0.02	0.04	0.05	0.06	0.21	0.00	0.03	0.03	0.04	0.05	0.07	0.22
Memphis, TN-AR	x	-	100	-	0.00	0.05	0.05	0.08	0.10	0.13	0.45	0.00	0.06	0.06	0.09	0.12	0.15	0.46
Milwaukee-Racine, WI	x	-	100	-	0.00	0.09	0.09	0.14	0.18	0.23	0.80	0.00	0.10	0.10	0.17	0.20	0.26	0.82
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.72	0.73	1.19	1.48	1.89	6.56	0.00	0.85	0.86	1.37	1.69	2.16	6.78
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.01	0.02	0.02	0.07
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	0.36	0.36	0.59	0.73	0.93	3.23	0.00	0.42	0.42	0.67	0.83	1.06	3.33

Table B2-50
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.22	0.23	0.37	0.46	0.59	2.04	0.00	0.26	0.27	0.42	0.52	0.67	2.10
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.09	0.10	0.16	0.19	0.25	0.86	0.00	0.11	0.11	0.18	0.22	0.28	0.89
Poughkeepsie, NY	x	x	100	100	0.00	0.07	0.07	0.11	0.14	0.17	0.60	0.00	0.08	0.08	0.13	0.15	0.20	0.62
Providence (All RI), RI	x	-	100	-	0.00	0.05	0.05	0.08	0.09	0.12	0.42	0.00	0.05	0.05	0.09	0.11	0.14	0.43
Reading, PA	-	x	-	100	0.00	0.02	0.02	0.03	0.04	0.05	0.18	0.00	0.02	0.02	0.04	0.05	0.06	0.18
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.05	0.05	0.08	0.09	0.12	0.42	0.00	0.05	0.06	0.09	0.11	0.14	0.43
Rochester, NY	x	-	100	-	0.00	0.06	0.07	0.11	0.13	0.17	0.59	0.00	0.08	0.08	0.12	0.15	0.19	0.61
Rome, GA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Sacramento Metro, CA	x	-	50	-	0.00	0.12	0.12	0.19	0.24	0.31	1.06	0.00	0.14	0.14	0.22	0.27	0.35	1.09
San Diego, CA	x	-	100	-	0.00	0.15	0.15	0.25	0.31	0.39	1.36	0.00	0.18	0.18	0.28	0.35	0.45	1.41
San Francisco Bay Area, CA	x	-	100	-	0.00	0.33	0.34	0.55	0.68	0.87	3.03	0.00	0.39	0.40	0.63	0.78	1.00	3.13
San Joaquin Valley, CA	x	x	50	100	0.00	0.25	0.25	0.41	0.50	0.65	2.24	0.00	0.29	0.29	0.47	0.58	0.74	2.31
Sheboygan, WI	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.06
Springfield (Western MA), MA	x	-	100	-	0.00	0.05	0.05	0.08	0.10	0.12	0.42	0.00	0.05	0.06	0.09	0.11	0.14	0.44
St. Louis, MO-IL	x	x	100	100	0.00	0.15	0.15	0.25	0.31	0.40	1.39	0.00	0.18	0.18	0.29	0.36	0.46	1.44
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.03	0.03	0.05	0.07	0.08	0.29	0.00	0.04	0.04	0.06	0.07	0.09	0.30
Washington, DC-MD-VA	x	x	100	100	0.00	0.25	0.26	0.42	0.52	0.67	2.31	0.00	0.30	0.30	0.48	0.59	0.76	2.39
Wheeling, WV-OH	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.02	0.02	0.02	0.08
York, PA	-	x	-	100	0.00	0.02	0.02	0.03	0.04	0.06	0.19	0.00	0.02	0.03	0.04	0.05	0.06	0.20

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-51
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.11	0.11	0.18	0.22	0.27	0.94	0.00	0.14	0.14	0.23	0.27	0.34	1.00
Allegan Co., MI	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.02	0.02	0.02	0.03	0.04	0.11
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.11	0.00	0.02	0.02	0.03	0.03	0.04	0.11
Atlanta, GA	x	x	100	100	0.00	0.70	0.67	1.13	1.38	1.73	5.98	0.00	0.92	0.91	1.44	1.75	2.20	6.38
Baltimore, MD	x	x	100	100	0.00	0.24	0.23	0.39	0.47	0.59	2.05	0.00	0.31	0.31	0.49	0.60	0.75	2.19
Baton Rouge, LA	x	-	100	-	0.00	0.06	0.06	0.09	0.11	0.14	0.49	0.00	0.08	0.08	0.12	0.14	0.18	0.53
Beaumont/Port Arthur, TX	x	-	100	-	0.00	0.03	0.03	0.05	0.07	0.08	0.28	0.00	0.04	0.04	0.07	0.08	0.10	0.30
Birmingham, AL	-	x	-	100	0.00	0.08	0.08	0.14	0.17	0.21	0.72	0.00	0.11	0.11	0.17	0.21	0.26	0.77
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.36	0.35	0.58	0.71	0.90	3.10	0.00	0.47	0.47	0.75	0.91	1.14	3.31
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.05	0.05	0.08	0.10	0.13	0.45	0.00	0.07	0.07	0.11	0.13	0.16	0.48
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.09	0.08	0.14	0.17	0.21	0.73	0.00	0.11	0.11	0.18	0.22	0.27	0.78
Canton-Massillon, OH	-	x	-	100	0.00	0.02	0.02	0.04	0.05	0.06	0.21	0.00	0.03	0.03	0.05	0.06	0.08	0.23
Charleston, WV	-	x	-	100	0.00	0.02	0.02	0.04	0.04	0.05	0.19	0.00	0.03	0.03	0.05	0.06	0.07	0.20
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.18	0.17	0.28	0.35	0.44	1.51	0.00	0.23	0.23	0.36	0.44	0.55	1.61
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.04	0.04	0.07	0.08	0.10	0.36	0.00	0.06	0.06	0.09	0.11	0.13	0.39
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	0.59	0.57	0.96	1.17	1.48	5.09	0.00	0.78	0.78	1.22	1.49	1.87	5.43
Chico, CA	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.04	0.14	0.00	0.02	0.02	0.03	0.04	0.05	0.15
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.15	0.15	0.25	0.30	0.38	1.30	0.00	0.20	0.20	0.31	0.38	0.48	1.39
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.01	0.01	0.02	0.03	0.03	0.11	0.00	0.02	0.02	0.03	0.03	0.04	0.12
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.20	0.20	0.33	0.40	0.50	1.74	0.00	0.27	0.27	0.42	0.51	0.64	1.86
Columbus, OH	x	x	100	100	0.00	0.15	0.15	0.24	0.30	0.37	1.29	0.00	0.20	0.20	0.31	0.38	0.47	1.38
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.67	0.65	1.08	1.33	1.67	5.76	0.00	0.88	0.88	1.39	1.69	2.12	6.15
Dayton-Springfield, OH	-	x	-	100	0.00	0.06	0.06	0.10	0.12	0.15	0.53	0.00	0.08	0.08	0.13	0.16	0.19	0.57
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.29	0.28	0.47	0.58	0.72	2.50	0.00	0.38	0.38	0.60	0.73	0.92	2.67
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.38	0.37	0.62	0.76	0.95	3.28	0.00	0.50	0.50	0.79	0.96	1.21	3.50
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.02
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.03	0.03	0.05	0.06	0.07	0.24	0.00	0.04	0.04	0.06	0.07	0.09	0.26
Greater Connecticut, CT	x	-	100	-	0.00	0.14	0.14	0.23	0.28	0.36	1.24	0.00	0.19	0.19	0.30	0.36	0.45	1.32
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.07	0.06	0.11	0.13	0.16	0.56	0.00	0.09	0.09	0.14	0.16	0.21	0.60

Table B2-51
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.06	0.06	0.09	0.11	0.14	0.49	0.00	0.08	0.08	0.12	0.15	0.18	0.53
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.02	0.02	0.03	0.03	0.04	0.14	0.00	0.02	0.02	0.03	0.04	0.05	0.15
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	0.44	0.43	0.71	0.87	1.10	3.79	0.00	0.58	0.58	0.91	1.11	1.39	4.04
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	0.03	0.03	0.05	0.07	0.08	0.29	0.00	0.04	0.04	0.07	0.09	0.11	0.31
Imperial Co., CA	x	-	100	-	0.00	0.02	0.02	0.04	0.04	0.06	0.19	0.00	0.03	0.03	0.05	0.06	0.07	0.20
Indianapolis, IN	-	x	-	100	0.00	0.14	0.14	0.23	0.28	0.35	1.20	0.00	0.18	0.18	0.29	0.35	0.44	1.28
Jamestown, NY	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.01	0.01	0.02	0.03	0.04	0.10
Jefferson Co., NY	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.02	0.02	0.03	0.03	0.04	0.11
Johnstown, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.08	0.00	0.01	0.01	0.02	0.02	0.03	0.08
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.02	0.02	0.02	0.03	0.04	0.11
Knoxville, TN	x	x	100	100	0.00	0.09	0.09	0.15	0.18	0.23	0.79	0.00	0.12	0.12	0.19	0.23	0.29	0.84
Lancaster, PA	-	x	-	100	0.00	0.03	0.03	0.06	0.07	0.09	0.29	0.00	0.04	0.04	0.07	0.09	0.11	0.31
Las Vegas, NV	x	-	100	-	0.00	0.15	0.15	0.25	0.30	0.38	1.30	0.00	0.20	0.20	0.31	0.38	0.48	1.39
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	1.31	1.27	2.13	2.60	3.28	11.30	0.00	1.73	1.72	2.72	3.31	4.15	12.06
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.07	0.07	0.11	0.13	0.17	0.58	0.00	0.09	0.09	0.14	0.17	0.21	0.62
Louisville, KY-IN	-	x	-	100	0.00	0.09	0.08	0.14	0.17	0.21	0.74	0.00	0.11	0.11	0.18	0.22	0.27	0.79
Macon, GA	-	x	-	100	0.00	0.02	0.02	0.03	0.03	0.04	0.14	0.00	0.02	0.02	0.03	0.04	0.05	0.15
Manitowoc Co., WI	x	-		-	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.02	0.02	0.03	0.07
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.09	0.00	0.01	0.01	0.02	0.03	0.03	0.09
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.04	0.04	0.07	0.08	0.10	0.36	0.00	0.06	0.05	0.09	0.11	0.13	0.38
Memphis, TN-AR	x	-	100	-	0.00	0.08	0.07	0.12	0.15	0.19	0.66	0.00	0.10	0.10	0.16	0.19	0.24	0.71
Milwaukee-Racine, WI	x	-	100	-	0.00	0.14	0.13	0.22	0.27	0.34	1.18	0.00	0.18	0.18	0.28	0.35	0.43	1.26
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.02	0.02	0.03	0.08
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	1.14	1.10	1.84	2.25	2.84	9.78	0.00	1.50	1.49	2.35	2.87	3.59	10.43
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.02	0.02	0.02	0.03	0.04	0.11
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	0.58	0.56	0.93	1.14	1.44	4.96	0.00	0.76	0.76	1.19	1.45	1.82	5.29

Table B2-51
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.40	0.39	0.65	0.80	1.01	3.47	0.00	0.53	0.53	0.83	1.02	1.27	3.70
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.14	0.14	0.23	0.28	0.36	1.23	0.00	0.19	0.19	0.30	0.36	0.45	1.32
Poughkeepsie, NY	x	x	100	100	0.00	0.11	0.11	0.18	0.22	0.27	0.93	0.00	0.14	0.14	0.22	0.27	0.34	1.00
Providence (All RI), RI	x	-	100	-	0.00	0.07	0.07	0.12	0.14	0.18	0.62	0.00	0.09	0.09	0.15	0.18	0.23	0.66
Reading, PA	-	x	-	100	0.00	0.03	0.03	0.05	0.06	0.08	0.28	0.00	0.04	0.04	0.07	0.08	0.10	0.29
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.09	0.09	0.15	0.18	0.23	0.78	0.00	0.12	0.12	0.19	0.23	0.29	0.83
Rochester, NY	x	-	100	-	0.00	0.10	0.10	0.16	0.20	0.25	0.88	0.00	0.13	0.13	0.21	0.26	0.32	0.94
Rome, GA	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.08	0.00	0.01	0.01	0.02	0.02	0.03	0.08
Sacramento Metro, CA	x	-	50	-	0.00	0.20	0.19	0.32	0.39	0.49	1.71	0.00	0.26	0.26	0.41	0.50	0.63	1.82
San Diego, CA	x	-	100	-	0.00	0.23	0.23	0.38	0.46	0.58	2.01	0.00	0.31	0.31	0.48	0.59	0.74	2.15
San Francisco Bay Area, CA	x	-	100	-	0.00	0.53	0.51	0.85	1.05	1.32	4.54	0.00	0.69	0.69	1.09	1.33	1.67	4.84
San Joaquin Valley, CA	x	x	50	100	0.00	0.43	0.42	0.70	0.86	1.08	3.73	0.00	0.57	0.57	0.90	1.09	1.37	3.98
Sheboygan, WI	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.02	0.08	0.00	0.01	0.01	0.02	0.02	0.03	0.09
Springfield (Western MA), MA	x	-	100	-	0.00	0.07	0.07	0.12	0.15	0.19	0.64	0.00	0.10	0.10	0.15	0.19	0.24	0.68
St. Louis, MO-IL	x	x	100	100	0.00	0.24	0.23	0.39	0.48	0.61	2.09	0.00	0.32	0.32	0.50	0.61	0.77	2.23
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.02	0.02	0.02	0.07
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.05	0.05	0.08	0.10	0.13	0.43	0.00	0.07	0.07	0.10	0.13	0.16	0.46
Washington, DC-MD-VA	x	x	100	100	0.00	0.42	0.41	0.68	0.84	1.05	3.63	0.00	0.56	0.55	0.87	1.07	1.33	3.88
Wheeling, WV-OH	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.11	0.00	0.02	0.02	0.03	0.03	0.04	0.11
York, PA	-	x	-	100	0.00	0.04	0.03	0.06	0.07	0.09	0.31	0.00	0.05	0.05	0.07	0.09	0.11	0.33

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-52
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.15	0.14	0.24	0.29	0.37	1.25	0.00	0.22	0.22	0.34	0.41	0.51	1.38
Allegan Co., MI	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.04	0.14	0.00	0.02	0.02	0.04	0.04	0.06	0.15
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.02	0.03	0.04	0.05	0.16	0.00	0.03	0.03	0.04	0.05	0.07	0.18
Atlanta, GA	x	x	100	100	0.00	1.21	1.15	1.92	2.33	2.92	9.94	0.00	1.77	1.76	2.72	3.27	4.06	10.98
Baltimore, MD	x	x	100	100	0.00	0.33	0.31	0.52	0.63	0.80	2.71	0.00	0.48	0.48	0.74	0.89	1.11	2.99
Baton Rouge, LA	x	-	100	-	0.00	0.08	0.08	0.13	0.16	0.20	0.69	0.00	0.12	0.12	0.19	0.23	0.28	0.76
Beaumont/Port Arthur, TX	x	-	100	-	0.00	0.04	0.04	0.07	0.08	0.10	0.36	0.00	0.06	0.06	0.10	0.12	0.15	0.39
Birmingham, AL	-	x	-	100	0.00	0.11	0.11	0.18	0.22	0.27	0.93	0.00	0.17	0.16	0.25	0.31	0.38	1.03
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.47	0.44	0.74	0.90	1.13	3.84	0.00	0.68	0.68	1.05	1.26	1.57	4.24
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.07	0.07	0.11	0.14	0.17	0.58	0.00	0.10	0.10	0.16	0.19	0.24	0.64
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.11	0.10	0.17	0.21	0.26	0.89	0.00	0.16	0.16	0.24	0.29	0.36	0.98
Canton-Massillon, OH	-	x	-	100	0.00	0.03	0.03	0.05	0.06	0.08	0.26	0.00	0.05	0.05	0.07	0.08	0.10	0.28
Charleston, WV	-	x	-	100	0.00	0.03	0.03	0.04	0.05	0.06	0.22	0.00	0.04	0.04	0.06	0.07	0.09	0.24
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.29	0.27	0.45	0.55	0.69	2.35	0.00	0.42	0.42	0.64	0.77	0.96	2.60
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.06	0.05	0.09	0.11	0.13	0.45	0.00	0.08	0.08	0.12	0.15	0.18	0.50
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	0.86	0.81	1.36	1.64	2.06	7.02	0.00	1.25	1.24	1.92	2.31	2.87	7.75
Chico, CA	x	-	100	-	0.00	0.02	0.02	0.03	0.04	0.05	0.18	0.00	0.03	0.03	0.05	0.06	0.07	0.20
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.22	0.21	0.34	0.42	0.52	1.77	0.00	0.32	0.31	0.48	0.58	0.72	1.96
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.02	0.01	0.02	0.03	0.04	0.13	0.00	0.02	0.02	0.03	0.04	0.05	0.14
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.26	0.24	0.40	0.49	0.62	2.09	0.00	0.37	0.37	0.57	0.69	0.85	2.31
Columbus, OH	x	x	100	100	0.00	0.22	0.21	0.35	0.43	0.54	1.82	0.00	0.32	0.32	0.50	0.60	0.74	2.01
Dallas-Fort Worth, TX	x	-	100	-	0.00	1.10	1.05	1.75	2.11	2.65	9.02	0.00	1.61	1.60	2.47	2.96	3.69	9.97
Dayton-Springfield, OH	-	x	-	100	0.00	0.08	0.07	0.12	0.15	0.19	0.64	0.00	0.11	0.11	0.17	0.21	0.26	0.71
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.44	0.42	0.70	0.85	1.07	3.64	0.00	0.65	0.64	0.99	1.20	1.49	4.02
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.50	0.47	0.79	0.96	1.20	4.09	0.00	0.73	0.72	1.12	1.34	1.67	4.52
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.04	0.04	0.06	0.07	0.09	0.31	0.00	0.05	0.05	0.08	0.10	0.12	0.34
Greater Connecticut, CT	x	-	100	-	0.00	0.19	0.18	0.31	0.37	0.47	1.59	0.00	0.28	0.28	0.43	0.52	0.65	1.76
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.09	0.08	0.14	0.17	0.21	0.73	0.00	0.13	0.13	0.20	0.24	0.30	0.80

Table B2-52
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Acrolein 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.08	0.07	0.12	0.15	0.18	0.62	0.00	0.11	0.11	0.17	0.20	0.25	0.69
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.02	0.02	0.04	0.04	0.05	0.18	0.00	0.03	0.03	0.05	0.06	0.07	0.20
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	0.65	0.62	1.03	1.25	1.57	5.34	0.00	0.95	0.94	1.46	1.75	2.18	5.90
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	0.04	0.04	0.07	0.08	0.10	0.35	0.00	0.06	0.06	0.10	0.12	0.14	0.39
Imperial Co., CA	x	-	100	-	0.00	0.04	0.03	0.06	0.07	0.09	0.30	0.00	0.05	0.05	0.08	0.10	0.12	0.33
Indianapolis, IN	-	x	-	100	0.00	0.21	0.20	0.33	0.40	0.50	1.70	0.00	0.30	0.30	0.46	0.56	0.69	1.88
Jamestown, NY	x	-	100	-	0.00	0.01	0.01	0.02	0.03	0.03	0.12	0.00	0.02	0.02	0.03	0.04	0.05	0.13
Jefferson Co., NY	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.04	0.14	0.00	0.03	0.03	0.04	0.05	0.06	0.16
Johnstown, PA	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.09	0.00	0.02	0.02	0.02	0.03	0.04	0.10
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.02	0.02	0.03	0.04	0.05	0.15	0.00	0.03	0.03	0.04	0.05	0.06	0.17
Knoxville, TN	x	x	100	100	0.00	0.13	0.12	0.20	0.24	0.31	1.05	0.00	0.19	0.18	0.29	0.34	0.43	1.15
Lancaster, PA	-	x	-	100	0.00	0.05	0.04	0.07	0.09	0.11	0.37	0.00	0.07	0.07	0.10	0.12	0.15	0.41
Las Vegas, NV	x	-	100	-	0.00	0.27	0.25	0.43	0.51	0.65	2.20	0.00	0.39	0.39	0.60	0.72	0.90	2.43
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	2.00	1.90	3.17	3.84	4.83	16.41	0.00	2.93	2.90	4.49	5.39	6.70	18.13
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.10	0.10	0.17	0.20	0.25	0.86	0.00	0.15	0.15	0.23	0.28	0.35	0.95
Louisville, KY-IN	-	x	-	100	0.00	0.11	0.10	0.17	0.21	0.26	0.90	0.00	0.16	0.16	0.25	0.30	0.37	0.99
Macon, GA	-	x	-	100	0.00	0.02	0.02	0.03	0.04	0.05	0.17	0.00	0.03	0.03	0.05	0.06	0.07	0.19
Manitowoc Co., WI	x	-		-	0.00	0.01	0.01	0.02	0.02	0.02	0.08	0.00	0.02	0.01	0.02	0.03	0.03	0.09
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.04	0.14	0.00	0.02	0.02	0.04	0.05	0.06	0.15
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.07	0.07	0.11	0.14	0.17	0.59	0.00	0.10	0.10	0.16	0.19	0.24	0.65
Memphis, TN-AR	x	-	100	-	0.00	0.10	0.09	0.16	0.19	0.24	0.81	0.00	0.14	0.14	0.22	0.27	0.33	0.90
Milwaukee-Racine, WI	x	-	100	-	0.00	0.18	0.17	0.28	0.34	0.43	1.47	0.00	0.26	0.26	0.40	0.48	0.60	1.62
Nevada (Western Part), CA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.02	0.02	0.03	0.03	0.04	0.11
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	1.48	1.41	2.35	2.84	3.57	12.14	0.00	2.16	2.15	3.32	3.99	4.96	13.41
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.01	0.01	0.02	0.03	0.03	0.12	0.00	0.02	0.02	0.03	0.04	0.05	0.13
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	0.80	0.76	1.27	1.54	1.93	6.58	0.00	1.17	1.16	1.80	2.16	2.69	7.26

Table B2-52
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Acrolein 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.69	0.65	1.09	1.32	1.65	5.62	0.00	1.00	0.99	1.54	1.85	2.30	6.21
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.17	0.17	0.28	0.33	0.42	1.43	0.00	0.25	0.25	0.39	0.47	0.58	1.58
Poughkeepsie, NY	x	x	100	100	0.00	0.15	0.15	0.24	0.29	0.37	1.26	0.00	0.22	0.22	0.34	0.41	0.51	1.39
Providence (All RI), RI	x	-	100	-	0.00	0.09	0.09	0.15	0.18	0.22	0.76	0.00	0.13	0.13	0.21	0.25	0.31	0.83
Reading, PA	-	x	-	100	0.00	0.05	0.04	0.07	0.09	0.11	0.37	0.00	0.07	0.07	0.10	0.12	0.15	0.41
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.18	0.17	0.29	0.35	0.44	1.50	0.00	0.27	0.27	0.41	0.49	0.61	1.66
Rochester, NY	x	-	100	-	0.00	0.13	0.13	0.21	0.26	0.32	1.09	0.00	0.19	0.19	0.30	0.36	0.45	1.21
Rome, GA	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.09	0.00	0.02	0.02	0.03	0.03	0.04	0.10
Sacramento Metro, CA	x	-	50	-	0.00	0.31	0.29	0.48	0.59	0.74	2.50	0.00	0.45	0.44	0.68	0.82	1.02	2.77
San Diego, CA	x	-	100	-	0.00	0.30	0.28	0.47	0.57	0.72	2.45	0.00	0.44	0.43	0.67	0.80	1.00	2.71
San Francisco Bay Area, CA	x	-	100	-	0.00	0.69	0.66	1.10	1.33	1.67	5.68	0.00	1.01	1.01	1.55	1.87	2.32	6.28
San Joaquin Valley, CA	x	x	50	100	0.00	0.71	0.67	1.12	1.36	1.71	5.81	0.00	1.04	1.03	1.59	1.91	2.37	6.41
Sheboygan, WI	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.02	0.02	0.03	0.03	0.04	0.11
Springfield (Western MA), MA	x	-	100	-	0.00	0.10	0.09	0.16	0.19	0.24	0.81	0.00	0.14	0.14	0.22	0.27	0.33	0.90
St. Louis, MO-IL	x	x	100	100	0.00	0.32	0.31	0.51	0.62	0.78	2.64	0.00	0.47	0.47	0.72	0.87	1.08	2.92
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.02	0.02	0.03	0.08
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.07	0.06	0.10	0.13	0.16	0.53	0.00	0.10	0.09	0.15	0.18	0.22	0.59
Washington, DC-MD-VA	x	x	100	100	0.00	0.64	0.60	1.01	1.22	1.53	5.20	0.00	0.93	0.92	1.42	1.71	2.12	5.75
Wheeling, WV-OH	-	x	-	100	0.00	0.02	0.01	0.02	0.03	0.04	0.12	0.00	0.02	0.02	0.03	0.04	0.05	0.14
York, PA	-	x	-	100	0.00	0.05	0.05	0.08	0.10	0.13	0.43	0.00	0.08	0.08	0.12	0.14	0.18	0.48

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
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Table B2-53
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-0.23	-0.29	-0.63	-0.75	-1.07	-3.90	0.00	-0.23	-0.29	-0.63	-0.75	-1.07	-3.90
Allegan Co., MI	x	-	100	-	0.00	-0.03	-0.03	-0.07	-0.08	-0.12	-0.43	0.00	-0.03	-0.03	-0.07	-0.08	-0.12	-0.43
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.02	-0.03	-0.06	-0.07	-0.11	-0.39	0.00	-0.02	-0.03	-0.06	-0.07	-0.11	-0.39
Atlanta, GA	x	x	100	100	0.00	-1.23	-1.54	-3.37	-4.01	-5.70	-20.76	0.00	-1.23	-1.54	-3.37	-4.01	-5.70	-20.76
Baltimore, MD	x	x	100	100	0.00	-0.51	-0.64	-1.40	-1.67	-2.37	-8.62	0.00	-0.51	-0.64	-1.40	-1.67	-2.37	-8.62
Baton Rouge, LA	x	-	100	-	0.00	-3.05	-3.77	-5.29	-6.08	-7.38	-17.32	0.00	-3.05	-3.78	-5.30	-6.09	-7.38	-17.33
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-5.97	-7.38	-10.19	-11.71	-14.08	-32.08	0.00	-5.98	-7.40	-10.21	-11.72	-14.10	-32.09
Birmingham, AL	-	x	-	100	0.00	-0.19	-0.23	-0.51	-0.61	-0.87	-3.16	0.00	-0.19	-0.23	-0.51	-0.61	-0.87	-3.16
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-0.83	-1.04	-2.28	-2.71	-3.85	-14.03	0.00	-0.83	-1.04	-2.28	-2.71	-3.85	-14.03
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.11	-0.14	-0.31	-0.37	-0.52	-1.90	0.00	-0.11	-0.14	-0.31	-0.37	-0.52	-1.90
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-0.20	-0.25	-0.55	-0.65	-0.93	-3.37	0.00	-0.20	-0.25	-0.55	-0.65	-0.93	-3.37
Canton-Massillon, OH	-	x	-	100	0.00	-0.44	-0.54	-0.80	-0.93	-1.16	-2.96	0.00	-0.44	-0.55	-0.81	-0.93	-1.16	-2.96
Charleston, WV	-	x	-	100	0.00	-0.05	-0.07	-0.15	-0.17	-0.25	-0.90	0.00	-0.05	-0.07	-0.15	-0.17	-0.25	-0.90
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-0.32	-0.41	-0.89	-1.05	-1.50	-5.46	0.00	-0.32	-0.41	-0.89	-1.05	-1.50	-5.46
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.10	-0.12	-0.26	-0.31	-0.44	-1.62	0.00	-0.10	-0.12	-0.26	-0.31	-0.44	-1.62
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-5.53	-6.87	-10.71	-12.43	-15.82	-43.69	0.00	-5.54	-6.88	-10.72	-12.45	-15.83	-43.70
Chico, CA	x	-	100	-	0.00	-0.03	-0.04	-0.09	-0.11	-0.16	-0.58	0.00	-0.03	-0.04	-0.09	-0.11	-0.16	-0.58
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-0.33	-0.42	-0.91	-1.08	-1.53	-5.59	0.00	-0.33	-0.42	-0.91	-1.08	-1.53	-5.59
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.03	-0.04	-0.09	-0.10	-0.15	-0.53	0.00	-0.03	-0.04	-0.09	-0.10	-0.15	-0.53
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-0.48	-0.60	-1.31	-1.56	-2.21	-8.05	0.00	-0.48	-0.60	-1.31	-1.56	-2.21	-8.05
Columbus, OH	x	x	100	100	0.00	-0.31	-0.39	-0.85	-1.01	-1.43	-5.20	0.00	-0.31	-0.39	-0.85	-1.01	-1.43	-5.20
Dallas-Fort Worth, TX	x	-	100	-	0.00	-1.25	-1.57	-3.42	-4.08	-5.79	-21.09	0.00	-1.25	-1.57	-3.42	-4.08	-5.79	-21.09
Dayton-Springfield, OH	-	x	-	100	0.00	-0.14	-0.18	-0.40	-0.47	-0.67	-2.44	0.00	-0.14	-0.18	-0.40	-0.47	-0.67	-2.44
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-1.07	-1.33	-2.42	-2.85	-3.83	-12.34	0.00	-1.07	-1.34	-2.42	-2.85	-3.83	-12.34
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-1.39	-1.74	-3.28	-3.86	-5.26	-17.44	0.00	-1.39	-1.74	-3.28	-3.86	-5.26	-17.44
Door Co., WI	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.10	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.10
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	-0.06	-0.08	-0.17	-0.20	-0.29	-1.05	0.00	-0.06	-0.08	-0.17	-0.20	-0.29	-1.05
Greater Connecticut, CT	x	-	100	-	0.00	-0.32	-0.40	-0.87	-1.03	-1.47	-5.34	0.00	-0.32	-0.40	-0.87	-1.03	-1.47	-5.34
Greene Co., PA	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.12	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.12
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-0.14	-0.18	-0.39	-0.47	-0.66	-2.41	0.00	-0.14	-0.18	-0.39	-0.47	-0.66	-2.41

Table B2-53
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-0.13	-0.16	-0.36	-0.42	-0.60	-2.19	0.00	-0.13	-0.16	-0.36	-0.42	-0.60	-2.19
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.02
Hickory, NC	-	x	-	100	0.00	-0.03	-0.04	-0.09	-0.11	-0.16	-0.57	0.00	-0.03	-0.04	-0.09	-0.11	-0.16	-0.57
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-12.99	-16.07	-22.98	-26.48	-32.40	-78.66	0.00	-13.02	-16.10	-23.01	-26.51	-32.43	-78.68
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-1.24	-1.54	-2.19	-2.52	-3.07	-7.41	0.00	-1.24	-1.54	-2.19	-2.52	-3.08	-7.41
Imperial Co., CA	x	-	100	-	0.00	-0.04	-0.05	-0.11	-0.13	-0.18	-0.67	0.00	-0.04	-0.05	-0.11	-0.13	-0.18	-0.67
Indianapolis, IN	-	x	-	100	0.00	-0.29	-0.36	-0.79	-0.94	-1.33	-4.86	0.00	-0.29	-0.36	-0.79	-0.94	-1.33	-4.86
Jamestown, NY	x	-	100	-	0.00	-0.03	-0.03	-0.07	-0.09	-0.12	-0.45	0.00	-0.03	-0.03	-0.07	-0.09	-0.12	-0.45
Jefferson Co., NY	x	-	100	-	0.00	-0.02	-0.03	-0.07	-0.08	-0.11	-0.42	0.00	-0.02	-0.03	-0.07	-0.08	-0.11	-0.42
Johnstown, PA	-	x	-	100	0.00	-0.02	-0.03	-0.06	-0.07	-0.10	-0.37	0.00	-0.02	-0.03	-0.06	-0.07	-0.10	-0.37
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.02	-0.03	-0.06	-0.07	-0.10	-0.35	0.00	-0.02	-0.03	-0.06	-0.07	-0.10	-0.35
Knoxville, TN	x	x	100	100	0.00	-0.20	-0.25	-0.54	-0.64	-0.91	-3.30	0.00	-0.20	-0.25	-0.54	-0.64	-0.91	-3.30
Lancaster, PA	-	x	-	100	0.00	-0.08	-0.10	-0.21	-0.25	-0.35	-1.29	0.00	-0.08	-0.10	-0.21	-0.25	-0.35	-1.29
Las Vegas, NV	x	-	100	-	0.00	-0.25	-0.32	-0.69	-0.83	-1.17	-4.27	0.00	-0.25	-0.32	-0.69	-0.83	-1.17	-4.27
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	-0.01	-0.02	0.00	0.00	0.00	0.00	0.00	-0.01	-0.02
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.04	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.04
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-9.14	-11.35	-18.27	-21.27	-27.41	-78.67	0.00	-9.15	-11.37	-18.29	-21.29	-27.43	-78.68
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-0.13	-0.16	-0.36	-0.43	-0.61	-2.20	0.00	-0.13	-0.16	-0.36	-0.43	-0.61	-2.20
Louisville, KY-IN	-	x	-	100	0.00	-0.20	-0.25	-0.55	-0.66	-0.93	-3.39	0.00	-0.20	-0.25	-0.55	-0.66	-0.93	-3.39
Macon, GA	-	x	-	100	0.00	-0.04	-0.05	-0.10	-0.12	-0.17	-0.63	0.00	-0.04	-0.05	-0.10	-0.12	-0.17	-0.63
Manitowoc Co., WI	x	-		-	0.00	-0.02	-0.02	-0.05	-0.06	-0.09	-0.32	0.00	-0.02	-0.02	-0.05	-0.06	-0.09	-0.32
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.02	-0.02	-0.05	-0.06	-0.09	-0.32	0.00	-0.02	-0.02	-0.05	-0.06	-0.09	-0.32
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.07	-0.09	-0.20	-0.24	-0.34	-1.24	0.00	-0.07	-0.09	-0.20	-0.24	-0.34	-1.24
Memphis, TN-AR	x	-	100	-	0.00	-1.12	-1.39	-2.09	-2.41	-3.02	-7.93	0.00	-1.12	-1.39	-2.09	-2.42	-3.02	-7.93
Milwaukee-Racine, WI	x	-	100	-	0.00	-0.31	-0.40	-0.86	-1.03	-1.46	-5.32	0.00	-0.31	-0.40	-0.86	-1.03	-1.46	-5.32
Nevada (Western Part), CA	x	-	100	-	0.00	-0.02	-0.02	-0.05	-0.06	-0.08	-0.30	0.00	-0.02	-0.02	-0.05	-0.06	-0.08	-0.30
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-4.25	-5.31	-9.93	-11.70	-15.90	-52.49	0.00	-4.26	-5.32	-9.94	-11.70	-15.91	-52.49
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.03	-0.04	-0.08	-0.09	-0.13	-0.48	0.00	-0.03	-0.04	-0.08	-0.09	-0.13	-0.48
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-7.44	-9.23	-13.92	-16.11	-20.21	-53.37	0.00	-7.46	-9.24	-13.93	-16.13	-20.23	-53.38

Table B2-53
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-0.70	-0.88	-1.93	-2.30	-3.26	-11.88	0.00	-0.70	-0.88	-1.93	-2.30	-3.26	-11.88
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-0.35	-0.44	-0.97	-1.15	-1.63	-5.94	0.00	-0.35	-0.44	-0.97	-1.15	-1.63	-5.94
Poughkeepsie, NY	x	x	100	100	0.00	-0.23	-0.29	-0.63	-0.74	-1.06	-3.85	0.00	-0.23	-0.29	-0.63	-0.74	-1.06	-3.85
Providence (All RI), RI	x	-	100	-	0.00	-0.16	-0.21	-0.45	-0.54	-0.77	-2.79	0.00	-0.16	-0.21	-0.45	-0.54	-0.77	-2.79
Reading, PA	-	x	-	100	0.00	-0.07	-0.08	-0.18	-0.22	-0.31	-1.13	0.00	-0.07	-0.08	-0.18	-0.22	-0.31	-1.13
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-0.13	-0.17	-0.36	-0.43	-0.62	-2.25	0.00	-0.13	-0.17	-0.36	-0.43	-0.62	-2.25
Rochester, NY	x	-	100	-	0.00	-0.23	-0.29	-0.63	-0.75	-1.07	-3.90	0.00	-0.23	-0.29	-0.63	-0.75	-1.07	-3.90
Rome, GA	-	x	-	100	0.00	-0.02	-0.03	-0.06	-0.07	-0.09	-0.34	0.00	-0.02	-0.03	-0.06	-0.07	-0.09	-0.34
Sacramento Metro, CA	x	-	50	-	0.00	-0.39	-0.49	-1.06	-1.27	-1.80	-6.56	0.00	-0.39	-0.49	-1.06	-1.27	-1.80	-6.56
San Diego, CA	x	-	100	-	0.00	-0.54	-0.68	-1.49	-1.77	-2.52	-9.18	0.00	-0.54	-0.68	-1.49	-1.77	-2.52	-9.18
San Francisco Bay Area, CA	x	-	100	-	0.00	-4.66	-5.79	-9.15	-10.64	-13.62	-38.30	0.00	-4.67	-5.80	-9.16	-10.65	-13.63	-38.30
San Joaquin Valley, CA	x	x	50	100	0.00	-1.37	-1.71	-3.16	-3.72	-5.03	-16.42	0.00	-1.37	-1.71	-3.16	-3.72	-5.03	-16.42
Sheboygan, WI	x	-	100	-	0.00	-0.02	-0.03	-0.06	-0.07	-0.10	-0.36	0.00	-0.02	-0.03	-0.06	-0.07	-0.10	-0.36
Springfield (Western MA), MA	x	-	100	-	0.00	-0.17	-0.21	-0.46	-0.54	-0.77	-2.80	0.00	-0.17	-0.21	-0.46	-0.54	-0.77	-2.80
St. Louis, MO-IL	x	x	100	100	0.00	-2.15	-2.67	-4.22	-4.91	-6.28	-17.65	0.00	-2.15	-2.67	-4.23	-4.91	-6.29	-17.66
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.12	-0.15	-0.23	-0.27	-0.33	-0.87	0.00	-0.12	-0.15	-0.23	-0.27	-0.33	-0.87
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-0.13	-0.16	-0.34	-0.40	-0.56	-2.00	0.00	-0.13	-0.16	-0.34	-0.40	-0.56	-2.00
Washington, DC-MD-VA	x	x	100	100	0.00	-0.87	-1.10	-2.40	-2.85	-4.05	-14.75	0.00	-0.87	-1.10	-2.40	-2.85	-4.05	-14.75
Wheeling, WV-OH	-	x	-	100	0.00	-0.03	-0.04	-0.08	-0.10	-0.14	-0.51	0.00	-0.03	-0.04	-0.08	-0.10	-0.14	-0.51
York, PA	-	x	-	100	0.00	-0.07	-0.09	-0.19	-0.23	-0.33	-1.20	0.00	-0.07	-0.09	-0.19	-0.23	-0.33	-1.20

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-54
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-1.24	-1.20	-2.41	-3.02	-4.07	-15.29	0.00	-1.11	-1.04	-2.31	-2.97	-4.09	-14.96
Allegan Co., MI	x	-	100	-	0.00	-0.14	-0.13	-0.26	-0.33	-0.44	-1.67	0.00	-0.12	-0.11	-0.25	-0.32	-0.45	-1.64
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.13	-0.13	-0.25	-0.32	-0.43	-1.62	0.00	-0.12	-0.11	-0.24	-0.31	-0.43	-1.58
Atlanta, GA	x	x	100	100	0.00	-7.20	-6.97	-13.95	-17.49	-23.58	-88.61	0.00	-6.43	-6.03	-13.37	-17.21	-23.70	-86.74
Baltimore, MD	x	x	100	100	0.00	-2.73	-2.64	-5.29	-6.63	-8.94	-33.61	0.00	-2.44	-2.29	-5.07	-6.53	-8.99	-32.90
Baton Rouge, LA	x	-	100	-	0.00	-9.89	-11.13	-14.67	-16.68	-19.53	-46.47	0.00	-14.97	-16.57	-20.31	-22.60	-25.59	-50.07
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-19.00	-21.52	-27.76	-31.37	-36.34	-82.33	0.00	-29.33	-32.60	-39.20	-43.31	-48.52	-89.80
Birmingham, AL	-	x	-	100	0.00	-0.98	-0.94	-1.89	-2.37	-3.19	-12.01	0.00	-0.87	-0.82	-1.81	-2.33	-3.21	-11.75
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-4.28	-4.14	-8.29	-10.40	-14.02	-52.68	0.00	-3.82	-3.58	-7.95	-10.23	-14.09	-51.57
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.60	-0.58	-1.16	-1.45	-1.96	-7.37	0.00	-0.53	-0.50	-1.11	-1.43	-1.97	-7.21
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-1.02	-0.99	-1.98	-2.49	-3.35	-12.59	0.00	-0.91	-0.86	-1.90	-2.45	-3.37	-12.33
Canton-Massillon, OH	-	x	-	100	0.00	-1.50	-1.65	-2.32	-2.69	-3.23	-8.64	0.00	-2.14	-2.34	-3.04	-3.45	-4.03	-9.05
Charleston, WV	-	x	-	100	0.00	-0.27	-0.26	-0.52	-0.65	-0.88	-3.30	0.00	-0.24	-0.22	-0.50	-0.64	-0.88	-3.24
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-1.86	-1.80	-3.61	-4.53	-6.10	-22.93	0.00	-1.66	-1.56	-3.46	-4.45	-6.13	-22.45
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.50	-0.48	-0.96	-1.21	-1.63	-6.11	0.00	-0.44	-0.42	-0.92	-1.19	-1.63	-5.98
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-20.23	-21.85	-32.64	-38.44	-47.50	-139.22	0.00	-27.02	-29.04	-40.41	-46.84	-56.44	-142.96
Chico, CA	x	-	100	-	0.00	-0.18	-0.18	-0.36	-0.45	-0.60	-2.27	0.00	-0.16	-0.15	-0.34	-0.44	-0.61	-2.22
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-1.74	-1.69	-3.37	-4.23	-5.70	-21.43	0.00	-1.55	-1.46	-3.23	-4.16	-5.73	-20.98
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.16	-0.15	-0.30	-0.38	-0.51	-1.93	0.00	-0.14	-0.13	-0.29	-0.38	-0.52	-1.89
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-2.43	-2.35	-4.71	-5.91	-7.96	-29.92	0.00	-2.17	-2.04	-4.51	-5.81	-8.00	-29.29
Columbus, OH	x	x	100	100	0.00	-1.68	-1.63	-3.26	-4.08	-5.50	-20.69	0.00	-1.50	-1.41	-3.12	-4.02	-5.53	-20.25
Dallas-Fort Worth, TX	x	-	100	-	0.00	-7.14	-6.91	-13.82	-17.34	-23.37	-87.83	0.00	-6.37	-5.97	-13.25	-17.06	-23.49	-85.98
Dayton-Springfield, OH	-	x	-	100	0.00	-0.74	-0.72	-1.43	-1.80	-2.42	-9.10	0.00	-0.66	-0.62	-1.37	-1.77	-2.43	-8.91
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-4.76	-4.86	-8.46	-10.32	-13.41	-45.87	0.00	-5.28	-5.38	-9.16	-11.19	-14.48	-45.67
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-6.17	-6.25	-11.14	-13.66	-17.89	-62.42	0.00	-6.60	-6.65	-11.80	-14.55	-19.05	-61.92
Door Co., WI	x	-	100	-	0.00	-0.03	-0.03	-0.06	-0.07	-0.10	-0.37	0.00	-0.03	-0.03	-0.06	-0.07	-0.10	-0.36
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.02
Evansville, IN	-	x	-	100	0.00	-0.33	-0.31	-0.63	-0.79	-1.07	-4.00	0.00	-0.29	-0.27	-0.60	-0.78	-1.07	-3.92
Greater Connecticut, CT	x	-	100	-	0.00	-1.67	-1.62	-3.23	-4.06	-5.47	-20.55	0.00	-1.49	-1.40	-3.10	-3.99	-5.50	-20.12
Greene Co., PA	x	-	100	-	0.00	-0.04	-0.03	-0.07	-0.09	-0.12	-0.44	0.00	-0.03	-0.03	-0.07	-0.09	-0.12	-0.43
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-0.76	-0.73	-1.47	-1.84	-2.48	-9.32	0.00	-0.68	-0.63	-1.41	-1.81	-2.49	-9.12

Table B2-54
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-0.68	-0.65	-1.31	-1.64	-2.21	-8.32	0.00	-0.60	-0.57	-1.25	-1.62	-2.22	-8.14
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.06	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.06
Hickory, NC	-	x	-	100	0.00	-0.18	-0.18	-0.35	-0.44	-0.59	-2.23	0.00	-0.16	-0.15	-0.34	-0.43	-0.60	-2.18
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-43.06	-48.09	-64.91	-74.35	-88.05	-219.90	0.00	-63.76	-70.23	-87.99	-98.64	-113.06	-234.12
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-4.07	-4.56	-6.11	-6.98	-8.24	-20.26	0.00	-6.08	-6.70	-8.34	-9.32	-10.65	-21.65
Imperial Co., CA	x	-	100	-	0.00	-0.23	-0.23	-0.45	-0.57	-0.76	-2.87	0.00	-0.21	-0.20	-0.43	-0.56	-0.77	-2.81
Indianapolis, IN	-	x	-	100	0.00	-1.57	-1.52	-3.03	-3.80	-5.13	-19.26	0.00	-1.40	-1.31	-2.91	-3.74	-5.15	-18.86
Jamestown, NY	x	-	100	-	0.00	-0.14	-0.13	-0.26	-0.33	-0.45	-1.67	0.00	-0.12	-0.11	-0.25	-0.32	-0.45	-1.64
Jefferson Co., NY	x	-	100	-	0.00	-0.14	-0.13	-0.26	-0.33	-0.44	-1.67	0.00	-0.12	-0.11	-0.25	-0.32	-0.45	-1.63
Johnstown, PA	-	x	-	100	0.00	-0.11	-0.11	-0.21	-0.26	-0.36	-1.34	0.00	-0.10	-0.09	-0.20	-0.26	-0.36	-1.31
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.12	-0.12	-0.24	-0.30	-0.40	-1.50	0.00	-0.11	-0.10	-0.23	-0.29	-0.40	-1.47
Knoxville, TN	x	x	100	100	0.00	-1.05	-1.01	-2.03	-2.54	-3.43	-12.89	0.00	-0.93	-0.88	-1.95	-2.50	-3.45	-12.62
Lancaster, PA	-	x	-	100	0.00	-0.40	-0.39	-0.78	-0.97	-1.31	-4.92	0.00	-0.36	-0.33	-0.74	-0.96	-1.32	-4.82
Las Vegas, NV	x	-	100	-	0.00	-1.53	-1.48	-2.97	-3.72	-5.02	-18.87	0.00	-1.37	-1.28	-2.85	-3.67	-5.05	-18.47
Libby, MT	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.08	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.08
Liberty-Clairton, PA	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.03	-0.04	-0.14	0.00	-0.01	-0.01	-0.02	-0.03	-0.04	-0.14
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-35.06	-37.38	-57.94	-68.87	-86.28	-264.54	0.00	-44.92	-47.75	-69.42	-81.49	-99.96	-269.11
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-0.74	-0.71	-1.42	-1.79	-2.41	-9.04	0.00	-0.66	-0.62	-1.36	-1.76	-2.42	-8.85
Louisville, KY-IN	-	x	-	100	0.00	-1.03	-1.00	-1.99	-2.50	-3.37	-12.67	0.00	-0.92	-0.86	-1.91	-2.46	-3.39	-12.40
Macon, GA	-	x	-	100	0.00	-0.19	-0.19	-0.37	-0.47	-0.63	-2.37	0.00	-0.17	-0.16	-0.36	-0.46	-0.63	-2.32
Manitowoc Co., WI	x	-		-	0.00	-0.10	-0.09	-0.19	-0.24	-0.32	-1.21	0.00	-0.09	-0.08	-0.18	-0.23	-0.32	-1.18
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.11	-0.11	-0.21	-0.26	-0.36	-1.34	0.00	-0.10	-0.09	-0.20	-0.26	-0.36	-1.31
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.43	-0.42	-0.84	-1.05	-1.42	-5.34	0.00	-0.39	-0.36	-0.80	-1.04	-1.43	-5.22
Memphis, TN-AR	x	-	100	-	0.00	-3.89	-4.27	-6.10	-7.09	-8.61	-23.69	0.00	-5.45	-5.93	-7.86	-8.97	-10.57	-24.66
Milwaukee-Racine, WI	x	-	100	-	0.00	-1.63	-1.58	-3.16	-3.96	-5.33	-20.05	0.00	-1.45	-1.36	-3.02	-3.89	-5.36	-19.63
Nevada (Western Part), CA	x	-	100	-	0.00	-0.10	-0.09	-0.19	-0.24	-0.32	-1.20	0.00	-0.09	-0.08	-0.18	-0.23	-0.32	-1.17
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-18.71	-18.99	-33.68	-41.26	-53.94	-187.41	0.00	-20.19	-20.38	-35.84	-44.12	-57.61	-186.06
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.14	-0.14	-0.28	-0.35	-0.47	-1.76	0.00	-0.13	-0.12	-0.27	-0.34	-0.47	-1.72
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-26.21	-28.67	-41.25	-48.11	-58.59	-163.08	0.00	-36.42	-39.53	-52.80	-60.45	-71.52	-169.34

Table B2-54
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-4.17	-4.04	-8.08	-10.14	-13.67	-51.36	0.00	-3.72	-3.49	-7.75	-9.98	-13.74	-50.28
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-1.76	-1.70	-3.41	-4.27	-5.76	-21.65	0.00	-1.57	-1.47	-3.27	-4.21	-5.79	-21.20
Poughkeepsie, NY	x	x	100	100	0.00	-1.23	-1.19	-2.39	-3.00	-4.04	-15.18	0.00	-1.10	-1.03	-2.29	-2.95	-4.06	-14.86
Providence (All RI), RI	x	-	100	-	0.00	-0.85	-0.82	-1.65	-2.07	-2.79	-10.48	0.00	-0.76	-0.71	-1.58	-2.04	-2.80	-10.26
Reading, PA	-	x	-	100	0.00	-0.36	-0.35	-0.70	-0.88	-1.19	-4.47	0.00	-0.32	-0.30	-0.67	-0.87	-1.19	-4.37
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-0.86	-0.83	-1.67	-2.09	-2.82	-10.59	0.00	-0.77	-0.72	-1.60	-2.06	-2.83	-10.37
Rochester, NY	x	-	100	-	0.00	-1.20	-1.16	-2.33	-2.92	-3.94	-14.79	0.00	-1.07	-1.01	-2.23	-2.87	-3.96	-14.48
Rome, GA	-	x	-	100	0.00	-0.10	-0.10	-0.20	-0.25	-0.34	-1.28	0.00	-0.09	-0.09	-0.19	-0.25	-0.34	-1.25
Sacramento Metro, CA	x	-	50	-	0.00	-2.17	-2.10	-4.20	-5.27	-7.10	-26.70	0.00	-1.94	-1.82	-4.03	-5.19	-7.14	-26.14
San Diego, CA	x	-	100	-	0.00	-2.80	-2.71	-5.41	-6.79	-9.15	-34.40	0.00	-2.49	-2.34	-5.19	-6.68	-9.20	-33.67
San Francisco Bay Area, CA	x	-	100	-	0.00	-17.17	-18.46	-27.94	-33.01	-40.99	-122.12	0.00	-22.61	-24.21	-34.19	-39.81	-48.27	-124.97
San Joaquin Valley, CA	x	x	50	100	0.00	-6.43	-6.53	-11.56	-14.15	-18.49	-64.15	0.00	-6.95	-7.03	-12.32	-15.16	-19.77	-63.70
Sheboygan, WI	x	-	100	-	0.00	-0.11	-0.11	-0.22	-0.27	-0.37	-1.38	0.00	-0.10	-0.09	-0.21	-0.27	-0.37	-1.35
Springfield (Western MA), MA	x	-	100	-	0.00	-0.87	-0.84	-1.69	-2.11	-2.85	-10.72	0.00	-0.78	-0.73	-1.62	-2.08	-2.87	-10.49
St. Louis, MO-IL	x	x	100	100	0.00	-7.91	-8.51	-12.87	-15.21	-18.88	-56.22	0.00	-10.43	-11.17	-15.76	-18.35	-22.24	-57.54
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.43	-0.47	-0.66	-0.77	-0.94	-2.55	0.00	-0.60	-0.65	-0.86	-0.98	-1.15	-2.66
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-0.64	-0.63	-1.21	-1.51	-2.03	-7.48	0.00	-0.60	-0.58	-1.20	-1.52	-2.07	-7.35
Washington, DC-MD-VA	x	x	100	100	0.00	-4.73	-4.58	-9.16	-11.49	-15.49	-58.23	0.00	-4.22	-3.96	-8.78	-11.31	-15.57	-57.00
Wheeling, WV-OH	-	x	-	100	0.00	-0.15	-0.15	-0.30	-0.37	-0.50	-1.88	0.00	-0.14	-0.13	-0.28	-0.37	-0.50	-1.84
York, PA	-	x	-	100	0.00	-0.39	-0.38	-0.76	-0.95	-1.29	-4.83	0.00	-0.35	-0.33	-0.73	-0.94	-1.29	-4.73

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-55
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-2.66	-2.39	-4.75	-6.01	-7.95	-30.03	0.00	-2.17	-1.80	-4.42	-5.90	-8.12	-28.82
Allegan Co., MI	x	-	100	-	0.00	-0.29	-0.26	-0.52	-0.66	-0.87	-3.28	0.00	-0.24	-0.20	-0.48	-0.64	-0.89	-3.15
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.30	-0.27	-0.54	-0.68	-0.90	-3.38	0.00	-0.25	-0.20	-0.50	-0.66	-0.92	-3.25
Atlanta, GA	x	x	100	100	0.00	-16.96	-15.26	-30.33	-38.40	-50.79	-191.74	0.00	-13.89	-11.51	-28.21	-37.65	-51.87	-184.05
Baltimore, MD	x	x	100	100	0.00	-5.81	-5.23	-10.39	-13.16	-17.40	-65.70	0.00	-4.76	-3.94	-9.66	-12.90	-17.77	-63.06
Baton Rouge, LA	x	-	100	-	0.00	-15.91	-17.46	-22.89	-26.01	-30.26	-73.17	0.00	-29.35	-31.83	-37.83	-41.71	-46.39	-82.41
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-30.02	-33.34	-42.48	-47.80	-54.89	-124.55	0.00	-57.44	-62.71	-72.82	-79.50	-87.25	-144.07
Birmingham, AL	-	x	-	100	0.00	-2.04	-1.83	-3.64	-4.61	-6.10	-23.03	0.00	-1.67	-1.38	-3.39	-4.52	-6.23	-22.10
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-8.80	-7.91	-15.73	-19.91	-26.34	-99.44	0.00	-7.20	-5.97	-14.63	-19.52	-26.90	-95.45
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-1.27	-1.14	-2.27	-2.87	-3.80	-14.33	0.00	-1.04	-0.86	-2.11	-2.81	-3.88	-13.76
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-2.08	-1.87	-3.72	-4.72	-6.24	-23.55	0.00	-1.71	-1.41	-3.46	-4.62	-6.37	-22.60
Canton-Massillon, OH	-	x	-	100	0.00	-2.49	-2.65	-3.73	-4.34	-5.20	-14.26	0.00	-4.17	-4.44	-5.63	-6.37	-7.33	-15.27
Charleston, WV	-	x	-	100	0.00	-0.54	-0.48	-0.96	-1.21	-1.61	-6.06	0.00	-0.44	-0.36	-0.89	-1.19	-1.64	-5.82
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-4.29	-3.86	-7.66	-9.70	-12.83	-48.44	0.00	-3.51	-2.91	-7.13	-9.51	-13.10	-46.50
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-1.03	-0.92	-1.83	-2.32	-3.07	-11.59	0.00	-0.84	-0.70	-1.71	-2.28	-3.14	-11.13
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-35.61	-36.63	-55.56	-66.01	-81.27	-246.89	0.00	-52.97	-54.84	-75.81	-88.37	-105.59	-254.75
Chico, CA	x	-	100	-	0.00	-0.39	-0.35	-0.70	-0.88	-1.17	-4.41	0.00	-0.32	-0.26	-0.65	-0.87	-1.19	-4.24
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-3.69	-3.32	-6.60	-8.36	-11.06	-41.75	0.00	-3.02	-2.51	-6.14	-8.20	-11.29	-40.07
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.31	-0.28	-0.56	-0.71	-0.94	-3.54	0.00	-0.26	-0.21	-0.52	-0.69	-0.96	-3.40
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-4.93	-4.44	-8.82	-11.17	-14.78	-55.78	0.00	-4.04	-3.35	-8.21	-10.95	-15.09	-53.55
Columbus, OH	x	x	100	100	0.00	-3.66	-3.30	-6.55	-8.30	-10.97	-41.43	0.00	-3.00	-2.49	-6.09	-8.13	-11.21	-39.76
Dallas-Fort Worth, TX	x	-	100	-	0.00	-16.34	-14.71	-29.23	-37.01	-48.95	-184.78	0.00	-13.38	-11.09	-27.18	-36.28	-49.98	-177.37
Dayton-Springfield, OH	-	x	-	100	0.00	-1.50	-1.35	-2.69	-3.40	-4.50	-17.00	0.00	-1.23	-1.02	-2.50	-3.34	-4.60	-16.32
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-9.53	-9.10	-16.10	-19.88	-25.60	-89.75	0.00	-10.54	-10.00	-17.75	-22.22	-28.75	-88.20
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-11.91	-11.27	-20.29	-25.16	-32.54	-115.50	0.00	-12.67	-11.84	-21.83	-27.57	-36.00	-113.05
Door Co., WI	x	-	100	-	0.00	-0.06	-0.05	-0.11	-0.14	-0.18	-0.69	0.00	-0.05	-0.04	-0.10	-0.14	-0.19	-0.66
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.03	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.03
Evansville, IN	-	x	-	100	0.00	-0.68	-0.61	-1.22	-1.54	-2.03	-7.68	0.00	-0.56	-0.46	-1.13	-1.51	-2.08	-7.37
Greater Connecticut, CT	x	-	100	-	0.00	-3.51	-3.16	-6.27	-7.94	-10.51	-39.66	0.00	-2.87	-2.38	-5.83	-7.79	-10.73	-38.07
Greene Co., PA	x	-	100	-	0.00	-0.07	-0.06	-0.13	-0.16	-0.21	-0.79	0.00	-0.06	-0.05	-0.12	-0.16	-0.21	-0.76
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-1.59	-1.43	-2.85	-3.61	-4.77	-18.03	0.00	-1.31	-1.08	-2.65	-3.54	-4.88	-17.30

Table B2-55
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-1.40	-1.26	-2.51	-3.18	-4.20	-15.86	0.00	-1.15	-0.95	-2.33	-3.11	-4.29	-15.22
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.11	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.11
Hickory, NC	-	x	-	100	0.00	-0.39	-0.35	-0.69	-0.88	-1.16	-4.39	0.00	-0.32	-0.26	-0.65	-0.86	-1.19	-4.21
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-70.56	-76.44	-103.24	-118.47	-139.64	-357.91	0.00	-125.04	-134.55	-164.21	-182.95	-206.44	-393.74
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-6.59	-7.17	-9.57	-10.93	-12.82	-32.08	0.00	-11.87	-12.82	-15.47	-17.16	-19.24	-35.63
Imperial Co., CA	x	-	100	-	0.00	-0.54	-0.49	-0.97	-1.23	-1.62	-6.13	0.00	-0.44	-0.37	-0.90	-1.20	-1.66	-5.89
Indianapolis, IN	-	x	-	100	0.00	-3.41	-3.07	-6.10	-7.72	-10.21	-38.55	0.00	-2.79	-2.31	-5.67	-7.57	-10.43	-37.00
Jamestown, NY	x	-	100	-	0.00	-0.28	-0.25	-0.49	-0.63	-0.83	-3.12	0.00	-0.23	-0.19	-0.46	-0.61	-0.84	-3.00
Jefferson Co., NY	x	-	100	-	0.00	-0.30	-0.27	-0.53	-0.67	-0.88	-3.34	0.00	-0.24	-0.20	-0.49	-0.65	-0.90	-3.20
Johnstown, PA	-	x	-	100	0.00	-0.22	-0.19	-0.38	-0.49	-0.64	-2.43	0.00	-0.18	-0.15	-0.36	-0.48	-0.66	-2.34
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.28	-0.25	-0.50	-0.64	-0.84	-3.18	0.00	-0.23	-0.19	-0.47	-0.63	-0.86	-3.06
Knoxville, TN	x	x	100	100	0.00	-2.23	-2.01	-3.99	-5.06	-6.69	-25.25	0.00	-1.83	-1.52	-3.71	-4.96	-6.83	-24.24
Lancaster, PA	-	x	-	100	0.00	-0.83	-0.75	-1.49	-1.89	-2.49	-9.42	0.00	-0.68	-0.57	-1.39	-1.85	-2.55	-9.04
Las Vegas, NV	x	-	100	-	0.00	-3.69	-3.32	-6.60	-8.36	-11.06	-41.74	0.00	-3.02	-2.50	-6.14	-8.20	-11.29	-40.07
Libby, MT	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.03	-0.04	-0.16	0.00	-0.01	-0.01	-0.02	-0.03	-0.04	-0.15
Liberty-Clairton, PA	-	x	-	100	0.00	-0.02	-0.02	-0.04	-0.05	-0.07	-0.25	0.00	-0.02	-0.02	-0.04	-0.05	-0.07	-0.24
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-64.25	-64.78	-102.54	-123.24	-153.83	-489.62	0.00	-88.81	-90.25	-132.08	-156.79	-191.46	-496.99
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-1.65	-1.48	-2.95	-3.73	-4.94	-18.64	0.00	-1.35	-1.12	-2.74	-3.66	-5.04	-17.89
Louisville, KY-IN	-	x	-	100	0.00	-2.10	-1.89	-3.76	-4.76	-6.29	-23.75	0.00	-1.72	-1.43	-3.49	-4.66	-6.42	-22.80
Macon, GA	-	x	-	100	0.00	-0.39	-0.35	-0.70	-0.89	-1.18	-4.46	0.00	-0.32	-0.27	-0.66	-0.87	-1.21	-4.28
Manitowoc Co., WI	x	-		-	0.00	-0.20	-0.18	-0.36	-0.45	-0.60	-2.25	0.00	-0.16	-0.13	-0.33	-0.44	-0.61	-2.16
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.25	-0.23	-0.45	-0.57	-0.75	-2.84	0.00	-0.21	-0.17	-0.42	-0.56	-0.77	-2.73
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-1.02	-0.92	-1.83	-2.32	-3.06	-11.56	0.00	-0.84	-0.69	-1.70	-2.27	-3.13	-11.10
Memphis, TN-AR	x	-	100	-	0.00	-6.55	-6.91	-9.93	-11.61	-14.03	-39.72	0.00	-10.62	-11.22	-14.56	-16.60	-19.31	-42.05
Milwaukee-Racine, WI	x	-	100	-	0.00	-3.35	-3.02	-6.00	-7.60	-10.05	-37.93	0.00	-2.75	-2.28	-5.58	-7.45	-10.26	-36.41
Nevada (Western Part), CA	x	-	100	-	0.00	-0.21	-0.19	-0.38	-0.48	-0.63	-2.40	0.00	-0.17	-0.14	-0.35	-0.47	-0.65	-2.30
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-36.00	-34.18	-61.20	-75.80	-97.91	-346.26	0.00	-38.76	-36.39	-66.33	-83.54	-108.80	-339.29
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.29	-0.26	-0.51	-0.65	-0.86	-3.23	0.00	-0.23	-0.19	-0.48	-0.63	-0.87	-3.10
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-44.84	-47.01	-68.38	-80.28	-97.41	-280.68	0.00	-71.31	-75.01	-98.68	-113.08	-132.32	-295.24

Table B2-55
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-9.84	-8.86	-17.60	-22.29	-29.48	-111.28	0.00	-8.06	-6.68	-16.37	-21.85	-30.10	-106.82
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-3.50	-3.15	-6.26	-7.93	-10.48	-39.57	0.00	-2.87	-2.37	-5.82	-7.77	-10.70	-37.99
Poughkeepsie, NY	x	x	100	100	0.00	-2.65	-2.38	-4.74	-6.00	-7.94	-29.96	0.00	-2.17	-1.80	-4.41	-5.88	-8.10	-28.76
Providence (All RI), RI	x	-	100	-	0.00	-1.75	-1.57	-3.12	-3.96	-5.23	-19.76	0.00	-1.43	-1.19	-2.91	-3.88	-5.34	-18.96
Reading, PA	-	x	-	100	0.00	-0.78	-0.70	-1.40	-1.77	-2.34	-8.83	0.00	-0.64	-0.53	-1.30	-1.73	-2.39	-8.47
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-2.21	-1.99	-3.96	-5.01	-6.63	-25.03	0.00	-1.81	-1.50	-3.68	-4.91	-6.77	-24.03
Rochester, NY	x	-	100	-	0.00	-2.49	-2.24	-4.45	-5.63	-7.45	-28.11	0.00	-2.04	-1.69	-4.13	-5.52	-7.60	-26.98
Rome, GA	-	x	-	100	0.00	-0.21	-0.19	-0.38	-0.48	-0.64	-2.41	0.00	-0.17	-0.14	-0.35	-0.47	-0.65	-2.31
Sacramento Metro, CA	x	-	50	-	0.00	-4.84	-4.35	-8.65	-10.96	-14.49	-54.71	0.00	-3.96	-3.28	-8.05	-10.74	-14.80	-52.51
San Diego, CA	x	-	100	-	0.00	-5.71	-5.14	-10.22	-12.94	-17.11	-64.59	0.00	-4.68	-3.88	-9.50	-12.68	-17.47	-62.00
San Francisco Bay Area, CA	x	-	100	-	0.00	-30.07	-30.79	-47.18	-56.21	-69.45	-213.49	0.00	-43.97	-45.34	-63.49	-74.33	-89.28	-219.36
San Joaquin Valley, CA	x	x	50	100	0.00	-13.47	-12.74	-22.98	-28.51	-36.89	-131.09	0.00	-14.27	-13.31	-24.66	-31.17	-40.74	-128.25
Sheboygan, WI	x	-	100	-	0.00	-0.23	-0.21	-0.42	-0.53	-0.70	-2.64	0.00	-0.19	-0.16	-0.39	-0.52	-0.71	-2.53
Springfield (Western MA), MA	x	-	100	-	0.00	-1.82	-1.63	-3.25	-4.11	-5.44	-20.53	0.00	-1.49	-1.23	-3.02	-4.03	-5.55	-19.71
St. Louis, MO-IL	x	x	100	100	0.00	-13.86	-14.19	-21.74	-25.90	-31.99	-98.30	0.00	-20.28	-20.92	-29.28	-34.27	-41.15	-101.02
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.71	-0.75	-1.07	-1.24	-1.50	-4.18	0.00	-1.16	-1.23	-1.58	-1.80	-2.08	-4.44
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-1.30	-1.18	-2.29	-2.88	-3.79	-14.11	0.00	-1.14	-0.98	-2.21	-2.91	-3.95	-13.60
Washington, DC-MD-VA	x	x	100	100	0.00	-10.30	-9.27	-18.43	-23.33	-30.86	-116.50	0.00	-8.44	-6.99	-17.14	-22.87	-31.51	-111.82
Wheeling, WV-OH	-	x	-	100	0.00	-0.30	-0.27	-0.55	-0.69	-0.91	-3.45	0.00	-0.25	-0.21	-0.51	-0.68	-0.93	-3.31
York, PA	-	x	-	100	0.00	-0.87	-0.78	-1.55	-1.96	-2.59	-9.78	0.00	-0.71	-0.59	-1.44	-1.92	-2.65	-9.39

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-56
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-5.08	-4.40	-8.15	-10.51	-13.93	-52.40	0.00	-3.86	-2.89	-7.38	-10.35	-14.58	-49.27
Allegan Co., MI	x	-	100	-	0.00	-0.55	-0.48	-0.89	-1.14	-1.52	-5.70	0.00	-0.42	-0.31	-0.80	-1.13	-1.59	-5.36
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.65	-0.56	-1.04	-1.34	-1.78	-6.69	0.00	-0.49	-0.37	-0.94	-1.32	-1.86	-6.29
Atlanta, GA	x	x	100	100	0.00	-40.42	-34.99	-64.87	-83.67	-110.86	-417.01	0.00	-30.70	-23.02	-58.73	-82.38	-116.05	-392.07
Baltimore, MD	x	x	100	100	0.00	-11.01	-9.54	-17.68	-22.80	-30.21	-113.65	0.00	-8.37	-6.27	-16.01	-22.45	-31.63	-106.85
Baton Rouge, LA	x	-	100	-	0.00	-23.19	-24.93	-32.44	-37.02	-43.14	-106.75	0.00	-47.71	-51.09	-59.82	-65.91	-73.00	-123.11
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-42.52	-46.59	-58.61	-65.90	-75.41	-171.87	0.00	-92.89	-100.49	-114.38	-124.21	-134.99	-207.39
Birmingham, AL	-	x	-	100	0.00	-3.78	-3.27	-6.07	-7.83	-10.37	-39.02	0.00	-2.87	-2.15	-5.50	-7.71	-10.86	-36.68
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-15.62	-13.52	-25.07	-32.33	-42.84	-161.14	0.00	-11.86	-8.89	-22.69	-31.83	-44.84	-151.50
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-2.37	-2.05	-3.81	-4.91	-6.51	-24.48	0.00	-1.80	-1.35	-3.45	-4.83	-6.81	-23.01
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-3.60	-3.12	-5.78	-7.46	-9.88	-37.17	0.00	-2.74	-2.05	-5.24	-7.34	-10.34	-34.95
Canton-Massillon, OH	-	x	-	100	0.00	-3.71	-3.84	-5.33	-6.24	-7.49	-20.94	0.00	-6.75	-7.06	-8.80	-9.99	-11.48	-22.66
Charleston, WV	-	x	-	100	0.00	-0.90	-0.78	-1.44	-1.86	-2.46	-9.25	0.00	-0.68	-0.51	-1.30	-1.83	-2.57	-8.70
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-9.56	-8.28	-15.35	-19.80	-26.23	-98.67	0.00	-7.26	-5.45	-13.90	-19.49	-27.46	-92.77
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-1.84	-1.59	-2.95	-3.81	-5.05	-18.99	0.00	-1.40	-1.05	-2.67	-3.75	-5.29	-17.86
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-58.30	-57.56	-86.60	-104.67	-130.05	-408.20	0.00	-88.19	-88.48	-122.83	-146.04	-176.76	-416.97
Chico, CA	x	-	100	-	0.00	-0.73	-0.63	-1.18	-1.52	-2.01	-7.55	0.00	-0.56	-0.42	-1.06	-1.49	-2.10	-7.10
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-7.21	-6.24	-11.57	-14.92	-19.77	-74.36	0.00	-5.47	-4.10	-10.47	-14.69	-20.69	-69.91
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.52	-0.45	-0.83	-1.08	-1.42	-5.36	0.00	-0.39	-0.30	-0.75	-1.06	-1.49	-5.04
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-8.51	-7.37	-13.66	-17.61	-23.34	-87.79	0.00	-6.46	-4.85	-12.36	-17.34	-24.43	-82.54
Columbus, OH	x	x	100	100	0.00	-7.41	-6.41	-11.89	-15.33	-20.31	-76.40	0.00	-5.62	-4.22	-10.76	-15.09	-21.26	-71.83
Dallas-Fort Worth, TX	x	-	100	-	0.00	-36.70	-31.77	-58.90	-75.98	-100.67	-378.66	0.00	-27.87	-20.90	-53.33	-74.80	-105.38	-356.01
Dayton-Springfield, OH	-	x	-	100	0.00	-2.60	-2.25	-4.17	-5.38	-7.12	-26.79	0.00	-1.97	-1.48	-3.77	-5.29	-7.46	-25.19
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-18.23	-16.59	-28.45	-35.88	-46.55	-165.77	0.00	-18.90	-16.75	-30.88	-40.28	-53.41	-159.68
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-20.28	-18.42	-31.69	-40.01	-51.95	-185.49	0.00	-20.78	-18.32	-34.14	-44.66	-59.36	-178.46
Door Co., WI	x	-	100	-	0.00	-0.11	-0.09	-0.17	-0.22	-0.29	-1.08	0.00	-0.08	-0.06	-0.15	-0.21	-0.30	-1.02
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.05	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.05
Evansville, IN	-	x	-	100	0.00	-1.24	-1.07	-1.99	-2.57	-3.40	-12.80	0.00	-0.94	-0.71	-1.80	-2.53	-3.56	-12.04
Greater Connecticut, CT	x	-	100	-	0.00	-6.46	-5.60	-10.38	-13.38	-17.73	-66.70	0.00	-4.91	-3.68	-9.39	-13.18	-18.56	-62.71
Greene Co., PA	x	-	100	-	0.00	-0.11	-0.10	-0.18	-0.23	-0.31	-1.16	0.00	-0.09	-0.06	-0.16	-0.23	-0.32	-1.09
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-2.95	-2.56	-4.74	-6.11	-8.10	-30.45	0.00	-2.24	-1.68	-4.29	-6.02	-8.47	-28.63

Table B2-56
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-2.52	-2.18	-4.05	-5.23	-6.92	-26.04	0.00	-1.92	-1.44	-3.67	-5.14	-7.25	-24.48
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.02	-0.02	-0.03	-0.04	-0.05	-0.19	0.00	-0.01	-0.01	-0.03	-0.04	-0.05	-0.18
Hickory, NC	-	x	-	100	0.00	-0.74	-0.64	-1.20	-1.54	-2.04	-7.69	0.00	-0.57	-0.42	-1.08	-1.52	-2.14	-7.23
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-105.80	-111.60	-150.09	-173.73	-205.81	-545.34	0.00	-204.38	-216.39	-261.38	-292.48	-330.18	-606.48
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-9.54	-10.19	-13.41	-15.39	-18.04	-45.80	0.00	-19.20	-20.48	-24.24	-26.85	-29.94	-52.09
Imperial Co., CA	x	-	100	-	0.00	-1.22	-1.06	-1.96	-2.53	-3.36	-12.63	0.00	-0.93	-0.70	-1.78	-2.50	-3.52	-11.88
Indianapolis, IN	-	x	-	100	0.00	-6.91	-5.98	-11.08	-14.30	-18.94	-71.25	0.00	-5.24	-3.93	-10.04	-14.07	-19.83	-66.99
Jamestown, NY	x	-	100	-	0.00	-0.48	-0.41	-0.76	-0.98	-1.30	-4.91	0.00	-0.36	-0.27	-0.69	-0.97	-1.37	-4.61
Jefferson Co., NY	x	-	100	-	0.00	-0.58	-0.51	-0.94	-1.21	-1.60	-6.04	0.00	-0.44	-0.33	-0.85	-1.19	-1.68	-5.67
Johnstown, PA	-	x	-	100	0.00	-0.35	-0.31	-0.57	-0.73	-0.97	-3.64	0.00	-0.27	-0.20	-0.51	-0.72	-1.01	-3.42
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.63	-0.54	-1.01	-1.30	-1.73	-6.49	0.00	-0.48	-0.36	-0.91	-1.28	-1.81	-6.11
Knoxville, TN	x	x	100	100	0.00	-4.25	-3.68	-6.83	-8.80	-11.66	-43.88	0.00	-3.23	-2.42	-6.18	-8.67	-12.21	-41.25
Lancaster, PA	-	x	-	100	0.00	-1.51	-1.30	-2.42	-3.12	-4.13	-15.55	0.00	-1.14	-0.86	-2.19	-3.07	-4.33	-14.62
Las Vegas, NV	x	-	100	-	0.00	-8.94	-7.74	-14.35	-18.50	-24.52	-92.22	0.00	-6.79	-5.09	-12.99	-18.22	-25.66	-86.71
Libby, MT	-	x	-	100	0.00	-0.03	-0.02	-0.04	-0.05	-0.07	-0.26	0.00	-0.02	-0.01	-0.04	-0.05	-0.07	-0.24
Liberty-Clairton, PA	-	x	-	100	0.00	-0.03	-0.03	-0.05	-0.07	-0.09	-0.34	0.00	-0.03	-0.02	-0.05	-0.07	-0.10	-0.32
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-111.99	-107.72	-169.14	-207.47	-261.77	-861.48	0.00	-151.83	-147.83	-220.69	-269.63	-335.78	-860.42
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-3.49	-3.02	-5.60	-7.22	-9.57	-35.99	0.00	-2.65	-1.99	-5.07	-7.11	-10.02	-33.84
Louisville, KY-IN	-	x	-	100	0.00	-3.66	-3.17	-5.87	-7.57	-10.03	-37.74	0.00	-2.78	-2.08	-5.31	-7.45	-10.50	-35.48
Macon, GA	-	x	-	100	0.00	-0.69	-0.60	-1.11	-1.43	-1.89	-7.11	0.00	-0.52	-0.39	-1.00	-1.41	-1.98	-6.69
Manitowoc Co., WI	x	-		-	0.00	-0.34	-0.30	-0.55	-0.71	-0.94	-3.54	0.00	-0.26	-0.20	-0.50	-0.70	-0.98	-3.33
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.56	-0.49	-0.90	-1.16	-1.54	-5.80	0.00	-0.43	-0.32	-0.82	-1.15	-1.61	-5.45
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-2.39	-2.07	-3.84	-4.95	-6.56	-24.68	0.00	-1.82	-1.36	-3.48	-4.88	-6.87	-23.20
Memphis, TN-AR	x	-	100	-	0.00	-9.87	-10.11	-14.30	-16.89	-20.48	-59.16	0.00	-17.19	-17.82	-22.75	-26.12	-30.40	-62.95
Milwaukee-Racine, WI	x	-	100	-	0.00	-5.96	-5.16	-9.57	-12.34	-16.35	-61.50	0.00	-4.53	-3.39	-8.66	-12.15	-17.11	-57.82
Nevada (Western Part), CA	x	-	100	-	0.00	-0.42	-0.36	-0.67	-0.87	-1.15	-4.32	0.00	-0.32	-0.24	-0.61	-0.85	-1.20	-4.07
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-60.96	-55.54	-95.12	-119.95	-155.57	-553.61	0.00	-63.42	-56.27	-103.45	-134.86	-178.69	-533.43
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.48	-0.41	-0.77	-0.99	-1.31	-4.94	0.00	-0.36	-0.27	-0.70	-0.97	-1.37	-4.64
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-69.99	-70.89	-102.20	-121.60	-148.58	-441.17	0.00	-116.97	-120.18	-157.09	-182.19	-214.56	-463.02

Table B2-56
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Benzene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-22.86	-19.79	-36.68	-47.32	-62.69	-235.82	0.00	-17.36	-13.02	-33.21	-46.58	-65.63	-221.71
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-5.80	-5.02	-9.31	-12.01	-15.91	-59.84	0.00	-4.41	-3.30	-8.43	-11.82	-16.65	-56.26
Poughkeepsie, NY	x	x	100	100	0.00	-5.11	-4.43	-8.21	-10.59	-14.03	-52.76	0.00	-3.88	-2.91	-7.43	-10.42	-14.68	-49.60
Providence (All RI), RI	x	-	100	-	0.00	-3.07	-2.66	-4.93	-6.36	-8.43	-31.71	0.00	-2.33	-1.75	-4.47	-6.26	-8.82	-29.81
Reading, PA	-	x	-	100	0.00	-1.51	-1.31	-2.42	-3.12	-4.14	-15.57	0.00	-1.15	-0.86	-2.19	-3.08	-4.33	-14.64
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-6.11	-5.29	-9.81	-12.66	-16.77	-63.07	0.00	-4.64	-3.48	-8.88	-12.46	-17.55	-59.30
Rochester, NY	x	-	100	-	0.00	-4.45	-3.85	-7.14	-9.20	-12.19	-45.87	0.00	-3.38	-2.53	-6.46	-9.06	-12.77	-43.13
Rome, GA	-	x	-	100	0.00	-0.37	-0.32	-0.60	-0.77	-1.02	-3.84	0.00	-0.28	-0.21	-0.54	-0.76	-1.07	-3.61
Sacramento Metro, CA	x	-	50	-	0.00	-10.19	-8.82	-16.35	-21.09	-27.94	-105.10	0.00	-7.74	-5.80	-14.80	-20.76	-29.25	-98.81
San Diego, CA	x	-	100	-	0.00	-9.96	-8.63	-15.99	-20.63	-27.33	-102.81	0.00	-7.57	-5.67	-14.48	-20.31	-28.61	-96.66
San Francisco Bay Area, CA	x	-	100	-	0.00	-47.30	-46.70	-70.25	-84.89	-105.47	-330.92	0.00	-71.60	-71.85	-99.70	-118.51	-143.41	-338.10
San Joaquin Valley, CA	x	x	50	100	0.00	-27.66	-24.91	-43.45	-55.09	-71.81	-259.10	0.00	-26.99	-23.28	-45.38	-60.08	-80.70	-248.12
Sheboygan, WI	x	-	100	-	0.00	-0.42	-0.37	-0.68	-0.87	-1.16	-4.35	0.00	-0.32	-0.24	-0.61	-0.86	-1.21	-4.09
Springfield (Western MA), MA	x	-	100	-	0.00	-3.30	-2.86	-5.30	-6.83	-9.05	-34.05	0.00	-2.51	-1.88	-4.80	-6.73	-9.48	-32.02
St. Louis, MO-IL	x	x	100	100	0.00	-21.90	-21.62	-32.53	-39.32	-48.87	-153.42	0.00	-33.11	-33.21	-46.12	-54.85	-66.39	-156.69
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-1.03	-1.07	-1.49	-1.75	-2.10	-5.92	0.00	-1.86	-1.94	-2.44	-2.77	-3.20	-6.38
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-2.28	-2.00	-3.63	-4.66	-6.15	-22.84	0.00	-1.88	-1.49	-3.44	-4.74	-6.57	-21.58
Washington, DC-MD-VA	x	x	100	100	0.00	-21.15	-18.31	-33.95	-43.79	-58.02	-218.26	0.00	-16.07	-12.05	-30.74	-43.11	-60.74	-205.20
Wheeling, WV-OH	-	x	-	100	0.00	-0.51	-0.44	-0.81	-1.05	-1.39	-5.24	0.00	-0.39	-0.29	-0.74	-1.03	-1.46	-4.92
York, PA	-	x	-	100	0.00	-1.75	-1.52	-2.82	-3.63	-4.81	-18.10	0.00	-1.33	-1.00	-2.55	-3.58	-5.04	-17.02

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-57
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.03	0.10	0.00	0.02	0.02	0.03	0.03	0.03	0.10
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Atlanta, GA	x	x	100	100	0.00	0.08	0.09	0.13	0.16	0.19	0.54	0.00	0.08	0.09	0.13	0.16	0.19	0.54
Baltimore, MD	x	x	100	100	0.00	0.03	0.04	0.06	0.07	0.08	0.22	0.00	0.03	0.04	0.06	0.07	0.08	0.22
Baton Rouge, LA	x	-	100	-	0.00	-0.13	-0.16	-0.21	-0.24	-0.28	-0.56	0.00	-0.13	-0.16	-0.21	-0.24	-0.28	-0.56
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-0.27	-0.33	-0.44	-0.50	-0.59	-1.19	0.00	-0.27	-0.34	-0.44	-0.50	-0.59	-1.19
Birmingham, AL	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.08	0.00	0.01	0.01	0.02	0.02	0.03	0.08
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.06	0.06	0.09	0.11	0.13	0.37	0.00	0.06	0.06	0.09	0.11	0.13	0.37
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.01	0.02	0.02	0.03	0.03	0.09	0.00	0.01	0.02	0.02	0.03	0.03	0.09
Canton-Massillon, OH	-	x	-	100	0.00	-0.01	-0.02	-0.02	-0.03	-0.03	-0.05	0.00	-0.01	-0.02	-0.02	-0.03	-0.03	-0.05
Charleston, WV	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.02
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.02	0.02	0.04	0.04	0.05	0.14	0.00	0.02	0.02	0.04	0.04	0.05	0.14
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.01	0.04	0.00	0.01	0.01	0.01	0.01	0.01	0.04
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.11	-0.15	-0.19	-0.20	-0.24	-0.33	0.00	-0.11	-0.15	-0.19	-0.20	-0.24	-0.33
Chico, CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.02	0.03	0.04	0.04	0.05	0.15	0.00	0.02	0.03	0.04	0.04	0.05	0.15
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.03	0.04	0.05	0.06	0.07	0.21	0.00	0.03	0.04	0.05	0.06	0.07	0.21
Columbus, OH	x	x	100	100	0.00	0.02	0.02	0.03	0.04	0.05	0.14	0.00	0.02	0.02	0.03	0.04	0.05	0.14
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.09	0.10	0.14	0.16	0.19	0.55	0.00	0.09	0.10	0.14	0.16	0.19	0.55
Dayton-Springfield, OH	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.02	0.06	0.00	0.01	0.01	0.02	0.02	0.02	0.06
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.04	0.15	0.00	0.02	0.02	0.03	0.03	0.04	0.15
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.04	0.04	0.06	0.07	0.08	0.27	0.00	0.04	0.04	0.06	0.07	0.08	0.27
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Greater Connecticut, CT	x	-	100	-	0.00	0.02	0.02	0.03	0.04	0.05	0.14	0.00	0.02	0.02	0.03	0.04	0.05	0.14
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.02	0.06	0.00	0.01	0.01	0.02	0.02	0.02	0.06

Table B2-57
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.06	0.00	0.01	0.01	0.01	0.02	0.02	0.06
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-0.49	-0.63	-0.81	-0.92	-1.09	-2.11	0.00	-0.50	-0.63	-0.81	-0.92	-1.09	-2.11
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.05	-0.06	-0.08	-0.09	-0.11	-0.21	0.00	-0.05	-0.06	-0.08	-0.09	-0.11	-0.21
Imperial Co., CA	x	-	100	-	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Indianapolis, IN	-	x	-	100	0.00	0.02	0.02	0.03	0.04	0.04	0.13	0.00	0.02	0.02	0.03	0.04	0.04	0.13
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Knoxville, TN	x	x	100	100	0.00	0.01	0.02	0.02	0.03	0.03	0.09	0.00	0.01	0.02	0.02	0.03	0.03	0.09
Lancaster, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.01	0.03	0.00	0.01	0.01	0.01	0.01	0.01	0.03
Las Vegas, NV	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.04	0.11	0.00	0.02	0.02	0.03	0.03	0.04	0.11
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-0.12	-0.17	-0.20	-0.21	-0.26	-0.19	0.00	-0.12	-0.17	-0.20	-0.21	-0.26	-0.19
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.02	0.06	0.00	0.01	0.01	0.01	0.02	0.02	0.06
Louisville, KY-IN	-	x	-	100	0.00	0.01	0.02	0.02	0.03	0.03	0.09	0.00	0.01	0.02	0.02	0.03	0.03	0.09
Macon, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.00	0.00	0.01	0.01	0.01	0.01	0.03
Memphis, TN-AR	x	-	100	-	0.00	-0.03	-0.04	-0.05	-0.06	-0.07	-0.12	0.00	-0.03	-0.04	-0.05	-0.06	-0.07	-0.12
Milwaukee-Racine, WI	x	-	100	-	0.00	0.02	0.02	0.03	0.04	0.05	0.14	0.00	0.02	0.02	0.03	0.04	0.05	0.14
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	0.10	0.10	0.16	0.20	0.22	0.79	0.00	0.10	0.10	0.16	0.20	0.22	0.79
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-0.20	-0.26	-0.33	-0.37	-0.45	-0.75	0.00	-0.20	-0.26	-0.34	-0.37	-0.45	-0.75

Table B2-57
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.05	0.05	0.08	0.09	0.11	0.31	0.00	0.05	0.05	0.08	0.09	0.11	0.31
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.02	0.03	0.04	0.05	0.05	0.15	0.00	0.02	0.03	0.04	0.05	0.05	0.15
Poughkeepsie, NY	x	x	100	100	0.00	0.02	0.02	0.02	0.03	0.03	0.10	0.00	0.02	0.02	0.02	0.03	0.03	0.10
Providence (All RI), RI	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.02	0.07	0.00	0.01	0.01	0.02	0.02	0.02	0.07
Reading, PA	-	x	-	100	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.00	0.00	0.01	0.01	0.01	0.01	0.03
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.02	0.06	0.00	0.01	0.01	0.01	0.02	0.02	0.06
Rochester, NY	x	-	100	-	0.00	0.02	0.02	0.03	0.03	0.03	0.10	0.00	0.02	0.02	0.03	0.03	0.03	0.10
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Sacramento Metro, CA	x	-	50	-	0.00	0.03	0.03	0.04	0.05	0.06	0.17	0.00	0.03	0.03	0.04	0.05	0.06	0.17
San Diego, CA	x	-	100	-	0.00	0.04	0.04	0.06	0.07	0.08	0.24	0.00	0.04	0.04	0.06	0.07	0.08	0.24
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.08	-0.11	-0.13	-0.14	-0.17	-0.20	0.00	-0.08	-0.11	-0.13	-0.14	-0.17	-0.20
San Joaquin Valley, CA	x	x	50	100	0.00	0.03	0.03	0.04	0.05	0.06	0.23	0.00	0.03	0.03	0.04	0.05	0.06	0.23
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Springfield (Western MA), MA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.07	0.00	0.01	0.01	0.02	0.02	0.03	0.07
St. Louis, MO-IL	x	x	100	100	0.00	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	0.00	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Washington, DC-MD-VA	x	x	100	100	0.00	0.06	0.07	0.10	0.12	0.13	0.38	0.00	0.06	0.07	0.10	0.12	0.13	0.38
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
York, PA	-	x	-	100	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.00	0.00	0.01	0.01	0.01	0.01	0.03

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-58
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.02	0.02	0.01	0.01	-0.01	-0.13	0.00	0.05	0.05	0.05	0.05	0.03	-0.08
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.01	0.01	0.01	0.01	0.00	-0.01
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.01	0.01	0.00	0.00	-0.01
Atlanta, GA	x	x	100	100	0.00	0.10	0.11	0.08	0.05	-0.07	-0.78	0.00	0.27	0.30	0.28	0.27	0.17	-0.45
Baltimore, MD	x	x	100	100	0.00	0.04	0.04	0.03	0.02	-0.03	-0.30	0.00	0.10	0.11	0.11	0.10	0.06	-0.17
Baton Rouge, LA	x	-	100	-	0.00	-0.41	-0.48	-0.60	-0.67	-0.77	-1.58	0.00	-0.66	-0.75	-0.87	-0.96	-1.06	-1.76
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-0.85	-0.98	-1.21	-1.35	-1.54	-3.08	0.00	-1.37	-1.54	-1.79	-1.96	-2.15	-3.48
Birmingham, AL	-	x	-	100	0.00	0.01	0.01	0.01	0.01	-0.01	-0.11	0.00	0.04	0.04	0.04	0.04	0.02	-0.06
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.06	0.07	0.05	0.03	-0.04	-0.46	0.00	0.16	0.18	0.17	0.16	0.10	-0.26
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.01	0.01	0.01	0.00	-0.01	-0.07	0.00	0.02	0.02	0.02	0.02	0.01	-0.04
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.01	0.02	0.01	0.01	-0.01	-0.11	0.00	0.04	0.04	0.04	0.04	0.02	-0.06
Canton-Massillon, OH	-	x	-	100	0.00	-0.05	-0.06	-0.08	-0.09	-0.10	-0.23	0.00	-0.08	-0.09	-0.11	-0.12	-0.13	-0.24
Charleston, WV	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.01	0.01	0.01	0.01	0.01	-0.02
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.03	0.03	0.02	0.01	-0.02	-0.20	0.00	0.07	0.08	0.07	0.07	0.04	-0.12
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.01	0.01	0.01	0.00	0.00	-0.05	0.00	0.02	0.02	0.02	0.02	0.01	-0.03
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.52	-0.61	-0.81	-0.94	-1.17	-2.94	0.00	-0.75	-0.85	-1.04	-1.18	-1.41	-2.92
Chico, CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.01	0.01	0.01	0.01	0.00	-0.01
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.02	0.03	0.02	0.01	-0.02	-0.19	0.00	0.07	0.07	0.07	0.06	0.04	-0.11
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.01	0.01	0.01	0.01	0.00	-0.01
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.03	0.04	0.03	0.02	-0.02	-0.26	0.00	0.09	0.10	0.10	0.09	0.06	-0.15
Columbus, OH	x	x	100	100	0.00	0.02	0.03	0.02	0.01	-0.02	-0.18	0.00	0.06	0.07	0.07	0.06	0.04	-0.10
Dallas-Fort Worth, TX	x	-	100	-	0.00	0.10	0.11	0.08	0.05	-0.07	-0.77	0.00	0.27	0.30	0.28	0.26	0.17	-0.44
Dayton-Springfield, OH	-	x	-	100	0.00	0.01	0.01	0.01	0.01	-0.01	-0.08	0.00	0.03	0.03	0.03	0.03	0.02	-0.05
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.03	-0.03	-0.07	-0.09	-0.16	-0.60	0.00	0.01	0.00	-0.02	-0.05	-0.11	-0.49
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.01	-0.02	-0.06	-0.09	-0.18	-0.76	0.00	0.05	0.05	0.02	-0.01	-0.09	-0.59
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.01	0.01	0.01	0.01	0.01	-0.02
Greater Connecticut, CT	x	-	100	-	0.00	0.02	0.03	0.02	0.01	-0.02	-0.18	0.00	0.06	0.07	0.07	0.06	0.04	-0.10
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.01	0.01	0.01	0.01	-0.01	-0.08	0.00	0.03	0.03	0.03	0.03	0.02	-0.05

Table B2-58
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.00	-0.01	-0.07	0.00	0.03	0.03	0.03	0.03	0.02	-0.04
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.01	0.01	0.01	0.01	0.00	-0.01
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-1.68	-1.95	-2.43	-2.74	-3.18	-6.77	0.00	-2.65	-2.98	-3.49	-3.86	-4.30	-7.38
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.16	-0.19	-0.23	-0.26	-0.31	-0.64	0.00	-0.26	-0.29	-0.34	-0.37	-0.42	-0.71
Imperial Co., CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.01	0.01	0.01	0.01	0.01	-0.01
Indianapolis, IN	-	x	-	100	0.00	0.02	0.02	0.02	0.01	-0.01	-0.17	0.00	0.06	0.06	0.06	0.06	0.04	-0.10
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.01	0.01	0.01	0.01	0.00	-0.01
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.01	0.01	0.01	0.01	0.00	-0.01
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00	0.00	-0.01
Knoxville, TN	x	x	100	100	0.00	0.01	0.02	0.01	0.01	-0.01	-0.11	0.00	0.04	0.04	0.04	0.04	0.02	-0.06
Lancaster, PA	-	x	-	100	0.00	0.01	0.01	0.00	0.00	0.00	-0.04	0.00	0.02	0.02	0.02	0.01	0.01	-0.02
Las Vegas, NV	x	-	100	-	0.00	0.02	0.02	0.02	0.01	-0.01	-0.17	0.00	0.06	0.06	0.06	0.06	0.04	-0.09
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-0.73	-0.87	-1.18	-1.40	-1.82	-4.93	0.00	-0.98	-1.11	-1.41	-1.64	-2.04	-4.71
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.01	0.01	0.01	0.00	-0.01	-0.08	0.00	0.03	0.03	0.03	0.03	0.02	-0.05
Louisville, KY-IN	-	x	-	100	0.00	0.01	0.02	0.01	0.01	-0.01	-0.11	0.00	0.04	0.04	0.04	0.04	0.02	-0.06
Macon, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.01	0.01	0.01	0.01	0.00	-0.01
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.01	0.01	0.00	0.00	0.00	-0.05	0.00	0.02	0.02	0.02	0.02	0.01	-0.03
Memphis, TN-AR	x	-	100	-	0.00	-0.12	-0.14	-0.18	-0.21	-0.25	-0.59	0.00	-0.19	-0.21	-0.25	-0.28	-0.32	-0.61
Milwaukee-Racine, WI	x	-	100	-	0.00	0.02	0.02	0.02	0.01	-0.01	-0.18	0.00	0.06	0.07	0.06	0.06	0.04	-0.10
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.05	-0.07	-0.20	-0.29	-0.56	-2.32	0.00	0.12	0.12	0.02	-0.06	-0.29	-1.81
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.01	0.01	0.01	0.01	0.00	-0.01
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-0.80	-0.94	-1.20	-1.38	-1.68	-3.92	0.00	-1.21	-1.37	-1.64	-1.84	-2.12	-4.05

Table B2-58
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.06	0.06	0.05	0.03	-0.04	-0.45	0.00	0.16	0.17	0.16	0.15	0.10	-0.26
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.03	0.03	0.02	0.01	-0.02	-0.19	0.00	0.07	0.07	0.07	0.07	0.04	-0.11
Poughkeepsie, NY	x	x	100	100	0.00	0.02	0.02	0.01	0.01	-0.01	-0.13	0.00	0.05	0.05	0.05	0.05	0.03	-0.08
Providence (All RI), RI	x	-	100	-	0.00	0.01	0.01	0.01	0.01	-0.01	-0.09	0.00	0.03	0.04	0.03	0.03	0.02	-0.05
Reading, PA	-	x	-	100	0.00	0.01	0.01	0.00	0.00	0.00	-0.04	0.00	0.01	0.02	0.01	0.01	0.01	-0.02
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.01	0.01	0.01	0.01	-0.01	-0.09	0.00	0.03	0.04	0.03	0.03	0.02	-0.05
Rochester, NY	x	-	100	-	0.00	0.02	0.02	0.01	0.01	-0.01	-0.13	0.00	0.05	0.05	0.05	0.04	0.03	-0.07
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Sacramento Metro, CA	x	-	50	-	0.00	0.03	0.03	0.02	0.01	-0.02	-0.24	0.00	0.08	0.09	0.09	0.08	0.05	-0.13
San Diego, CA	x	-	100	-	0.00	0.04	0.04	0.03	0.02	-0.03	-0.30	0.00	0.11	0.12	0.11	0.10	0.07	-0.17
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.41	-0.49	-0.65	-0.76	-0.96	-2.47	0.00	-0.58	-0.66	-0.82	-0.93	-1.13	-2.42
San Joaquin Valley, CA	x	x	50	100	0.00	-0.02	-0.03	-0.07	-0.10	-0.19	-0.80	0.00	0.04	0.04	0.00	-0.02	-0.11	-0.62
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Springfield (Western MA), MA	x	-	100	-	0.00	0.01	0.01	0.01	0.01	-0.01	-0.09	0.00	0.03	0.04	0.03	0.03	0.02	-0.05
St. Louis, MO-IL	x	x	100	100	0.00	-0.19	-0.23	-0.30	-0.35	-0.44	-1.14	0.00	-0.27	-0.31	-0.38	-0.43	-0.52	-1.12
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.01	-0.02	-0.02	-0.02	-0.03	-0.06	0.00	-0.02	-0.02	-0.03	-0.03	-0.04	-0.07
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.01	0.01	0.00	0.00	-0.01	-0.07	0.00	0.02	0.02	0.02	0.02	0.01	-0.05
Washington, DC-MD-VA	x	x	100	100	0.00	0.07	0.07	0.05	0.03	-0.04	-0.51	0.00	0.18	0.20	0.19	0.18	0.11	-0.29
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.01	0.01	0.01	0.01	0.00	-0.01
York, PA	-	x	-	100	0.00	0.01	0.01	0.00	0.00	0.00	-0.04	0.00	0.01	0.02	0.02	0.01	0.01	-0.02

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-59
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-0.03	-0.02	-0.06	-0.10	-0.17	-0.81	0.00	0.07	0.09	0.05	0.01	-0.06	-0.61
Allegan Co., MI	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.09	0.00	0.01	0.01	0.01	0.00	-0.01	-0.07
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.09	0.00	0.01	0.01	0.01	0.00	-0.01	-0.07
Atlanta, GA	x	x	100	100	0.00	-0.20	-0.12	-0.39	-0.66	-1.08	-5.20	0.00	0.42	0.59	0.33	0.06	-0.36	-3.89
Baltimore, MD	x	x	100	100	0.00	-0.07	-0.04	-0.13	-0.23	-0.37	-1.78	0.00	0.15	0.20	0.11	0.02	-0.12	-1.33
Baton Rouge, LA	x	-	100	-	0.00	-0.68	-0.77	-0.95	-1.07	-1.23	-2.67	0.00	-1.33	-1.46	-1.67	-1.83	-1.99	-3.10
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1.35	-1.53	-1.86	-2.08	-2.35	-4.76	0.00	-2.73	-3.01	-3.40	-3.69	-3.97	-5.78
Birmingham, AL	-	x	-	100	0.00	-0.02	-0.01	-0.05	-0.08	-0.13	-0.62	0.00	0.05	0.07	0.04	0.01	-0.04	-0.47
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-0.10	-0.06	-0.20	-0.34	-0.56	-2.69	0.00	0.22	0.30	0.17	0.03	-0.19	-2.02
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.01	-0.01	-0.03	-0.05	-0.08	-0.39	0.00	0.03	0.04	0.02	0.00	-0.03	-0.29
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-0.02	-0.01	-0.05	-0.08	-0.13	-0.64	0.00	0.05	0.07	0.04	0.01	-0.04	-0.48
Canton-Massillon, OH	-	x	-	100	0.00	-0.09	-0.10	-0.13	-0.16	-0.19	-0.48	0.00	-0.16	-0.18	-0.21	-0.24	-0.27	-0.50
Charleston, WV	-	x	-	100	0.00	-0.01	0.00	-0.01	-0.02	-0.03	-0.16	0.00	0.01	0.02	0.01	0.00	-0.01	-0.12
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-0.05	-0.03	-0.10	-0.17	-0.27	-1.31	0.00	0.11	0.15	0.08	0.01	-0.09	-0.98
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.04	-0.07	-0.31	0.00	0.03	0.04	0.02	0.00	-0.02	-0.24
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-1.14	-1.20	-1.67	-2.05	-2.58	-7.69	0.00	-1.63	-1.70	-2.19	-2.63	-3.17	-7.37
Chico, CA	x	-	100	-	0.00	0.00	0.00	-0.01	-0.02	-0.02	-0.12	0.00	0.01	0.01	0.01	0.00	-0.01	-0.09
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-0.04	-0.03	-0.09	-0.14	-0.23	-1.13	0.00	0.09	0.13	0.07	0.01	-0.08	-0.85
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.10	0.00	0.01	0.01	0.01	0.00	-0.01	-0.07
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-0.06	-0.03	-0.11	-0.19	-0.31	-1.51	0.00	0.12	0.17	0.10	0.02	-0.11	-1.13
Columbus, OH	x	x	100	100	0.00	-0.04	-0.03	-0.08	-0.14	-0.23	-1.12	0.00	0.09	0.13	0.07	0.01	-0.08	-0.84
Dallas-Fort Worth, TX	x	-	100	-	0.00	-0.19	-0.11	-0.38	-0.63	-1.04	-5.01	0.00	0.41	0.57	0.32	0.06	-0.35	-3.75
Dayton-Springfield, OH	-	x	-	100	0.00	-0.02	-0.01	-0.03	-0.06	-0.10	-0.46	0.00	0.04	0.05	0.03	0.01	-0.03	-0.34
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.19	-0.18	-0.32	-0.45	-0.64	-2.55	0.00	-0.05	-0.01	-0.15	-0.28	-0.48	-2.09
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.23	-0.20	-0.38	-0.54	-0.80	-3.25	0.00	-0.01	0.05	-0.12	-0.30	-0.55	-2.63
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	-0.01	0.00	-0.02	-0.03	-0.04	-0.21	0.00	0.02	0.02	0.01	0.00	-0.01	-0.16
Greater Connecticut, CT	x	-	100	-	0.00	-0.04	-0.02	-0.08	-0.14	-0.22	-1.07	0.00	0.09	0.12	0.07	0.01	-0.08	-0.80
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.02
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-0.02	-0.01	-0.04	-0.06	-0.10	-0.49	0.00	0.04	0.06	0.03	0.01	-0.03	-0.37

Table B2-59
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-0.02	-0.01	-0.03	-0.05	-0.09	-0.43	0.00	0.04	0.05	0.03	0.00	-0.03	-0.32
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hickory, NC	-	x	-	100	0.00	0.00	0.00	-0.01	-0.02	-0.02	-0.12	0.00	0.01	0.01	0.01	0.00	-0.01	-0.09
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-2.86	-3.19	-4.03	-4.62	-5.38	-12.53	0.00	-5.36	-5.85	-6.77	-7.52	-8.32	-13.92
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.27	-0.31	-0.38	-0.44	-0.51	-1.14	0.00	-0.52	-0.57	-0.66	-0.73	-0.80	-1.29
Imperial Co., CA	x	-	100	-	0.00	-0.01	0.00	-0.01	-0.02	-0.03	-0.17	0.00	0.01	0.02	0.01	0.00	-0.01	-0.12
Indianapolis, IN	-	x	-	100	0.00	-0.04	-0.02	-0.08	-0.13	-0.22	-1.04	0.00	0.09	0.12	0.07	0.01	-0.07	-0.78
Jamestown, NY	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.08	0.00	0.01	0.01	0.01	0.00	-0.01	-0.06
Jefferson Co., NY	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.09	0.00	0.01	0.01	0.01	0.00	-0.01	-0.07
Johnstown, PA	-	x	-	100	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.07	0.00	0.01	0.01	0.00	0.00	0.00	-0.05
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.09	0.00	0.01	0.01	0.01	0.00	-0.01	-0.06
Knoxville, TN	x	x	100	100	0.00	-0.03	-0.02	-0.05	-0.09	-0.14	-0.68	0.00	0.06	0.08	0.04	0.01	-0.05	-0.51
Lancaster, PA	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.03	-0.05	-0.26	0.00	0.02	0.03	0.02	0.00	-0.02	-0.19
Las Vegas, NV	x	-	100	-	0.00	-0.04	-0.03	-0.09	-0.14	-0.23	-1.13	0.00	0.09	0.13	0.07	0.01	-0.08	-0.85
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-1.85	-1.90	-2.77	-3.50	-4.57	-14.79	0.00	-2.23	-2.24	-3.14	-3.96	-5.04	-13.52
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-0.02	-0.01	-0.04	-0.06	-0.10	-0.51	0.00	0.04	0.06	0.03	0.01	-0.04	-0.38
Louisville, KY-IN	-	x	-	100	0.00	-0.02	-0.01	-0.05	-0.08	-0.13	-0.64	0.00	0.05	0.07	0.04	0.01	-0.04	-0.48
Macon, GA	-	x	-	100	0.00	0.00	0.00	-0.01	-0.02	-0.03	-0.12	0.00	0.01	0.01	0.01	0.00	-0.01	-0.09
Manitowoc Co., WI	x	-		-	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.06	0.00	0.00	0.01	0.00	0.00	0.00	-0.05
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.08	0.00	0.01	0.01	0.00	0.00	-0.01	-0.06
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.04	-0.07	-0.31	0.00	0.03	0.04	0.02	0.00	-0.02	-0.23
Memphis, TN-AR	x	-	100	-	0.00	-0.24	-0.26	-0.34	-0.40	-0.49	-1.30	0.00	-0.39	-0.42	-0.51	-0.58	-0.67	-1.33
Milwaukee-Racine, WI	x	-	100	-	0.00	-0.04	-0.02	-0.08	-0.13	-0.21	-1.03	0.00	0.08	0.12	0.07	0.01	-0.07	-0.77
Nevada (Western Part), CA	x	-	100	-	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.06	0.00	0.01	0.01	0.00	0.00	0.00	-0.05
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-0.70	-0.62	-1.16	-1.66	-2.41	-9.77	0.00	-0.08	0.10	-0.42	-0.95	-1.71	-7.94
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.09	0.00	0.01	0.01	0.01	0.00	-0.01	-0.07
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-1.57	-1.70	-2.27	-2.71	-3.31	-9.06	0.00	-2.55	-2.71	-3.32	-3.84	-4.46	-9.12

Table B2-59
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-0.11	-0.07	-0.23	-0.38	-0.63	-3.02	0.00	0.25	0.34	0.19	0.03	-0.21	-2.26
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-0.04	-0.02	-0.08	-0.14	-0.22	-1.07	0.00	0.09	0.12	0.07	0.01	-0.07	-0.80
Poughkeepsie, NY	x	x	100	100	0.00	-0.03	-0.02	-0.06	-0.10	-0.17	-0.81	0.00	0.07	0.09	0.05	0.01	-0.06	-0.61
Providence (All RI), RI	x	-	100	-	0.00	-0.02	-0.01	-0.04	-0.07	-0.11	-0.54	0.00	0.04	0.06	0.03	0.01	-0.04	-0.40
Reading, PA	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.03	-0.05	-0.24	0.00	0.02	0.03	0.02	0.00	-0.02	-0.18
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-0.03	-0.02	-0.05	-0.09	-0.14	-0.68	0.00	0.06	0.08	0.04	0.01	-0.05	-0.51
Rochester, NY	x	-	100	-	0.00	-0.03	-0.02	-0.06	-0.10	-0.16	-0.76	0.00	0.06	0.09	0.05	0.01	-0.05	-0.57
Rome, GA	-	x	-	100	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.07	0.00	0.01	0.01	0.00	0.00	0.00	-0.05
Sacramento Metro, CA	x	-	50	-	0.00	-0.06	-0.03	-0.11	-0.19	-0.31	-1.48	0.00	0.12	0.17	0.09	0.02	-0.10	-1.11
San Diego, CA	x	-	100	-	0.00	-0.07	-0.04	-0.13	-0.22	-0.36	-1.75	0.00	0.14	0.20	0.11	0.02	-0.12	-1.31
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.94	-0.99	-1.38	-1.71	-2.17	-6.60	0.00	-1.30	-1.34	-1.76	-2.13	-2.60	-6.25
San Joaquin Valley, CA	x	x	50	100	0.00	-0.25	-0.22	-0.43	-0.61	-0.90	-3.69	0.00	-0.01	0.07	-0.13	-0.33	-0.62	-2.98
Sheboygan, WI	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.07	0.00	0.01	0.01	0.00	0.00	0.00	-0.05
Springfield (Western MA), MA	x	-	100	-	0.00	-0.02	-0.01	-0.04	-0.07	-0.12	-0.56	0.00	0.05	0.06	0.04	0.01	-0.04	-0.42
St. Louis, MO-IL	x	x	100	100	0.00	-0.43	-0.46	-0.64	-0.79	-1.00	-3.04	0.00	-0.60	-0.62	-0.81	-0.98	-1.20	-2.88
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.03	-0.03	-0.04	-0.04	-0.05	-0.14	0.00	-0.04	-0.05	-0.06	-0.06	-0.07	-0.14
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-0.02	-0.01	-0.03	-0.05	-0.08	-0.39	0.00	0.02	0.03	0.02	-0.01	-0.04	-0.29
Washington, DC-MD-VA	x	x	100	100	0.00	-0.12	-0.07	-0.24	-0.40	-0.66	-3.16	0.00	0.26	0.36	0.20	0.03	-0.22	-2.36
Wheeling, WV-OH	-	x	-	100	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.09	0.00	0.01	0.01	0.01	0.00	-0.01	-0.07
York, PA	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.03	-0.06	-0.27	0.00	0.02	0.03	0.02	0.00	-0.02	-0.20

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-60
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-0.16	-0.12	-0.21	-0.33	-0.48	-2.12	0.00	0.07	0.14	0.03	-0.11	-0.29	-1.62
Allegan Co., MI	x	-	100	-	0.00	-0.02	-0.01	-0.02	-0.04	-0.05	-0.23	0.00	0.01	0.02	0.00	-0.01	-0.03	-0.18
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.02	-0.01	-0.03	-0.04	-0.06	-0.27	0.00	0.01	0.02	0.00	-0.01	-0.04	-0.21
Atlanta, GA	x	x	100	100	0.00	-1.25	-0.93	-1.68	-2.64	-3.86	-16.83	0.00	0.52	1.10	0.25	-0.88	-2.30	-12.91
Baltimore, MD	x	x	100	100	0.00	-0.34	-0.25	-0.46	-0.72	-1.05	-4.59	0.00	0.14	0.30	0.07	-0.24	-0.63	-3.52
Baton Rouge, LA	x	-	100	-	0.00	-1.02	-1.12	-1.37	-1.58	-1.82	-4.20	0.00	-2.19	-2.36	-2.67	-2.95	-3.22	-4.92
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1.92	-2.15	-2.59	-2.90	-3.26	-6.72	0.00	-4.46	-4.86	-5.40	-5.86	-6.25	-8.56
Birmingham, AL	-	x	-	100	0.00	-0.12	-0.09	-0.16	-0.25	-0.36	-1.57	0.00	0.05	0.10	0.02	-0.08	-0.21	-1.21
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-0.48	-0.36	-0.65	-1.02	-1.49	-6.50	0.00	0.20	0.43	0.10	-0.34	-0.89	-4.99
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.07	-0.05	-0.10	-0.15	-0.23	-0.99	0.00	0.03	0.06	0.01	-0.05	-0.13	-0.76
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-0.11	-0.08	-0.15	-0.24	-0.34	-1.50	0.00	0.05	0.10	0.02	-0.08	-0.20	-1.15
Canton-Massillon, OH	-	x	-	100	0.00	-0.15	-0.16	-0.21	-0.25	-0.30	-0.83	0.00	-0.28	-0.29	-0.34	-0.40	-0.46	-0.86
Charleston, WV	-	x	-	100	0.00	-0.03	-0.02	-0.04	-0.06	-0.09	-0.37	0.00	0.01	0.02	0.01	-0.02	-0.05	-0.29
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-0.30	-0.22	-0.40	-0.62	-0.91	-3.98	0.00	0.12	0.26	0.06	-0.21	-0.54	-3.06
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.06	-0.04	-0.08	-0.12	-0.18	-0.77	0.00	0.02	0.05	0.01	-0.04	-0.10	-0.59
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-2.24	-2.19	-3.03	-3.90	-4.98	-16.32	0.00	-2.88	-2.77	-3.74	-4.85	-6.09	-14.99
Chico, CA	x	-	100	-	0.00	-0.02	-0.02	-0.03	-0.05	-0.07	-0.30	0.00	0.01	0.02	0.00	-0.02	-0.04	-0.23
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-0.22	-0.17	-0.30	-0.47	-0.69	-3.00	0.00	0.09	0.20	0.05	-0.16	-0.41	-2.30
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.02	-0.01	-0.02	-0.03	-0.05	-0.22	0.00	0.01	0.01	0.00	-0.01	-0.03	-0.17
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-0.26	-0.20	-0.35	-0.56	-0.81	-3.54	0.00	0.11	0.23	0.05	-0.19	-0.48	-2.72
Columbus, OH	x	x	100	100	0.00	-0.23	-0.17	-0.31	-0.48	-0.71	-3.08	0.00	0.09	0.20	0.05	-0.16	-0.42	-2.37
Dallas-Fort Worth, TX	x	-	100	-	0.00	-1.14	-0.85	-1.53	-2.40	-3.50	-15.28	0.00	0.47	1.00	0.23	-0.80	-2.09	-11.72
Dayton-Springfield, OH	-	x	-	100	0.00	-0.08	-0.06	-0.11	-0.17	-0.25	-1.08	0.00	0.03	0.07	0.02	-0.06	-0.15	-0.83
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-0.62	-0.52	-0.83	-1.20	-1.67	-6.67	0.00	-0.18	-0.01	-0.36	-0.81	-1.36	-5.40
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-0.68	-0.57	-0.92	-1.34	-1.86	-7.47	0.00	-0.18	0.02	-0.38	-0.88	-1.49	-6.03
Door Co., WI	x	-	100	-	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.04	0.00	0.00	0.00	0.00	0.00	-0.01	-0.03
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	-0.04	-0.03	-0.05	-0.08	-0.12	-0.52	0.00	0.02	0.03	0.01	-0.03	-0.07	-0.40
Greater Connecticut, CT	x	-	100	-	0.00	-0.20	-0.15	-0.27	-0.42	-0.62	-2.69	0.00	0.08	0.18	0.04	-0.14	-0.37	-2.07
Greene Co., PA	x	-	100	-	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.05	0.00	0.00	0.00	0.00	0.00	-0.01	-0.04
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-0.09	-0.07	-0.12	-0.19	-0.28	-1.23	0.00	0.04	0.08	0.02	-0.06	-0.17	-0.94

Table B2-60
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-0.08	-0.06	-0.11	-0.16	-0.24	-1.05	0.00	0.03	0.07	0.02	-0.06	-0.14	-0.81
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Hickory, NC	-	x	-	100	0.00	-0.02	-0.02	-0.03	-0.05	-0.07	-0.31	0.00	0.01	0.02	0.00	-0.02	-0.04	-0.24
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-4.52	-4.84	-6.09	-7.17	-8.46	-21.56	0.00	-8.89	-9.44	-10.94	-12.40	-13.87	-23.52
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.42	-0.45	-0.56	-0.65	-0.75	-1.81	0.00	-0.86	-0.93	-1.06	-1.18	-1.30	-2.06
Imperial Co., CA	x	-	100	-	0.00	-0.04	-0.03	-0.05	-0.08	-0.12	-0.51	0.00	0.02	0.03	0.01	-0.03	-0.07	-0.39
Indianapolis, IN	-	x	-	100	0.00	-0.21	-0.16	-0.29	-0.45	-0.66	-2.88	0.00	0.09	0.19	0.04	-0.15	-0.39	-2.21
Jamestown, NY	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.03	-0.05	-0.20	0.00	0.01	0.01	0.00	-0.01	-0.03	-0.15
Jefferson Co., NY	x	-	100	-	0.00	-0.02	-0.01	-0.02	-0.04	-0.06	-0.24	0.00	0.01	0.02	0.00	-0.01	-0.03	-0.19
Johnstown, PA	-	x	-	100	0.00	-0.01	-0.01	-0.01	-0.02	-0.03	-0.15	0.00	0.00	0.01	0.00	-0.01	-0.02	-0.11
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.02	-0.01	-0.03	-0.04	-0.06	-0.26	0.00	0.01	0.02	0.00	-0.01	-0.04	-0.20
Knoxville, TN	x	x	100	100	0.00	-0.13	-0.10	-0.18	-0.28	-0.41	-1.77	0.00	0.05	0.12	0.03	-0.09	-0.24	-1.36
Lancaster, PA	-	x	-	100	0.00	-0.05	-0.03	-0.06	-0.10	-0.14	-0.63	0.00	0.02	0.04	0.01	-0.03	-0.09	-0.48
Las Vegas, NV	x	-	100	-	0.00	-0.28	-0.21	-0.37	-0.58	-0.85	-3.72	0.00	0.11	0.24	0.06	-0.20	-0.51	-2.86
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-4.14	-3.87	-5.57	-7.45	-9.81	-34.53	0.00	-4.08	-3.58	-5.55	-7.88	-10.59	-30.25
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-0.11	-0.08	-0.15	-0.23	-0.33	-1.45	0.00	0.04	0.10	0.02	-0.08	-0.20	-1.11
Louisville, KY-IN	-	x	-	100	0.00	-0.11	-0.08	-0.15	-0.24	-0.35	-1.52	0.00	0.05	0.10	0.02	-0.08	-0.21	-1.17
Macon, GA	-	x	-	100	0.00	-0.02	-0.02	-0.03	-0.05	-0.07	-0.29	0.00	0.01	0.02	0.00	-0.02	-0.04	-0.22
Manitowoc Co., WI	x	-		-	0.00	-0.01	-0.01	-0.01	-0.02	-0.03	-0.14	0.00	0.00	0.01	0.00	-0.01	-0.02	-0.11
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.02	-0.01	-0.02	-0.04	-0.05	-0.23	0.00	0.01	0.02	0.00	-0.01	-0.03	-0.18
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.07	-0.06	-0.10	-0.16	-0.23	-1.00	0.00	0.03	0.07	0.02	-0.05	-0.14	-0.76
Memphis, TN-AR	x	-	100	-	0.00	-0.40	-0.41	-0.54	-0.66	-0.81	-2.35	0.00	-0.67	-0.69	-0.84	-1.00	-1.17	-2.35
Milwaukee-Racine, WI	x	-	100	-	0.00	-0.18	-0.14	-0.25	-0.39	-0.57	-2.48	0.00	0.08	0.16	0.04	-0.13	-0.34	-1.90
Nevada (Western Part), CA	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.03	-0.04	-0.17	0.00	0.01	0.01	0.00	-0.01	-0.02	-0.13
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-2.06	-1.74	-2.77	-4.02	-5.59	-22.28	0.00	-0.63	-0.04	-1.22	-2.73	-4.55	-18.06
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.03	-0.05	-0.20	0.00	0.01	0.01	0.00	-0.01	-0.03	-0.15
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-2.81	-2.85	-3.78	-4.70	-5.84	-17.58	0.00	-4.37	-4.43	-5.53	-6.72	-8.02	-17.07

Table B2-60
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Butadiene 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-0.71	-0.53	-0.95	-1.49	-2.18	-9.52	0.00	0.29	0.62	0.14	-0.50	-1.30	-7.30
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-0.18	-0.13	-0.24	-0.38	-0.55	-2.42	0.00	0.07	0.16	0.04	-0.13	-0.33	-1.85
Poughkeepsie, NY	x	x	100	100	0.00	-0.16	-0.12	-0.21	-0.33	-0.49	-2.13	0.00	0.07	0.14	0.03	-0.11	-0.29	-1.63
Providence (All RI), RI	x	-	100	-	0.00	-0.10	-0.07	-0.13	-0.20	-0.29	-1.28	0.00	0.04	0.08	0.02	-0.07	-0.17	-0.98
Reading, PA	-	x	-	100	0.00	-0.05	-0.03	-0.06	-0.10	-0.14	-0.63	0.00	0.02	0.04	0.01	-0.03	-0.09	-0.48
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-0.19	-0.14	-0.25	-0.40	-0.58	-2.55	0.00	0.08	0.17	0.04	-0.13	-0.35	-1.95
Rochester, NY	x	-	100	-	0.00	-0.14	-0.10	-0.19	-0.29	-0.42	-1.85	0.00	0.06	0.12	0.03	-0.10	-0.25	-1.42
Rome, GA	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.02	-0.04	-0.16	0.00	0.00	0.01	0.00	-0.01	-0.02	-0.12
Sacramento Metro, CA	x	-	50	-	0.00	-0.32	-0.24	-0.42	-0.67	-0.97	-4.24	0.00	0.13	0.28	0.06	-0.22	-0.58	-3.25
San Diego, CA	x	-	100	-	0.00	-0.31	-0.23	-0.42	-0.65	-0.95	-4.15	0.00	0.13	0.27	0.06	-0.22	-0.57	-3.18
San Francisco Bay Area, CA	x	-	100	-	0.00	-1.82	-1.78	-2.46	-3.16	-4.04	-13.23	0.00	-2.34	-2.26	-3.04	-3.94	-4.95	-12.16
San Joaquin Valley, CA	x	x	50	100	0.00	-0.92	-0.75	-1.23	-1.82	-2.56	-10.44	0.00	-0.14	0.16	-0.39	-1.09	-1.95	-8.34
Sheboygan, WI	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.03	-0.04	-0.18	0.00	0.01	0.01	0.00	-0.01	-0.02	-0.13
Springfield (Western MA), MA	x	-	100	-	0.00	-0.10	-0.08	-0.14	-0.22	-0.31	-1.37	0.00	0.04	0.09	0.02	-0.07	-0.19	-1.05
St. Louis, MO-IL	x	x	100	100	0.00	-0.84	-0.82	-1.14	-1.46	-1.87	-6.13	0.00	-1.08	-1.04	-1.40	-1.82	-2.29	-5.63
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.04	-0.04	-0.06	-0.07	-0.08	-0.24	0.00	-0.08	-0.08	-0.09	-0.11	-0.13	-0.24
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-0.07	-0.06	-0.10	-0.15	-0.22	-0.92	0.00	0.02	0.05	0.00	-0.06	-0.14	-0.72
Washington, DC-MD-VA	x	x	100	100	0.00	-0.66	-0.49	-0.88	-1.38	-2.02	-8.81	0.00	0.27	0.58	0.13	-0.46	-1.20	-6.76
Wheeling, WV-OH	-	x	-	100	0.00	-0.02	-0.01	-0.02	-0.03	-0.05	-0.21	0.00	0.01	0.01	0.00	-0.01	-0.03	-0.16
York, PA	-	x	-	100	0.00	-0.05	-0.04	-0.07	-0.11	-0.17	-0.73	0.00	0.02	0.05	0.01	-0.04	-0.10	-0.56

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-61
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-162.27	-208.19	-420.79	-504.21	-727.77	-2,624.50	0.00	-162.27	-208.19	-420.80	-504.22	-727.78	-2,624.51
Allegan Co., MI	x	-	100	-	0.00	-17.75	-22.77	-46.03	-55.15	-79.61	-287.08	0.00	-17.75	-22.77	-46.03	-55.15	-79.61	-287.09
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-16.13	-20.70	-41.84	-50.13	-72.36	-260.94	0.00	-16.13	-20.70	-41.84	-50.13	-72.36	-260.94
Atlanta, GA	x	x	100	100	0.00	-863.08	-1,107.30	-2,238.12	-2,681.82	-3,870.89	-13,959.30	0.00	-863.10	-1,107.33	-2,238.14	-2,681.85	-3,870.91	-13,959.32
Baltimore, MD	x	x	100	100	0.00	-358.64	-460.12	-930.00	-1,114.38	-1,608.46	-5,800.46	0.00	-358.65	-460.13	-930.01	-1,114.39	-1,608.47	-5,800.47
Baton Rouge, LA	x	-	100	-	0.00	-111.80	-142.83	-261.71	-311.04	-434.25	-1,462.39	0.00	-111.88	-142.92	-261.81	-311.13	-434.35	-1,462.46
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-108.81	-138.40	-225.41	-264.94	-352.82	-1,063.74	0.00	-108.98	-138.58	-225.59	-265.13	-353.02	-1,063.87
Birmingham, AL	-	x	-	100	0.00	-131.19	-168.31	-340.20	-407.65	-588.39	-2,121.90	0.00	-131.19	-168.32	-340.21	-407.65	-588.40	-2,121.90
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-583.54	-748.66	-1,513.21	-1,813.20	-2,617.13	-9,437.94	0.00	-583.55	-748.68	-1,513.22	-1,813.22	-2,617.15	-9,437.96
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-78.93	-101.26	-204.69	-245.27	-354.03	-1,276.80	0.00	-78.93	-101.26	-204.69	-245.28	-354.04	-1,276.80
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-140.31	-180.01	-363.85	-435.98	-629.29	-2,269.34	0.00	-140.31	-180.02	-363.85	-435.99	-629.29	-2,269.35
Canton-Massillon, OH	-	x	-	100	0.00	-43.69	-55.98	-109.63	-131.02	-187.20	-661.55	0.00	-43.71	-55.99	-109.64	-131.04	-187.21	-661.56
Charleston, WV	-	x	-	100	0.00	-37.57	-48.21	-97.44	-116.75	-168.52	-607.72	0.00	-37.58	-48.21	-97.44	-116.75	-168.52	-607.72
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-226.84	-291.04	-588.39	-705.05	-1,017.72	-3,670.63	0.00	-226.85	-291.04	-588.39	-705.05	-1,017.73	-3,670.64
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-67.20	-86.22	-174.27	-208.82	-301.42	-1,087.00	0.00	-67.20	-86.22	-174.27	-208.83	-301.42	-1,087.00
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-928.89	-1,190.88	-2,367.77	-2,833.45	-4,068.36	-14,520.68	0.00	-929.03	-1,191.03	-2,367.92	-2,833.61	-4,068.53	-14,520.79
Chico, CA	x	-	100	-	0.00	-24.27	-31.13	-62.92	-75.40	-108.83	-392.46	0.00	-24.27	-31.13	-62.92	-75.40	-108.83	-392.46
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-232.37	-298.13	-602.60	-722.07	-1,042.23	-3,758.59	0.00	-232.38	-298.14	-602.61	-722.08	-1,042.24	-3,758.59
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-21.97	-28.19	-56.98	-68.28	-98.55	-355.40	0.00	-21.97	-28.19	-56.98	-68.28	-98.55	-355.40
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-334.77	-429.50	-868.12	-1,040.23	-1,501.44	-5,414.53	0.00	-334.78	-429.51	-868.13	-1,040.24	-1,501.45	-5,414.54
Columbus, OH	x	x	100	100	0.00	-216.42	-277.66	-561.21	-672.47	-970.63	-3,500.29	0.00	-216.42	-277.66	-561.21	-672.47	-970.63	-3,500.30
Dallas-Fort Worth, TX	x	-	100	-	0.00	-876.85	-1,124.97	-2,273.83	-2,724.61	-3,932.65	-14,182.00	0.00	-876.87	-1,125.00	-2,273.85	-2,724.64	-3,932.67	-14,182.02
Dayton-Springfield, OH	-	x	-	100	0.00	-101.52	-130.25	-263.27	-315.46	-455.33	-1,642.01	0.00	-101.53	-130.25	-263.27	-315.46	-455.33	-1,642.01
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-410.91	-527.09	-1,060.83	-1,270.71	-1,831.65	-6,587.92	0.00	-410.94	-527.12	-1,060.86	-1,270.74	-1,831.68	-6,587.94
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-616.39	-790.71	-1,593.37	-1,908.80	-2,752.48	-9,907.53	0.00	-616.42	-790.74	-1,593.40	-1,908.83	-2,752.52	-9,907.56
Door Co., WI	x	-	100	-	0.00	-4.12	-5.29	-10.68	-12.80	-18.48	-66.64	0.00	-4.12	-5.29	-10.68	-12.80	-18.48	-66.64
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.17	-0.22	-0.45	-0.54	-0.78	-2.80	0.00	-0.17	-0.22	-0.45	-0.54	-0.78	-2.80
Evansville, IN	-	x	-	100	0.00	-43.49	-55.79	-112.79	-135.15	-195.08	-703.58	0.00	-43.49	-55.79	-112.79	-135.15	-195.08	-703.58
Greater Connecticut, CT	x	-	100	-	0.00	-222.00	-284.81	-575.67	-689.79	-995.63	-3,590.44	0.00	-222.00	-284.82	-575.67	-689.80	-995.64	-3,590.44
Greene Co., PA	x	-	100	-	0.00	-5.10	-6.54	-13.22	-15.84	-22.86	-82.45	0.00	-5.10	-6.54	-13.22	-15.84	-22.86	-82.45
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-100.40	-128.81	-260.35	-311.97	-450.29	-1,623.84	0.00	-100.40	-128.81	-260.36	-311.97	-450.29	-1,623.84

Table B2-61
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-90.95	-116.69	-235.85	-282.61	-407.91	-1,471.01	0.00	-90.95	-116.69	-235.85	-282.61	-407.91	-1,471.01
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.63	-0.80	-1.62	-1.94	-2.81	-10.12	0.00	-0.63	-0.80	-1.62	-1.94	-2.81	-10.12
Hickory, NC	-	x	-	100	0.00	-23.58	-30.26	-61.15	-73.28	-105.77	-381.41	0.00	-23.58	-30.26	-61.15	-73.28	-105.77	-381.41
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-763.12	-976.60	-1,862.71	-2,221.44	-3,145.82	-10,917.46	0.00	-763.47	-976.98	-1,863.10	-2,221.84	-3,146.23	-10,917.74
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-66.26	-84.77	-160.70	-191.55	-270.68	-935.30	0.00	-66.29	-84.81	-160.74	-191.59	-270.72	-935.32
Imperial Co., CA	x	-	100	-	0.00	-27.99	-35.91	-72.59	-86.98	-125.55	-452.76	0.00	-27.99	-35.92	-72.59	-86.98	-125.55	-452.76
Indianapolis, IN	-	x	-	100	0.00	-202.03	-259.20	-523.90	-627.77	-906.10	-3,267.62	0.00	-202.04	-259.21	-523.91	-627.77	-906.11	-3,267.62
Jamestown, NY	x	-	100	-	0.00	-18.68	-23.97	-48.44	-58.05	-83.78	-302.14	0.00	-18.68	-23.97	-48.44	-58.05	-83.78	-302.14
Jefferson Co., NY	x	-	100	-	0.00	-17.35	-22.25	-44.98	-53.90	-77.80	-280.55	0.00	-17.35	-22.26	-44.98	-53.90	-77.80	-280.55
Johnstown, PA	-	x	-	100	0.00	-15.32	-19.66	-39.73	-47.61	-68.71	-247.80	0.00	-15.32	-19.66	-39.73	-47.61	-68.71	-247.80
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-14.70	-18.85	-38.10	-45.65	-65.89	-237.59	0.00	-14.70	-18.85	-38.10	-45.65	-65.89	-237.59
Knoxville, TN	x	x	100	100	0.00	-137.27	-176.12	-355.98	-426.55	-615.67	-2,220.26	0.00	-137.28	-176.12	-355.98	-426.55	-615.68	-2,220.26
Lancaster, PA	-	x	-	100	0.00	-53.65	-68.83	-139.13	-166.71	-240.62	-867.75	0.00	-53.65	-68.83	-139.13	-166.71	-240.63	-867.75
Las Vegas, NV	x	-	100	-	0.00	-177.73	-228.02	-460.88	-552.25	-797.11	-2,874.58	0.00	-177.73	-228.02	-460.89	-552.26	-797.12	-2,874.58
Libby, MT	-	x	-	100	0.00	-0.88	-1.13	-2.28	-2.74	-3.95	-14.25	0.00	-0.88	-1.13	-2.28	-2.74	-3.95	-14.25
Liberty-Clairton, PA	-	x	-	100	0.00	-1.73	-2.22	-4.48	-5.37	-7.75	-27.96	0.00	-1.73	-2.22	-4.48	-5.37	-7.75	-27.96
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-1,921.32	-2,463.68	-4,919.78	-5,889.44	-8,468.10	-30,307.98	0.00	-1,921.54	-2,463.92	-4,920.03	-5,889.70	-8,468.36	-30,308.16
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-91.64	-117.57	-237.62	-284.73	-410.97	-1,482.05	0.00	-91.64	-117.57	-237.63	-284.73	-410.98	-1,482.05
Louisville, KY-IN	-	x	-	100	0.00	-140.95	-180.84	-365.53	-438.00	-632.21	-2,279.95	0.00	-140.95	-180.84	-365.53	-438.00	-632.21	-2,279.95
Macon, GA	-	x	-	100	0.00	-26.27	-33.70	-68.12	-81.62	-117.82	-424.89	0.00	-26.27	-33.70	-68.12	-81.62	-117.82	-424.89
Manitowoc Co., WI	x	-		-	0.00	-13.46	-17.27	-34.90	-41.81	-60.35	-217.64	0.00	-13.46	-17.27	-34.90	-41.81	-60.35	-217.64
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-13.14	-16.86	-34.08	-40.84	-58.94	-212.56	0.00	-13.14	-16.86	-34.08	-40.84	-58.94	-212.56
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-51.44	-65.99	-133.39	-159.83	-230.70	-831.95	0.00	-51.44	-66.00	-133.39	-159.83	-230.70	-831.95
Memphis, TN-AR	x	-	100	-	0.00	-133.90	-171.60	-338.15	-404.36	-578.92	-2,054.34	0.00	-133.93	-171.63	-338.18	-404.40	-578.95	-2,054.36
Milwaukee-Racine, WI	x	-	100	-	0.00	-221.07	-283.63	-573.27	-686.92	-991.49	-3,575.52	0.00	-221.08	-283.63	-573.28	-686.93	-991.49	-3,575.52
Nevada (Western Part), CA	x	-	100	-	0.00	-12.50	-16.04	-32.42	-38.84	-56.07	-202.19	0.00	-12.50	-16.04	-32.42	-38.84	-56.07	-202.19
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-1,836.32	-2,355.60	-4,745.84	-5,685.25	-8,197.60	-29,503.37	0.00	-1,836.41	-2,355.70	-4,745.94	-5,685.35	-8,197.71	-29,503.45
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-19.91	-25.55	-51.64	-61.88	-89.32	-322.10	0.00	-19.91	-25.55	-51.64	-61.88	-89.32	-322.10
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-929.31	-1,191.02	-2,350.08	-2,810.56	-4,025.54	-14,297.23	0.00	-929.51	-1,191.23	-2,350.30	-2,810.78	-4,025.77	-14,297.39

Table B2-61
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-493.92	-633.69	-1,280.88	-1,534.82	-2,215.36	-7,989.33	0.00	-493.93	-633.70	-1,280.89	-1,534.84	-2,215.38	-7,989.34
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-247.14	-317.08	-640.89	-767.95	-1,108.44	-3,997.29	0.00	-247.15	-317.08	-640.90	-767.95	-1,108.45	-3,997.29
Poughkeepsie, NY	x	x	100	100	0.00	-160.19	-205.52	-415.41	-497.77	-718.47	-2,590.95	0.00	-160.20	-205.53	-415.42	-497.77	-718.47	-2,590.95
Providence (All RI), RI	x	-	100	-	0.00	-115.89	-148.68	-300.51	-360.09	-519.75	-1,874.32	0.00	-115.89	-148.68	-300.52	-360.09	-519.75	-1,874.32
Reading, PA	-	x	-	100	0.00	-47.07	-60.39	-122.07	-146.26	-211.11	-761.33	0.00	-47.07	-60.39	-122.07	-146.27	-211.12	-761.33
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-93.44	-119.88	-242.31	-290.34	-419.08	-1,511.27	0.00	-93.44	-119.89	-242.31	-290.35	-419.08	-1,511.27
Rochester, NY	x	-	100	-	0.00	-162.33	-208.27	-420.95	-504.40	-728.05	-2,625.50	0.00	-162.33	-208.27	-420.96	-504.41	-728.05	-2,625.50
Rome, GA	-	x	-	100	0.00	-14.19	-18.21	-36.80	-44.10	-63.65	-229.54	0.00	-14.19	-18.21	-36.80	-44.10	-63.65	-229.54
Sacramento Metro, CA	x	-	50	-	0.00	-272.70	-349.86	-707.15	-847.34	-1,223.04	-4,410.55	0.00	-272.70	-349.87	-707.16	-847.35	-1,223.04	-4,410.55
San Diego, CA	x	-	100	-	0.00	-381.74	-489.76	-989.91	-1,186.16	-1,712.08	-6,174.16	0.00	-381.75	-489.77	-989.92	-1,186.17	-1,712.10	-6,174.17
San Francisco Bay Area, CA	x	-	100	-	0.00	-870.81	-1,116.52	-2,225.02	-2,663.12	-3,826.61	-13,677.80	0.00	-870.92	-1,116.65	-2,225.15	-2,663.25	-3,826.75	-13,677.90
San Joaquin Valley, CA	x	x	50	100	0.00	-561.93	-720.82	-1,451.59	-1,738.86	-2,506.92	-9,019.98	0.00	-561.96	-720.85	-1,451.62	-1,738.89	-2,506.96	-9,020.01
Sheboygan, WI	x	-	100	-	0.00	-15.06	-19.32	-39.06	-46.80	-67.55	-243.61	0.00	-15.06	-19.33	-39.06	-46.80	-67.55	-243.61
Springfield (Western MA), MA	x	-	100	-	0.00	-116.52	-149.49	-302.15	-362.05	-522.58	-1,884.53	0.00	-116.52	-149.49	-302.15	-362.06	-522.58	-1,884.53
St. Louis, MO-IL	x	x	100	100	0.00	-401.07	-514.23	-1,024.58	-1,226.30	-1,761.96	-6,297.22	0.00	-401.12	-514.29	-1,024.64	-1,226.36	-1,762.02	-6,297.26
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-14.55	-18.64	-36.72	-43.91	-62.85	-222.93	0.00	-14.55	-18.65	-36.72	-43.91	-62.85	-222.93
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Ventura Co., CA	x	-	100	-	0.00	-80.20	-102.89	-207.83	-249.02	-359.36	-1,295.42	0.00	-80.20	-102.90	-207.84	-249.03	-359.37	-1,295.43
Washington, DC-MD-VA	x	x	100	100	0.00	-613.47	-787.07	-1,590.83	-1,906.21	-2,751.37	-9,921.96	0.00	-613.49	-787.09	-1,590.84	-1,906.22	-2,751.38	-9,921.97
Wheeling, WV-OH	-	x	-	100	0.00	-21.37	-27.42	-55.42	-66.41	-95.85	-345.67	0.00	-21.37	-27.42	-55.42	-66.41	-95.85	-345.67
York, PA	-	x	-	100	0.00	-49.74	-63.82	-128.99	-154.57	-223.10	-804.54	0.00	-49.74	-63.82	-128.99	-154.57	-223.10	-804.54

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-62
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-855.96	-827.58	-1,624.04	-2,043.57	-2,734.05	-10,278.77	0.00	-789.13	-744.90	-1,581.84	-2,038.85	-2,777.24	-10,104.10
Allegan Co., MI	x	-	100	-	0.00	-93.60	-90.50	-177.59	-223.47	-298.98	-1,124.01	0.00	-86.29	-81.46	-172.98	-222.95	-303.70	-1,104.91
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-90.62	-87.61	-171.93	-216.34	-289.44	-1,088.16	0.00	-83.54	-78.86	-167.46	-215.84	-294.01	-1,069.67
Atlanta, GA	x	x	100	100	0.00	-4,961.88	-4,797.33	-9,414.32	-11,846.31	-15,848.91	-59,584.74	0.00	-4,574.44	-4,318.05	-9,169.68	-11,818.94	-16,099.28	-58,572.20
Baltimore, MD	x	x	100	100	0.00	-1,882.08	-1,819.67	-3,570.91	-4,493.37	-6,011.57	-22,600.71	0.00	-1,735.13	-1,637.89	-3,478.13	-4,483.01	-6,106.56	-22,216.66
Baton Rouge, LA	x	-	100	-	0.00	-532.81	-533.51	-966.89	-1,198.71	-1,572.53	-5,611.09	0.00	-557.83	-554.61	-1,011.37	-1,266.16	-1,665.29	-5,568.74
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-443.66	-465.95	-753.14	-911.53	-1,156.72	-3,742.88	0.00	-543.17	-569.20	-873.70	-1,050.81	-1,311.74	-3,785.98
Birmingham, AL	-	x	-	100	0.00	-672.24	-649.94	-1,275.46	-1,604.95	-2,147.23	-8,072.63	0.00	-619.74	-585.00	-1,242.31	-1,601.23	-2,181.14	-7,935.45
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-2,950.04	-2,852.21	-5,597.18	-7,043.09	-9,422.78	-35,425.34	0.00	-2,719.70	-2,567.27	-5,451.75	-7,026.84	-9,571.66	-34,823.36
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-412.57	-398.88	-782.82	-985.05	-1,317.90	-4,954.91	0.00	-380.32	-358.98	-762.43	-982.73	-1,338.68	-4,870.67
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-705.07	-681.69	-1,337.75	-1,683.32	-2,252.08	-8,466.78	0.00	-650.02	-613.59	-1,302.99	-1,679.44	-2,287.66	-8,322.90
Canton-Massillon, OH	-	x	-	100	0.00	-213.33	-208.65	-399.01	-499.73	-664.51	-2,458.96	0.00	-205.37	-197.52	-397.73	-507.75	-683.88	-2,424.10
Charleston, WV	-	x	-	100	0.00	-185.05	-178.91	-351.10	-441.79	-591.07	-2,222.15	0.00	-170.60	-161.04	-341.97	-440.77	-600.41	-2,184.38
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-1,283.68	-1,241.03	-2,435.76	-3,065.06	-4,100.81	-15,418.53	0.00	-1,183.15	-1,116.72	-2,372.16	-3,057.67	-4,165.30	-15,156.28
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-342.06	-330.71	-648.99	-816.65	-1,092.58	-4,107.61	0.00	-315.34	-297.67	-632.13	-814.76	-1,109.84	-4,037.81
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-4,776.14	-4,644.46	-8,997.93	-11,296.25	-15,067.68	-56,210.34	0.00	-4,500.03	-4,288.58	-8,865.26	-11,372.22	-15,404.41	-55,332.17
Chico, CA	x	-	100	-	0.00	-126.96	-122.75	-240.88	-303.11	-405.52	-1,524.58	0.00	-117.05	-110.49	-234.62	-302.41	-411.93	-1,498.67
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-1,199.79	-1,160.00	-2,276.43	-2,864.51	-3,832.38	-14,408.20	0.00	-1,106.07	-1,044.06	-2,217.23	-2,857.85	-3,892.88	-14,163.32
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-108.17	-104.58	-205.23	-258.24	-345.49	-1,298.90	0.00	-99.72	-94.13	-199.89	-257.64	-350.95	-1,276.83
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-1,675.53	-1,619.97	-3,179.03	-4,000.27	-5,351.87	-20,120.57	0.00	-1,544.71	-1,458.13	-3,096.43	-3,991.04	-5,436.42	-19,778.66
Columbus, OH	x	x	100	100	0.00	-1,158.32	-1,119.91	-2,197.71	-2,765.44	-3,699.82	-13,909.67	0.00	-1,067.87	-1,008.02	-2,140.60	-2,759.06	-3,758.27	-13,673.30
Dallas-Fort Worth, TX	x	-	100	-	0.00	-4,918.09	-4,755.00	-9,331.23	-11,741.76	-15,709.03	-59,058.82	0.00	-4,534.08	-4,279.96	-9,088.76	-11,714.65	-15,957.20	-58,055.23
Dayton-Springfield, OH	-	x	-	100	0.00	-509.62	-492.72	-966.91	-1,216.69	-1,627.79	-6,119.73	0.00	-469.83	-443.49	-941.79	-1,213.88	-1,653.50	-6,015.74
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-2,220.50	-2,149.95	-4,205.62	-5,289.03	-7,070.82	-26,532.51	0.00	-2,058.32	-1,947.67	-4,108.03	-5,288.62	-7,193.95	-26,090.55
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-3,124.86	-3,024.53	-5,921.01	-7,447.37	-9,958.08	-37,384.02	0.00	-2,892.79	-2,735.68	-5,779.61	-7,442.74	-10,127.55	-36,758.23
Door Co., WI	x	-	100	-	0.00	-20.67	-19.98	-39.21	-49.34	-66.01	-248.18	0.00	-19.05	-17.99	-38.19	-49.23	-67.06	-243.96
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.88	-0.85	-1.68	-2.11	-2.82	-10.61	0.00	-0.81	-0.77	-1.63	-2.10	-2.87	-10.43
Evansville, IN	-	x	-	100	0.00	-224.11	-216.66	-425.23	-535.09	-715.91	-2,691.68	0.00	-206.56	-194.97	-414.13	-533.81	-727.17	-2,645.91
Greater Connecticut, CT	x	-	100	-	0.00	-1,150.97	-1,112.81	-2,183.76	-2,747.89	-3,676.33	-13,821.25	0.00	-1,061.12	-1,001.65	-2,127.03	-2,741.56	-3,734.42	-13,586.40
Greene Co., PA	x	-	100	-	0.00	-24.66	-23.84	-46.79	-58.87	-78.77	-296.12	0.00	-22.73	-21.46	-45.57	-58.74	-80.01	-291.09
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-521.82	-504.52	-990.07	-1,245.83	-1,666.77	-6,266.30	0.00	-481.08	-454.11	-964.34	-1,242.96	-1,693.10	-6,159.81

Table B2-62
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-465.77	-450.33	-883.73	-1,112.02	-1,487.74	-5,593.24	0.00	-429.41	-405.34	-860.76	-1,109.45	-1,511.25	-5,498.20
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-3.23	-3.13	-6.14	-7.72	-10.33	-38.85	0.00	-2.98	-2.81	-5.98	-7.71	-10.50	-38.19
Hickory, NC	-	x	-	100	0.00	-124.81	-120.67	-236.81	-297.98	-398.66	-1,498.77	0.00	-115.07	-108.62	-230.65	-297.29	-404.96	-1,473.30
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-3,785.04	-3,735.26	-7,000.04	-8,734.32	-11,556.91	-42,208.54	0.00	-3,764.09	-3,668.72	-7,104.99	-9,003.56	-12,019.39	-41,709.71
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-312.43	-309.31	-575.42	-716.98	-946.94	-3,441.38	0.00	-314.31	-307.75	-587.91	-743.02	-988.68	-3,403.80
Imperial Co., CA	x	-	100	-	0.00	-160.71	-155.38	-304.92	-383.69	-513.33	-1,929.87	0.00	-148.16	-139.86	-296.99	-382.80	-521.44	-1,897.08
Indianapolis, IN	-	x	-	100	0.00	-1,078.73	-1,042.96	-2,046.70	-2,575.43	-3,445.60	-12,953.91	0.00	-994.50	-938.76	-1,993.52	-2,569.48	-3,500.04	-12,733.78
Jamestown, NY	x	-	100	-	0.00	-93.67	-90.57	-177.73	-223.64	-299.20	-1,124.87	0.00	-86.36	-81.52	-173.11	-223.12	-303.93	-1,105.75
Jefferson Co., NY	x	-	100	-	0.00	-93.32	-90.22	-177.05	-222.79	-298.06	-1,120.58	0.00	-86.03	-81.21	-172.45	-222.27	-302.77	-1,101.54
Johnstown, PA	-	x	-	100	0.00	-74.91	-72.42	-142.12	-178.84	-239.26	-899.52	0.00	-69.06	-65.19	-138.43	-178.43	-243.04	-884.23
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-83.94	-81.16	-159.23	-200.36	-268.04	-1,007.57	0.00	-77.41	-73.09	-155.13	-199.93	-272.31	-990.48
Knoxville, TN	x	x	100	100	0.00	-721.90	-697.96	-1,369.68	-1,723.51	-2,305.84	-8,668.94	0.00	-665.53	-628.23	-1,334.09	-1,719.53	-2,342.27	-8,521.62
Lancaster, PA	-	x	-	100	0.00	-275.74	-266.60	-523.18	-658.33	-880.77	-3,311.28	0.00	-254.21	-239.97	-509.58	-656.81	-894.68	-3,255.01
Las Vegas, NV	x	-	100	-	0.00	-1,056.59	-1,021.54	-2,004.70	-2,522.58	-3,374.91	-12,688.19	0.00	-974.07	-919.47	-1,952.59	-2,516.74	-3,428.21	-12,472.57
Libby, MT	-	x	-	100	0.00	-4.55	-4.40	-8.63	-10.86	-14.53	-54.63	0.00	-4.19	-3.96	-8.41	-10.84	-14.76	-53.70
Liberty-Clairton, PA	-	x	-	100	0.00	-8.09	-7.82	-15.35	-19.31	-25.84	-97.12	0.00	-7.46	-7.04	-14.95	-19.27	-26.24	-95.47
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-10,221.78	-9,923.57	-19,296.43	-24,241.40	-32,362.84	-121,002.13	0.00	-9,571.43	-9,097.19	-18,949.39	-24,341.19	-33,024.76	-119,063.48
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-506.46	-489.67	-960.91	-1,209.13	-1,617.66	-6,081.58	0.00	-466.93	-440.77	-935.96	-1,206.36	-1,643.23	-5,978.25
Louisville, KY-IN	-	x	-	100	0.00	-709.48	-685.94	-1,346.15	-1,693.91	-2,266.27	-8,520.36	0.00	-654.04	-617.36	-1,311.12	-1,689.95	-2,302.03	-8,375.54
Macon, GA	-	x	-	100	0.00	-132.71	-128.31	-251.81	-316.86	-423.93	-1,593.82	0.00	-122.34	-115.48	-245.25	-316.12	-430.61	-1,566.73
Manitowoc Co., WI	x	-		-	0.00	-67.49	-65.26	-128.06	-161.14	-215.58	-810.47	0.00	-62.23	-58.74	-124.73	-160.77	-218.99	-796.70
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-74.93	-72.44	-142.16	-178.89	-239.33	-899.76	0.00	-69.08	-65.21	-138.47	-178.47	-243.11	-884.47
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-298.76	-288.85	-566.85	-713.28	-954.29	-3,587.68	0.00	-275.43	-260.00	-552.12	-711.64	-969.36	-3,526.71
Memphis, TN-AR	x	-	100	-	0.00	-660.18	-644.20	-1,238.40	-1,552.53	-2,067.06	-7,674.30	0.00	-630.09	-603.80	-1,228.63	-1,571.56	-2,121.58	-7,560.96
Milwaukee-Racine, WI	x	-	100	-	0.00	-1,122.61	-1,085.38	-2,129.95	-2,680.18	-3,585.75	-13,480.76	0.00	-1,034.96	-976.95	-2,074.61	-2,673.99	-3,642.40	-13,251.68
Nevada (Western Part), CA	x	-	100	-	0.00	-67.15	-64.93	-127.41	-160.32	-214.49	-806.39	0.00	-61.91	-58.44	-124.10	-159.95	-217.88	-792.69
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-9,316.61	-9,018.13	-17,651.62	-22,201.30	-29,684.86	-111,430.29	0.00	-8,627.09	-8,159.53	-17,232.57	-22,190.02	-30,192.49	-109,566.91
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-98.41	-95.15	-186.73	-234.96	-314.35	-1,181.83	0.00	-90.73	-85.64	-181.87	-234.42	-319.32	-1,161.75
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-4,744.56	-4,626.20	-8,908.64	-11,171.90	-14,880.49	-55,305.71	0.00	-4,515.40	-4,321.80	-8,824.75	-11,295.03	-15,259.60	-54,478.29

Table B2-62
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-2,875.92	-2,780.51	-5,456.68	-6,866.34	-9,186.40	-34,537.45	0.00	-2,651.20	-2,502.54	-5,314.72	-6,850.32	-9,331.36	-33,950.42
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-1,212.54	-1,172.33	-2,300.60	-2,894.91	-3,873.04	-14,560.89	0.00	-1,117.86	-1,055.20	-2,240.81	-2,888.22	-3,934.22	-14,313.45
Poughkeepsie, NY	x	x	100	100	0.00	-849.76	-821.58	-1,612.28	-2,028.77	-2,714.25	-10,204.34	0.00	-783.41	-739.50	-1,570.38	-2,024.09	-2,757.13	-10,030.94
Providence (All RI), RI	x	-	100	-	0.00	-586.89	-567.43	-1,113.53	-1,401.19	-1,874.61	-7,047.70	0.00	-541.07	-510.74	-1,084.60	-1,397.95	-1,904.23	-6,927.94
Reading, PA	-	x	-	100	0.00	-250.06	-241.77	-474.45	-597.02	-798.74	-3,002.88	0.00	-230.54	-217.62	-462.12	-595.64	-811.35	-2,951.86
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-593.27	-573.60	-1,125.61	-1,416.39	-1,894.95	-7,124.09	0.00	-546.96	-516.31	-1,096.38	-1,413.13	-1,924.90	-7,003.04
Rochester, NY	x	-	100	-	0.00	-828.41	-800.94	-1,571.77	-1,977.80	-2,646.05	-9,947.96	0.00	-763.73	-720.92	-1,530.93	-1,973.24	-2,687.86	-9,778.92
Rome, GA	-	x	-	100	0.00	-71.71	-69.33	-136.06	-171.21	-229.05	-861.14	0.00	-66.11	-62.41	-132.52	-170.81	-232.67	-846.51
Sacramento Metro, CA	x	-	50	-	0.00	-1,495.11	-1,445.53	-2,836.71	-3,569.52	-4,775.58	-17,954.00	0.00	-1,378.37	-1,301.11	-2,763.00	-3,561.28	-4,851.02	-17,648.91
San Diego, CA	x	-	100	-	0.00	-1,926.24	-1,862.36	-3,654.71	-4,598.82	-6,152.66	-23,131.22	0.00	-1,775.83	-1,676.30	-3,559.74	-4,588.21	-6,249.86	-22,738.15
San Francisco Bay Area, CA	x	-	100	-	0.00	-4,384.19	-4,260.42	-8,266.48	-10,380.83	-13,851.59	-51,721.81	0.00	-4,120.22	-3,922.28	-8,133.53	-10,439.44	-14,150.29	-50,905.22
San Joaquin Valley, CA	x	x	50	100	0.00	-3,180.91	-3,079.06	-6,026.52	-7,579.79	-10,134.65	-38,042.14	0.00	-2,945.72	-2,786.17	-5,883.69	-7,576.18	-10,308.20	-37,406.18
Sheboygan, WI	x	-	100	-	0.00	-77.36	-74.80	-146.78	-184.70	-247.11	-929.01	0.00	-71.32	-67.33	-142.97	-184.28	-251.01	-913.23
Springfield (Western MA), MA	x	-	100	-	0.00	-599.99	-580.09	-1,138.38	-1,432.45	-1,916.45	-7,204.97	0.00	-553.14	-522.14	-1,108.80	-1,429.15	-1,946.72	-7,082.53
St. Louis, MO-IL	x	x	100	100	0.00	-2,015.26	-1,958.51	-3,799.48	-4,771.15	-6,366.12	-23,768.77	0.00	-1,894.43	-1,803.63	-3,738.91	-4,798.63	-6,503.92	-23,393.92
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-68.92	-67.30	-129.20	-161.93	-215.52	-799.50	0.00	-65.93	-63.23	-128.33	-164.07	-221.36	-787.81
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.04	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.04
Ventura Co., CA	x	-	100	-	0.00	-408.51	-395.05	-774.85	-974.93	-1,304.17	-4,901.60	0.00	-376.94	-355.96	-755.06	-973.03	-1,325.12	-4,818.57
Washington, DC-MD-VA	x	x	100	100	0.00	-3,260.42	-3,152.32	-6,186.05	-7,784.07	-10,414.11	-39,152.08	0.00	-3,005.89	-2,837.44	-6,025.36	-7,766.15	-10,578.68	-38,486.81
Wheeling, WV-OH	-	x	-	100	0.00	-105.28	-101.79	-199.76	-251.36	-336.29	-1,264.31	0.00	-97.06	-91.62	-194.57	-250.78	-341.61	-1,242.82
York, PA	-	x	-	100	0.00	-270.61	-261.63	-513.43	-646.06	-864.35	-3,249.58	0.00	-249.48	-235.50	-500.09	-644.57	-878.01	-3,194.36

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-63
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-1,721.15	-1,540.56	-3,044.37	-3,848.39	-5,055.46	-19,027.11	0.00	-1,464.05	-1,220.47	-2,900.27	-3,850.01	-5,249.54	-18,354.26
Allegan Co., MI	x	-	100	-	0.00	-188.03	-168.30	-332.58	-420.42	-552.28	-2,078.62	0.00	-159.94	-133.33	-316.84	-420.59	-573.49	-2,005.11
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-193.99	-173.64	-343.13	-433.75	-569.79	-2,144.52	0.00	-165.01	-137.56	-326.89	-433.93	-591.67	-2,068.68
Atlanta, GA	x	x	100	100	0.00	-10,991.45	-9,838.20	-19,441.70	-24,576.29	-32,284.79	-121,509.51	0.00	-9,349.57	-7,794.03	-18,521.42	-24,586.58	-33,524.15	-117,212.58
Baltimore, MD	x	x	100	100	0.00	-3,766.14	-3,371.00	-6,661.54	-8,420.86	-11,062.11	-41,634.07	0.00	-3,203.61	-2,670.63	-6,346.26	-8,424.44	-11,486.80	-40,161.80
Baton Rouge, LA	x	-	100	-	0.00	-1,044.72	-971.39	-1,791.24	-2,234.47	-2,890.85	-10,423.39	0.00	-1,067.99	-972.70	-1,891.52	-2,420.79	-3,179.62	-10,195.69
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-798.06	-787.38	-1,297.50	-1,580.10	-1,986.17	-6,555.49	0.00	-1,039.90	-1,032.79	-1,608.71	-1,954.02	-2,420.40	-6,607.38
Birmingham, AL	-	x	-	100	0.00	-1,320.03	-1,181.52	-2,334.88	-2,951.52	-3,877.29	-14,592.91	0.00	-1,122.83	-936.01	-2,224.34	-2,952.74	-4,026.12	-14,076.85
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-5,700.32	-5,102.24	-10,082.73	-12,745.59	-16,743.32	-63,016.33	0.00	-4,848.86	-4,042.14	-9,605.50	-12,750.97	-17,386.10	-60,787.92
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-821.49	-735.27	-1,453.08	-1,836.86	-2,413.03	-9,082.13	0.00	-698.67	-582.38	-1,384.19	-1,837.52	-2,505.55	-8,760.88
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-1,349.70	-1,208.09	-2,387.35	-3,017.85	-3,964.42	-14,920.75	0.00	-1,148.09	-957.08	-2,274.35	-3,019.12	-4,116.61	-14,393.12
Canton-Massillon, OH	-	x	-	100	0.00	-405.86	-368.02	-710.49	-894.24	-1,168.91	-4,339.75	0.00	-368.66	-318.08	-701.03	-918.82	-1,237.01	-4,204.69
Charleston, WV	-	x	-	100	0.00	-347.57	-311.10	-614.79	-777.15	-1,020.91	-3,842.37	0.00	-295.65	-246.46	-585.69	-777.48	-1,060.10	-3,706.49
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-2,776.46	-2,485.01	-4,911.23	-6,208.41	-8,155.89	-30,697.91	0.00	-2,361.03	-1,967.89	-4,678.04	-6,210.30	-8,468.30	-29,611.80
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-664.66	-594.93	-1,175.64	-1,486.13	-1,952.25	-7,347.58	0.00	-565.40	-471.35	-1,120.02	-1,486.78	-2,027.22	-7,087.77
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-9,556.09	-8,606.09	-16,820.58	-21,219.64	-27,810.78	-104,007.89	0.00	-8,388.82	-7,112.69	-16,292.93	-21,497.53	-29,136.38	-100,534.33
Chico, CA	x	-	100	-	0.00	-253.04	-226.49	-447.58	-565.79	-743.25	-2,797.34	0.00	-215.24	-179.43	-426.39	-566.02	-771.78	-2,698.42
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-2,393.13	-2,142.01	-4,233.00	-5,350.96	-7,029.35	-26,456.47	0.00	-2,035.54	-1,696.83	-4,032.52	-5,353.09	-7,299.09	-25,520.81
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-202.83	-181.55	-358.76	-453.51	-595.75	-2,242.22	0.00	-172.53	-143.83	-341.78	-453.70	-618.63	-2,162.93
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-3,197.68	-2,862.18	-5,656.06	-7,149.84	-9,392.42	-35,350.00	0.00	-2,720.04	-2,267.50	-5,388.35	-7,152.85	-9,753.00	-34,099.93
Columbus, OH	x	x	100	100	0.00	-2,374.64	-2,125.48	-4,200.26	-5,309.56	-6,974.93	-26,251.39	0.00	-2,019.92	-1,683.86	-4,001.44	-5,311.78	-7,242.69	-25,323.06
Dallas-Fort Worth, TX	x	-	100	-	0.00	-10,592.26	-9,480.89	-18,735.59	-23,683.70	-31,112.23	-117,096.31	0.00	-9,010.03	-7,510.99	-17,848.76	-23,693.64	-32,306.59	-112,955.46
Dayton-Springfield, OH	-	x	-	100	0.00	-974.59	-872.33	-1,723.85	-2,179.12	-2,862.62	-10,773.97	0.00	-829.01	-691.08	-1,642.26	-2,180.04	-2,972.51	-10,392.97
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-4,615.08	-4,136.95	-8,153.63	-10,302.01	-13,525.82	-50,830.01	0.00	-3,955.83	-3,311.53	-7,798.79	-10,337.49	-14,074.94	-49,056.20
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-6,057.68	-5,428.59	-10,704.69	-13,526.48	-17,761.18	-66,765.56	0.00	-5,184.89	-4,337.01	-10,231.11	-13,565.33	-18,474.83	-64,429.75
Door Co., WI	x	-	100	-	0.00	-39.49	-35.35	-69.85	-88.30	-115.99	-436.56	0.00	-33.59	-28.00	-66.54	-88.34	-120.45	-421.13
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-1.72	-1.54	-3.04	-3.84	-5.04	-18.98	0.00	-1.46	-1.22	-2.89	-3.84	-5.24	-18.31
Evansville, IN	-	x	-	100	0.00	-440.28	-394.06	-778.80	-984.50	-1,293.32	-4,867.90	0.00	-374.40	-312.06	-741.82	-984.80	-1,342.86	-4,695.67
Greater Connecticut, CT	x	-	100	-	0.00	-2,273.59	-2,035.05	-4,021.52	-5,083.61	-6,678.10	-25,134.09	0.00	-1,934.01	-1,612.26	-3,831.21	-5,085.78	-6,934.50	-24,245.31
Greene Co., PA	x	-	100	-	0.00	-45.44	-40.67	-80.38	-101.61	-133.48	-502.36	0.00	-38.65	-32.22	-76.57	-101.65	-138.60	-484.59

Table B2-63
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-1,033.27	-924.85	-1,827.64	-2,310.32	-3,034.97	-11,422.64	0.00	-878.92	-732.69	-1,741.13	-2,311.29	-3,151.48	-11,018.71
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-908.97	-813.60	-1,607.79	-2,032.41	-2,669.88	-10,048.57	0.00	-773.19	-644.55	-1,531.69	-2,033.26	-2,772.38	-9,693.22
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-6.39	-5.72	-11.30	-14.28	-18.76	-70.62	0.00	-5.43	-4.53	-10.76	-14.29	-19.48	-68.12
Hickory, NC	-	x	-	100	0.00	-251.63	-225.23	-445.09	-562.63	-739.10	-2,781.74	0.00	-214.05	-178.44	-424.02	-562.87	-767.48	-2,683.37
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-7,535.31	-6,894.22	-13,094.88	-16,430.29	-21,400.45	-78,661.56	0.00	-7,148.77	-6,298.98	-13,237.80	-17,201.22	-22,954.77	-76,460.60
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-587.91	-540.54	-1,017.54	-1,274.50	-1,656.71	-6,055.09	0.00	-570.83	-508.36	-1,042.38	-1,348.16	-1,790.45	-5,896.55
Imperial Co., CA	x	-	100	-	0.00	-351.46	-314.58	-621.66	-785.84	-1,032.33	-3,885.34	0.00	-298.96	-249.22	-592.24	-786.17	-1,071.96	-3,747.95
Indianapolis, IN	-	x	-	100	0.00	-2,209.72	-1,977.87	-3,908.55	-4,940.81	-6,490.52	-24,428.22	0.00	-1,879.64	-1,566.92	-3,723.55	-4,942.88	-6,739.69	-23,564.37
Jamestown, NY	x	-	100	-	0.00	-178.93	-160.16	-316.49	-400.08	-525.57	-1,978.07	0.00	-152.20	-126.88	-301.51	-400.25	-545.74	-1,908.12
Jefferson Co., NY	x	-	100	-	0.00	-191.23	-171.17	-338.25	-427.58	-561.69	-2,114.03	0.00	-162.67	-135.60	-322.24	-427.76	-583.26	-2,039.28
Johnstown, PA	-	x	-	100	0.00	-139.52	-124.88	-246.77	-311.95	-409.79	-1,542.31	0.00	-118.68	-98.94	-235.10	-312.08	-425.53	-1,487.77
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-182.64	-163.50	-323.01	-408.30	-536.33	-2,018.25	0.00	-155.49	-129.68	-307.86	-408.61	-557.05	-1,946.99
Knoxville, TN	x	x	100	100	0.00	-1,447.60	-1,295.71	-2,560.51	-3,236.75	-4,251.98	-16,003.08	0.00	-1,231.35	-1,026.48	-2,439.31	-3,238.10	-4,415.20	-15,437.16
Lancaster, PA	-	x	-	100	0.00	-539.87	-483.22	-954.92	-1,207.11	-1,585.73	-5,968.16	0.00	-459.22	-382.82	-909.72	-1,207.62	-1,646.60	-5,757.11
Las Vegas, NV	x	-	100	-	0.00	-2,392.80	-2,141.72	-4,232.40	-5,350.19	-7,028.33	-26,452.53	0.00	-2,035.30	-1,696.65	-4,031.99	-5,352.37	-7,298.07	-25,517.04
Libby, MT	-	x	-	100	0.00	-8.95	-8.01	-15.83	-20.01	-26.29	-98.94	0.00	-7.61	-6.35	-15.08	-20.02	-27.30	-95.44
Liberty-Clairton, PA	-	x	-	100	0.00	-14.42	-12.91	-25.50	-32.23	-42.34	-159.35	0.00	-12.27	-10.23	-24.30	-32.25	-43.97	-153.72
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-21,078.88	- 18,947.70	-37,158.65	-46,906.14	-61,519.90	- 230,527.74	0.00	-18,327.90	- 15,461.35	-35,810.23	-47,336.97	-64,275.90	- 222,688.14
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-1,068.71	-956.59	-1,890.30	-2,389.52	-3,138.98	-11,813.90	0.00	-909.15	-757.93	-1,800.91	-2,390.61	-3,259.57	-11,396.19
Louisville, KY-IN	-	x	-	100	0.00	-1,361.27	-1,218.42	-2,407.85	-3,043.79	-3,998.52	-15,049.44	0.00	-1,157.81	-965.12	-2,293.75	-3,044.94	-4,151.90	-14,517.15
Macon, GA	-	x	-	100	0.00	-255.44	-228.63	-451.83	-571.16	-750.31	-2,824.01	0.00	-217.25	-181.09	-430.41	-571.37	-779.09	-2,724.13
Manitowoc Co., WI	x	-		-	0.00	-128.95	-115.42	-228.09	-288.33	-378.76	-1,425.53	0.00	-109.69	-91.45	-217.30	-288.45	-393.31	-1,375.12
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-162.89	-145.80	-288.12	-364.22	-478.45	-1,800.74	0.00	-138.56	-115.51	-274.49	-364.37	-496.82	-1,737.06
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-662.64	-593.11	-1,172.07	-1,481.62	-1,946.34	-7,325.39	0.00	-563.66	-469.88	-1,116.59	-1,482.24	-2,021.06	-7,066.34
Memphis, TN-AR	x	-	100	-	0.00	-1,262.92	-1,142.10	-2,215.61	-2,791.14	-3,652.28	-13,598.90	0.00	-1,132.01	-970.21	-2,170.32	-2,852.01	-3,849.74	-13,163.38
Milwaukee-Racine, WI	x	-	100	-	0.00	-2,174.13	-1,946.01	-3,845.59	-4,861.22	-6,385.96	-24,034.66	0.00	-1,849.38	-1,541.69	-3,663.58	-4,863.27	-6,631.13	-23,184.74
Nevada (Western Part), CA	x	-	100	-	0.00	-137.41	-122.99	-243.05	-307.24	-403.61	-1,519.06	0.00	-116.89	-97.44	-231.55	-307.37	-419.11	-1,465.34
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-18,057.02	- 16,183.09	-31,907.00	-40,316.71	-52,936.98	- 198,977.47	0.00	-15,461.82	- 12,936.28	-30,502.08	-40,439.18	-55,070.38	- 192,021.29
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-185.28	-165.84	-327.72	-414.27	-544.21	-2,048.26	0.00	-157.59	-131.37	-312.20	-414.44	-565.10	-1,975.82

Table B2-63
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-9,411.54	-8,501.00	-16,526.94	-20,828.46	-27,267.12	-101,655.74	0.00	-8,385.98	-7,165.51	-16,137.15	-21,230.36	-28,690.94	-98,359.74
Phoenix-Mesa, AZ	x	-	100	-	0.00	-6,378.75	-5,709.38	-11,282.90	-14,262.81	-18,736.55	-70,519.49	0.00	-5,425.44	-4,522.56	-10,748.33	-14,268.30	-19,455.34	-68,025.35
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-2,268.43	-2,030.42	-4,012.41	-5,072.09	-6,662.99	-25,077.36	0.00	-1,929.56	-1,608.53	-3,822.47	-5,074.20	-6,918.76	-24,190.54
Poughkeepsie, NY	x	x	100	100	0.00	-1,717.50	-1,537.30	-3,037.91	-3,840.23	-5,044.74	-18,986.77	0.00	-1,460.95	-1,217.88	-2,894.12	-3,841.85	-5,238.41	-18,315.35
Providence (All RI), RI	x	-	100	-	0.00	-1,132.49	-1,013.66	-2,003.14	-2,532.17	-3,326.40	-12,519.49	0.00	-963.32	-803.05	-1,908.33	-2,533.24	-3,454.10	-12,076.77
Reading, PA	-	x	-	100	0.00	-506.05	-452.95	-895.10	-1,131.50	-1,486.40	-5,594.33	0.00	-430.46	-358.84	-852.73	-1,131.97	-1,543.46	-5,396.50
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-1,434.88	-1,284.34	-2,537.99	-3,208.27	-4,214.55	-15,862.05	0.00	-1,220.59	-1,017.54	-2,417.91	-3,209.67	-4,376.39	-15,301.17
Rochester, NY	x	-	100	-	0.00	-1,611.21	-1,442.16	-2,849.90	-3,602.57	-4,732.54	-17,811.72	0.00	-1,370.53	-1,142.51	-2,715.01	-3,604.08	-4,914.21	-17,181.85
Rome, GA	-	x	-	100	0.00	-138.03	-123.55	-244.15	-308.63	-405.43	-1,525.90	0.00	-117.41	-97.88	-232.59	-308.76	-420.99	-1,471.94
Sacramento Metro, CA	x	-	50	-	0.00	-3,135.95	-2,806.92	-5,546.86	-7,011.79	-9,211.08	-34,667.47	0.00	-2,667.52	-2,223.72	-5,284.32	-7,014.75	-9,564.69	-33,441.55
San Diego, CA	x	-	100	-	0.00	-3,702.60	-3,314.11	-6,549.16	-8,278.81	-10,875.51	-40,931.87	0.00	-3,149.52	-2,625.52	-6,239.16	-8,282.28	-11,293.01	-39,484.41
San Francisco Bay Area, CA	x	-	100	-	0.00	-8,502.66	-7,653.23	-14,972.83	-18,892.07	-24,765.36	-92,671.25	0.00	-7,443.55	-6,302.08	-14,481.85	-19,118.12	-25,925.26	-89,559.93
San Joaquin Valley, CA	x	x	50	100	0.00	-6,889.19	-6,173.53	-12,174.41	-15,383.81	-20,200.25	-75,936.91	0.00	-5,895.53	-4,930.94	-11,634.71	-15,426.88	-21,010.83	-73,279.41
Sheboygan, WI	x	-	100	-	0.00	-151.37	-135.49	-267.74	-338.46	-444.61	-1,673.37	0.00	-128.76	-107.34	-255.07	-338.60	-461.68	-1,614.20
Springfield (Western MA), MA	x	-	100	-	0.00	-1,177.05	-1,053.55	-2,081.97	-2,631.82	-3,457.30	-13,012.17	0.00	-1,001.23	-834.65	-1,983.42	-2,632.92	-3,590.03	-12,552.02
St. Louis, MO-IL	x	x	100	100	0.00	-3,910.94	-3,520.49	-6,886.61	-8,689.03	-11,390.01	-42,617.89	0.00	-3,425.04	-2,900.36	-6,662.09	-8,794.29	-11,924.72	-41,188.04
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-126.67	-114.67	-222.02	-279.59	-365.69	-1,360.00	0.00	-114.16	-98.12	-218.13	-286.34	-386.09	-1,316.95
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.07	0.00	-0.01	0.00	-0.01	-0.01	-0.02	-0.07
Ventura Co., CA	x	-	100	-	0.00	-793.00	-709.98	-1,402.38	-1,772.61	-2,328.37	-8,760.94	0.00	-675.45	-563.48	-1,336.93	-1,774.28	-2,418.64	-8,451.84
Washington, DC-MD-VA	x	x	100	100	0.00	-6,678.18	-5,977.51	-11,812.31	-14,931.94	-19,615.40	-73,825.61	0.00	-5,680.76	-4,735.70	-11,253.34	-14,938.36	-20,368.56	-71,215.05
Wheeling, WV-OH	-	x	-	100	0.00	-197.62	-176.88	-349.55	-441.87	-580.46	-2,184.66	0.00	-168.10	-140.13	-333.00	-442.05	-602.74	-2,107.41
York, PA	-	x	-	100	0.00	-560.78	-501.94	-991.91	-1,253.88	-1,647.16	-6,199.38	0.00	-477.02	-397.65	-944.96	-1,254.40	-1,710.40	-5,980.15

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-64
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-2,875.38	-2,469.32	-4,645.25	-5,957.65	-7,836.68	-29,411.14	0.00	-2,249.30	-1,686.98	-4,318.65	-5,989.21	-8,349.27	-27,772.27
Allegan Co., MI	x	-	100	-	0.00	-312.87	-268.69	-505.46	-648.26	-852.72	-3,200.27	0.00	-244.75	-183.56	-469.92	-651.70	-908.50	-3,021.94
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-367.23	-315.37	-593.27	-760.89	-1,000.87	-3,756.26	0.00	-287.27	-215.46	-551.56	-764.92	-1,066.33	-3,546.95
Atlanta, GA	x	x	100	100	0.00	-22,882.74	-19,651.24	-36,967.65	-47,411.95	-62,365.53	-234,058.66	0.00	-17,900.20	-13,425.19	-34,368.46	-47,663.05	-66,444.77	-221,016.19
Baltimore, MD	x	x	100	100	0.00	-6,236.44	-5,355.74	-10,075.11	-12,921.58	-16,996.99	-63,789.78	0.00	-4,878.58	-3,658.99	-9,366.82	-12,990.09	-18,108.81	-60,235.28
Baton Rouge, LA	x	-	100	-	0.00	-1,774.40	-1,579.50	-2,811.56	-3,558.95	-4,617.96	-16,709.79	0.00	-1,722.11	-1,461.80	-2,956.01	-3,917.34	-5,242.75	-16,040.75
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1,209.98	-1,151.21	-1,843.95	-2,270.39	-2,858.67	-9,477.35	0.00	-1,619.15	-1,557.07	-2,403.16	-2,966.06	-3,695.47	-9,476.93
Birmingham, AL	-	x	-	100	0.00	-2,141.00	-1,838.64	-3,458.84	-4,436.05	-5,835.18	-21,899.55	0.00	-1,674.78	-1,256.07	-3,215.62	-4,459.52	-6,216.82	-20,679.21
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-8,842.11	-7,593.44	-14,284.65	-18,320.41	-24,098.60	-90,442.28	0.00	-6,916.86	-5,187.69	-13,280.35	-18,417.49	-25,674.91	-85,402.60
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-1,342.96	-1,153.28	-2,169.61	-2,782.60	-3,660.26	-13,737.32	0.00	-1,050.37	-787.69	-2,016.89	-2,797.17	-3,899.51	-12,971.70
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-2,039.69	-1,751.65	-3,295.17	-4,226.14	-5,559.05	-20,863.16	0.00	-1,595.58	-1,196.69	-3,063.50	-4,248.53	-5,922.67	-19,700.61
Canton-Massillon, OH	-	x	-	100	0.00	-615.85	-536.15	-987.74	-1,260.67	-1,649.99	-6,111.27	0.00	-525.38	-416.27	-962.97	-1,311.69	-1,800.06	-5,804.96
Charleston, WV	-	x	-	100	0.00	-507.54	-435.87	-819.95	-1,051.61	-1,383.28	-5,191.47	0.00	-397.03	-297.77	-762.30	-1,057.18	-1,473.76	-4,902.18
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-5,413.73	-4,649.05	-8,746.16	-11,217.30	-14,755.38	-55,378.83	0.00	-4,234.01	-3,175.05	-8,130.28	-11,275.78	-15,719.62	-52,292.23
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-1,042.28	-895.12	-1,683.81	-2,159.50	-2,840.57	-10,660.40	0.00	-815.49	-611.70	-1,565.58	-2,171.10	-3,026.52	-10,066.50
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-16,438.56	-14,197.50	-26,477.45	-33,890.22	-44,487.43	-166,064.57	0.00	-13,341.56	-10,251.97	-25,109.84	-34,559.96	-47,863.30	-157,189.37
Chico, CA	x	-	100	-	0.00	-414.50	-355.97	-669.64	-858.83	-1,129.70	-4,239.79	0.00	-324.25	-243.19	-622.56	-863.38	-1,203.60	-4,003.53
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-4,080.31	-3,504.05	-6,591.87	-8,454.27	-11,120.76	-41,736.71	0.00	-3,191.66	-2,393.65	-6,128.20	-8,498.85	-11,847.96	-39,410.86
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-294.09	-252.56	-475.11	-609.34	-801.52	-3,008.10	0.00	-230.05	-172.54	-441.70	-612.56	-853.94	-2,840.48
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-4,817.23	-4,136.94	-7,782.35	-9,981.06	-13,129.05	-49,273.45	0.00	-3,768.33	-2,826.27	-7,235.20	-10,033.94	-13,987.82	-46,527.79
Columbus, OH	x	x	100	100	0.00	-4,192.54	-3,600.47	-6,773.16	-8,686.75	-11,426.53	-42,883.90	0.00	-3,279.65	-2,459.75	-6,296.94	-8,732.76	-12,173.92	-40,494.27
Dallas-Fort Worth, TX	x	-	100	-	0.00	-20,778.37	-17,844.05	-33,567.97	-43,051.78	-56,630.16	-212,533.68	0.00	-16,254.07	-12,190.61	-31,207.85	-43,279.81	-60,334.28	-200,690.67
Dayton-Springfield, OH	-	x	-	100	0.00	-1,470.23	-1,262.61	-2,375.20	-3,046.25	-4,007.03	-15,038.44	0.00	-1,150.10	-862.58	-2,208.20	-3,062.39	-4,269.13	-14,200.46
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-8,409.59	-7,231.34	-13,576.67	-17,404.54	-22,883.21	-85,776.59	0.00	-6,634.58	-5,004.54	-12,679.56	-17,553.74	-24,434.17	-81,040.88
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-9,447.94	-8,123.67	-15,253.54	-19,554.65	-25,710.77	-96,381.63	0.00	-7,450.51	-5,618.37	-14,242.30	-19,718.98	-27,450.23	-91,057.85
Door Co., WI	x	-	100	-	0.00	-59.46	-51.06	-96.05	-123.19	-162.04	-608.15	0.00	-46.51	-34.88	-89.30	-123.84	-172.64	-574.27
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-2.67	-2.30	-4.32	-5.54	-7.28	-27.34	0.00	-2.09	-1.57	-4.01	-5.57	-7.76	-25.82
Evansville, IN	-	x	-	100	0.00	-702.51	-603.27	-1,134.95	-1,455.63	-1,914.76	-7,186.44	0.00	-549.38	-411.95	-1,054.98	-1,463.17	-2,039.84	-6,785.85
Greater Connecticut, CT	x	-	100	-	0.00	-3,660.31	-3,143.41	-5,913.31	-7,583.96	-9,975.90	-37,439.54	0.00	-2,863.38	-2,147.58	-5,497.62	-7,624.20	-10,628.48	-35,353.35
Greene Co., PA	x	-	100	-	0.00	-63.63	-54.65	-102.80	-131.85	-173.43	-650.88	0.00	-49.78	-37.33	-95.57	-132.54	-184.77	-614.61

Table B2-64
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

CO 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-1,671.10	-1,435.11	-2,699.71	-3,462.44	-4,554.49	-17,093.04	0.00	-1,307.23	-980.43	-2,509.89	-3,480.78	-4,852.39	-16,140.57
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-1,428.97	-1,227.17	-2,308.53	-2,960.75	-3,894.56	-14,616.33	0.00	-1,117.82	-838.37	-2,146.22	-2,976.44	-4,149.30	-13,801.87
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-10.35	-8.89	-16.73	-21.45	-28.22	-105.92	0.00	-8.09	-6.07	-15.55	-21.56	-30.06	-100.01
Hickory, NC	-	x	-	100	0.00	-421.77	-362.21	-681.38	-873.88	-1,149.50	-4,314.08	0.00	-329.94	-247.46	-633.47	-878.52	-1,224.69	-4,073.69
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-13,095.94	-11,476.02	-20,930.03	-26,649.81	-34,793.46	-128,018.97	0.00	-11,621.27	-9,417.50	-20,868.53	-28,190.34	-38,399.42	-121,965.54
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-891.03	-787.18	-1,417.77	-1,799.79	-2,342.38	-8,545.64	0.00	-828.90	-688.87	-1,453.14	-1,943.36	-2,623.00	-8,172.91
Imperial Co., CA	x	-	100	-	0.00	-693.14	-595.25	-1,119.78	-1,436.15	-1,889.11	-7,089.85	0.00	-542.22	-406.66	-1,041.05	-1,443.76	-2,012.67	-6,694.78
Indianapolis, IN	-	x	-	100	0.00	-3,909.77	-3,357.64	-6,316.34	-8,100.86	-10,655.85	-39,991.54	0.00	-3,058.46	-2,293.85	-5,872.24	-8,143.77	-11,352.84	-37,763.09
Jamestown, NY	x	-	100	-	0.00	-269.22	-231.20	-434.93	-557.81	-733.74	-2,753.74	0.00	-210.60	-157.95	-404.35	-560.77	-781.74	-2,600.30
Jefferson Co., NY	x	-	100	-	0.00	-331.16	-284.40	-535.00	-686.15	-902.56	-3,387.31	0.00	-259.06	-194.29	-497.39	-689.79	-961.60	-3,198.56
Johnstown, PA	-	x	-	100	0.00	-199.57	-171.39	-322.41	-413.50	-543.91	-2,041.30	0.00	-156.12	-117.10	-299.75	-415.70	-579.50	-1,927.56
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-356.62	-306.33	-576.05	-738.74	-971.65	-3,645.77	0.00	-279.41	-209.78	-536.00	-743.10	-1,035.63	-3,442.97
Knoxville, TN	x	x	100	100	0.00	-2,407.62	-2,067.62	-3,889.57	-4,988.48	-6,561.83	-24,626.65	0.00	-1,883.37	-1,412.53	-3,616.09	-5,014.89	-6,991.02	-23,254.37
Lancaster, PA	-	x	-	100	0.00	-853.34	-732.83	-1,378.59	-1,768.07	-2,325.72	-8,728.45	0.00	-667.53	-500.65	-1,281.66	-1,777.44	-2,477.84	-8,242.07
Las Vegas, NV	x	-	100	-	0.00	-5,060.38	-4,345.71	-8,175.20	-10,484.94	-13,791.90	-51,761.61	0.00	-3,958.29	-2,968.61	-7,600.17	-10,540.23	-14,693.78	-48,877.11
Libby, MT	-	x	-	100	0.00	-14.28	-12.27	-23.08	-29.60	-38.93	-146.11	0.00	-11.17	-8.38	-21.45	-29.75	-41.48	-137.97
Liberty-Clairton, PA	-	x	-	100	0.00	-18.89	-16.22	-30.51	-39.13	-51.46	-193.13	0.00	-14.78	-11.09	-28.37	-39.34	-54.84	-182.37
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-38,212.94	-32,939.95	-61,611.98	-78,914.85	-103,663.62	-387,673.23	0.00	-30,632.96	-23,352.14	-58,038.52	-80,085.50	-111,159.59	-366,651.89
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-1,975.02	-1,696.16	-3,190.63	-4,092.02	-5,382.56	-20,200.17	0.00	-1,545.32	-1,159.17	-2,966.65	-4,114.04	-5,734.96	-19,074.82
Louisville, KY-IN	-	x	-	100	0.00	-2,070.55	-1,778.12	-3,345.06	-4,290.16	-5,643.30	-21,179.73	0.00	-1,619.51	-1,214.54	-3,109.68	-4,312.68	-6,012.23	-19,999.37
Macon, GA	-	x	-	100	0.00	-390.27	-335.15	-630.51	-808.65	-1,063.70	-3,992.19	0.00	-305.24	-228.90	-586.12	-812.88	-1,133.23	-3,769.69
Manitowoc Co., WI	x	-		-	0.00	-194.11	-166.70	-313.59	-402.19	-529.03	-1,985.45	0.00	-151.85	-113.89	-291.55	-404.32	-563.64	-1,874.82
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-318.37	-273.41	-514.33	-659.65	-867.70	-3,256.47	0.00	-249.05	-186.79	-478.17	-663.14	-924.45	-3,075.01
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-1,354.27	-1,163.02	-2,187.86	-2,805.99	-3,690.99	-13,852.32	0.00	-1,059.39	-794.55	-2,034.04	-2,820.85	-3,932.41	-13,080.43
Memphis, TN-AR	x	-	100	-	0.00	-1,931.54	-1,676.70	-3,102.73	-3,964.21	-5,194.08	-19,293.32	0.00	-1,618.54	-1,268.72	-2,994.75	-4,094.54	-5,637.74	-18,302.63
Milwaukee-Racine, WI	x	-	100	-	0.00	-3,374.59	-2,898.03	-5,451.72	-6,991.97	-9,197.21	-34,517.21	0.00	-2,639.82	-1,979.88	-5,068.44	-7,029.03	-9,798.81	-32,593.82
Nevada (Western Part), CA	x	-	100	-	0.00	-237.26	-203.75	-383.30	-491.59	-646.63	-2,426.80	0.00	-185.60	-139.20	-356.35	-494.19	-688.93	-2,291.58
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-28,055.32	-24,125.05	-45,292.75	-58,062.37	-76,338.92	-286,147.13	0.00	-22,136.69	-16,699.49	-42,303.02	-58,563.19	-81,515.89	-270,351.34
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-270.82	-232.57	-437.51	-561.12	-738.10	-2,770.13	0.00	-211.84	-158.88	-406.74	-564.09	-786.37	-2,615.76

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CO 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ	x	x	100	100	0.00	-15,551.53	-13,473.43	-25,007.19	-31,972.79	-41,922.29	-156,016.90	0.00	-12,873.80	-10,016.37	-23,974.53	-32,862.21	-45,348.83	-147,878.98
Phoenix-Mesa, AZ	x	-	100	-	0.00	-12,939.56	-11,112.07	-20,904.36	-26,810.52	-35,266.66	-132,358.16	0.00	-10,121.04	-7,590.29	-19,433.53	-26,951.46	-37,572.41	-124,981.95
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-3,283.67	-2,819.95	-5,304.85	-6,803.61	-8,949.45	-33,587.46	0.00	-2,568.65	-1,926.49	-4,931.85	-6,839.62	-9,534.80	-31,715.85
Poughkeepsie, NY	x	x	100	100	0.00	-2,895.10	-2,486.25	-4,677.10	-5,998.50	-7,890.40	-29,612.77	0.00	-2,264.72	-1,698.55	-4,348.26	-6,030.27	-8,406.51	-27,962.66
Providence (All RI), RI	x	-	100	-	0.00	-1,739.89	-1,494.18	-2,810.83	-3,604.97	-4,741.96	-17,796.62	0.00	-1,361.05	-1,020.79	-2,613.21	-3,624.06	-5,052.13	-16,804.94
Reading, PA	-	x	-	100	0.00	-854.59	-733.90	-1,380.61	-1,770.66	-2,329.12	-8,741.23	0.00	-668.51	-501.38	-1,283.54	-1,780.04	-2,481.47	-8,254.14
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-3,461.16	-2,972.41	-5,591.55	-7,171.27	-9,433.02	-35,401.83	0.00	-2,707.74	-2,030.93	-5,198.64	-7,209.48	-10,050.24	-33,429.31
Rochester, NY	x	-	100	-	0.00	-2,517.06	-2,161.60	-4,066.37	-5,215.23	-6,860.09	-25,746.01	0.00	-1,969.00	-1,476.76	-3,780.48	-5,242.85	-7,308.81	-24,311.37
Rome, GA	-	x	-	100	0.00	-210.87	-181.09	-340.67	-436.92	-574.72	-2,156.95	0.00	-164.96	-123.72	-316.72	-439.24	-612.32	-2,036.76
Sacramento Metro, CA	x	-	50	-	0.00	-5,766.92	-4,952.53	-9,316.59	-11,948.75	-15,717.33	-58,987.20	0.00	-4,511.30	-3,383.53	-8,661.63	-12,012.12	-16,745.46	-55,700.32
San Diego, CA	x	-	100	-	0.00	-5,641.28	-4,844.62	-9,113.63	-11,688.46	-15,374.96	-57,702.40	0.00	-4,412.94	-3,309.72	-8,472.86	-11,750.36	-16,380.61	-54,487.05
San Francisco Bay Area, CA	x	-	100	-	0.00	-13,316.53	-11,501.54	-21,448.38	-27,452.80	-36,036.57	-134,513.83	0.00	-10,810.40	-8,308.28	-20,343.28	-27,998.07	-38,773.77	-127,326.97
San Joaquin Valley, CA	x	x	50	100	0.00	-13,406.61	-11,524.27	-21,647.89	-27,754.74	-36,496.02	-136,847.82	0.00	-10,553.11	-7,948.33	-20,193.11	-27,968.50	-38,946.63	-129,273.77
Sheboygan, WI	x	-	100	-	0.00	-238.96	-205.22	-386.05	-495.12	-651.27	-2,444.22	0.00	-186.94	-140.21	-358.91	-497.74	-693.88	-2,308.03
Springfield (Western MA), MA	x	-	100	-	0.00	-1,868.59	-1,604.70	-3,018.75	-3,871.62	-5,092.72	-19,113.03	0.00	-1,461.72	-1,096.29	-2,806.50	-3,892.13	-5,425.83	-18,047.99
St. Louis, MO-IL	x	x	100	100	0.00	-6,183.49	-5,340.78	-9,959.42	-12,747.48	-16,733.20	-62,459.29	0.00	-5,020.20	-3,858.46	-9,446.71	-13,001.10	-18,004.60	-59,122.52
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-178.90	-155.62	-287.04	-366.46	-479.77	-1,778.34	0.00	-151.90	-120.01	-279.10	-380.55	-522.70	-1,688.63
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.10	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.10
Ventura Co., CA	x	-	100	-	0.00	-1,232.68	-1,058.88	-1,991.15	-2,553.47	-3,358.51	-12,601.40	0.00	-965.95	-725.32	-1,852.87	-2,568.69	-3,579.80	-11,900.53
Washington, DC-MD-VA	x	x	100	100	0.00	-11,976.51	-10,285.24	-19,348.30	-24,814.65	-32,641.05	-122,501.72	0.00	-9,369.02	-7,026.95	-17,988.24	-24,946.38	-34,776.35	-115,675.79
Wheeling, WV-OH	-	x	-	100	0.00	-287.29	-246.72	-464.12	-595.25	-782.99	-2,938.57	0.00	-224.73	-168.55	-431.49	-598.40	-834.20	-2,774.83
York, PA	-	x	-	100	0.00	-993.07	-852.83	-1,604.33	-2,057.60	-2,706.56	-10,157.74	0.00	-776.84	-582.64	-1,491.54	-2,068.50	-2,883.59	-9,591.72

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-65
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-4.24	-5.43	-5.94	-6.71	-7.78	-10.10	0.00	-4.25	-5.45	-5.96	-6.73	-7.80	-10.11
Allegan Co., MI	x	-	100	-	0.00	-0.46	-0.59	-0.65	-0.73	-0.85	-1.10	0.00	-0.46	-0.60	-0.65	-0.74	-0.85	-1.11
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.42	-0.54	-0.59	-0.67	-0.77	-1.01	0.00	-0.42	-0.54	-0.59	-0.67	-0.78	-1.01
Atlanta, GA	x	x	100	100	0.00	-22.52	-28.87	-31.58	-35.66	-41.33	-53.63	0.00	-22.59	-28.94	-31.66	-35.74	-41.42	-53.69
Baltimore, MD	x	x	100	100	0.00	-9.38	-12.03	-13.17	-14.87	-17.24	-22.41	0.00	-9.41	-12.06	-13.20	-14.90	-17.27	-22.43
Baton Rouge, LA	x	-	100	-	0.00	-2.18	-2.80	-3.06	-3.46	-4.01	-5.21	0.00	-2.19	-2.81	-3.07	-3.47	-4.02	-5.21
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1.36	-1.75	-1.91	-2.16	-2.50	-3.26	0.00	-1.37	-1.75	-1.92	-2.17	-2.51	-3.26
Birmingham, AL	-	x	-	100	0.00	-3.41	-4.38	-4.78	-5.40	-6.26	-8.11	0.00	-3.42	-4.39	-4.80	-5.41	-6.27	-8.12
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-15.25	-19.55	-21.39	-24.16	-28.01	-36.38	0.00	-15.30	-19.60	-21.45	-24.22	-28.06	-36.42
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-1.99	-2.55	-2.77	-3.13	-3.62	-4.59	0.00	-1.99	-2.56	-2.78	-3.14	-3.63	-4.60
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-3.67	-4.70	-5.14	-5.81	-6.73	-8.75	0.00	-3.68	-4.71	-5.16	-5.82	-6.75	-8.76
Canton-Massillon, OH	-	x	-	100	0.00	-1.04	-1.34	-1.47	-1.65	-1.92	-2.49	0.00	-1.05	-1.34	-1.47	-1.66	-1.92	-2.49
Charleston, WV	-	x	-	100	0.00	-0.98	-1.26	-1.38	-1.55	-1.80	-2.34	0.00	-0.98	-1.26	-1.38	-1.56	-1.80	-2.34
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-5.41	-6.96	-7.48	-8.43	-9.77	-11.90	0.00	-5.43	-6.98	-7.50	-8.46	-9.79	-11.91
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-1.73	-2.22	-2.42	-2.73	-3.16	-4.06	0.00	-1.73	-2.22	-2.42	-2.74	-3.17	-4.07
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-22.75	-29.17	-31.81	-35.91	-41.61	-53.36	0.00	-22.82	-29.25	-31.89	-35.99	-41.70	-53.42
Chico, CA	x	-	100	-	0.00	-0.63	-0.81	-0.89	-1.00	-1.16	-1.51	0.00	-0.64	-0.81	-0.89	-1.01	-1.17	-1.51
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-6.00	-7.69	-8.40	-9.48	-10.99	-14.17	0.00	-6.02	-7.71	-8.42	-9.51	-11.02	-14.18
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.57	-0.74	-0.81	-0.91	-1.05	-1.37	0.00	-0.58	-0.74	-0.81	-0.91	-1.06	-1.37
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-8.75	-11.21	-12.27	-13.85	-16.06	-20.86	0.00	-8.77	-11.24	-12.30	-13.89	-16.09	-20.88
Columbus, OH	x	x	100	100	0.00	-5.65	-7.24	-7.92	-8.94	-10.37	-13.46	0.00	-5.67	-7.26	-7.94	-8.97	-10.39	-13.47
Dallas-Fort Worth, TX	x	-	100	-	0.00	-22.89	-29.35	-32.11	-36.26	-42.03	-54.56	0.00	-22.96	-29.43	-32.19	-36.34	-42.12	-54.62
Dayton-Springfield, OH	-	x	-	100	0.00	-2.65	-3.40	-3.72	-4.20	-4.87	-6.32	0.00	-2.66	-3.41	-3.73	-4.21	-4.88	-6.32
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-10.60	-13.59	-14.87	-16.79	-19.46	-25.26	0.00	-10.63	-13.63	-14.90	-16.83	-19.50	-25.28
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-15.97	-20.47	-22.39	-25.29	-29.32	-38.06	0.00	-16.02	-20.52	-22.45	-25.35	-29.38	-38.10
Door Co., WI	x	-	100	-	0.00	-0.11	-0.14	-0.15	-0.17	-0.20	-0.26	0.00	-0.11	-0.14	-0.15	-0.17	-0.20	-0.26
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01
Evansville, IN	-	x	-	100	0.00	-1.06	-1.36	-1.47	-1.66	-1.92	-2.38	0.00	-1.07	-1.37	-1.48	-1.67	-1.93	-2.39
Greater Connecticut, CT	x	-	100	-	0.00	-5.82	-7.46	-8.17	-9.23	-10.70	-13.92	0.00	-5.84	-7.48	-8.19	-9.25	-10.72	-13.94
Greene Co., PA	x	-	100	-	0.00	-0.13	-0.17	-0.19	-0.21	-0.24	-0.32	0.00	-0.13	-0.17	-0.19	-0.21	-0.24	-0.32
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-2.62	-3.36	-3.68	-4.15	-4.81	-6.25	0.00	-2.63	-3.37	-3.69	-4.16	-4.82	-6.25

Table B2-65
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-2.38	-3.04	-3.33	-3.76	-4.36	-5.66	0.00	-2.38	-3.05	-3.34	-3.77	-4.37	-5.67
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.02	-0.02	-0.02	-0.03	-0.03	-0.04	0.00	-0.02	-0.02	-0.02	-0.03	-0.03	-0.04
Hickory, NC	-	x	-	100	0.00	-0.62	-0.79	-0.87	-0.98	-1.13	-1.47	0.00	-0.62	-0.79	-0.87	-0.98	-1.14	-1.48
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-16.89	-21.65	-23.69	-26.75	-31.01	-40.25	0.00	-16.94	-21.71	-23.75	-26.81	-31.07	-40.30
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-1.14	-1.47	-1.53	-1.72	-1.99	-2.13	0.00	-1.14	-1.47	-1.54	-1.73	-2.00	-2.13
Imperial Co., CA	x	-	100	-	0.00	-0.73	-0.94	-1.03	-1.16	-1.34	-1.74	0.00	-0.73	-0.94	-1.03	-1.16	-1.34	-1.74
Indianapolis, IN	-	x	-	100	0.00	-5.27	-6.76	-7.40	-8.35	-9.68	-12.57	0.00	-5.29	-6.78	-7.42	-8.37	-9.70	-12.58
Jamestown, NY	x	-	100	-	0.00	-0.49	-0.63	-0.68	-0.77	-0.90	-1.16	0.00	-0.49	-0.63	-0.69	-0.77	-0.90	-1.17
Jefferson Co., NY	x	-	100	-	0.00	-0.45	-0.58	-0.64	-0.72	-0.83	-1.08	0.00	-0.46	-0.58	-0.64	-0.72	-0.83	-1.08
Johnstown, PA	-	x	-	100	0.00	-0.40	-0.51	-0.56	-0.64	-0.74	-0.96	0.00	-0.40	-0.52	-0.56	-0.64	-0.74	-0.96
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.41	-0.53	-0.58	-0.66	-0.77	-1.04	0.00	-0.41	-0.53	-0.58	-0.66	-0.77	-1.04
Knoxville, TN	x	x	100	100	0.00	-3.58	-4.59	-5.02	-5.67	-6.57	-8.52	0.00	-3.59	-4.60	-5.03	-5.68	-6.58	-8.53
Lancaster, PA	-	x	-	100	0.00	-1.40	-1.80	-1.96	-2.22	-2.57	-3.34	0.00	-1.41	-1.80	-1.97	-2.22	-2.58	-3.34
Las Vegas, NV	x	-	100	-	0.00	-4.63	-5.93	-6.48	-7.32	-8.49	-11.00	0.00	-4.64	-5.95	-6.50	-7.34	-8.51	-11.01
Libby, MT	-	x	-	100	0.00	-0.02	-0.03	-0.03	-0.04	-0.04	-0.05	0.00	-0.02	-0.03	-0.03	-0.04	-0.04	-0.05
Liberty-Clairton, PA	-	x	-	100	0.00	-0.05	-0.06	-0.07	-0.07	-0.09	-0.11	0.00	-0.05	-0.06	-0.07	-0.07	-0.09	-0.11
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-48.51	-62.19	-68.03	-76.82	-89.05	-115.58	0.00	-48.66	-62.36	-68.21	-77.01	-89.24	-115.70
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-2.41	-3.08	-3.38	-3.81	-4.42	-5.76	0.00	-2.41	-3.09	-3.39	-3.82	-4.43	-5.76
Louisville, KY-IN	-	x	-	100	0.00	-3.60	-4.62	-5.04	-5.69	-6.59	-8.44	0.00	-3.61	-4.63	-5.05	-5.70	-6.60	-8.45
Macon, GA	-	x	-	100	0.00	-0.67	-0.86	-0.93	-1.05	-1.22	-1.56	0.00	-0.67	-0.86	-0.94	-1.06	-1.22	-1.56
Manitowoc Co., WI	x	-		-	0.00	-0.35	-0.45	-0.50	-0.56	-0.65	-0.85	0.00	-0.36	-0.46	-0.50	-0.56	-0.65	-0.85
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.34	-0.44	-0.48	-0.54	-0.63	-0.82	0.00	-0.34	-0.44	-0.48	-0.55	-0.63	-0.82
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-1.34	-1.72	-1.88	-2.13	-2.47	-3.20	0.00	-1.35	-1.73	-1.89	-2.13	-2.47	-3.20
Memphis, TN-AR	x	-	100	-	0.00	-3.26	-4.18	-4.57	-5.16	-5.98	-7.77	0.00	-3.27	-4.19	-4.58	-5.17	-6.00	-7.78
Milwaukee-Racine, WI	x	-	100	-	0.00	-5.78	-7.41	-8.11	-9.16	-10.61	-13.79	0.00	-5.80	-7.43	-8.13	-9.18	-10.64	-13.80
Nevada (Western Part), CA	x	-	100	-	0.00	-0.33	-0.42	-0.46	-0.52	-0.60	-0.78	0.00	-0.33	-0.42	-0.46	-0.52	-0.60	-0.78
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-47.57	-60.99	-66.74	-75.36	-87.36	-113.48	0.00	-47.72	-61.15	-66.91	-75.54	-87.54	-113.60
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.52	-0.66	-0.72	-0.82	-0.95	-1.22	0.00	-0.52	-0.66	-0.72	-0.82	-0.95	-1.22
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-22.76	-29.18	-31.94	-36.07	-41.81	-54.37	0.00	-22.83	-29.26	-32.02	-36.15	-41.90	-54.42

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Diesel PM 10 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-12.66	-16.24	-17.70	-19.99	-23.16	-29.71	0.00	-12.70	-16.28	-17.75	-20.03	-23.21	-29.74
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-6.44	-8.26	-9.03	-10.20	-11.82	-15.33	0.00	-6.46	-8.28	-9.05	-10.22	-11.85	-15.34
Poughkeepsie, NY	x	x	100	100	0.00	-4.18	-5.36	-5.87	-6.63	-7.68	-9.97	0.00	-4.20	-5.38	-5.88	-6.64	-7.70	-9.98
Providence (All RI), RI	x	-	100	-	0.00	-3.03	-3.88	-4.25	-4.80	-5.56	-7.22	0.00	-3.04	-3.89	-4.26	-4.81	-5.57	-7.23
Reading, PA	-	x	-	100	0.00	-1.23	-1.58	-1.72	-1.95	-2.26	-2.93	0.00	-1.23	-1.58	-1.73	-1.95	-2.26	-2.93
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-2.45	-3.14	-3.44	-3.88	-4.50	-5.86	0.00	-2.46	-3.15	-3.45	-3.89	-4.51	-5.86
Rochester, NY	x	-	100	-	0.00	-4.24	-5.43	-5.95	-6.71	-7.78	-10.10	0.00	-4.25	-5.45	-5.96	-6.73	-7.80	-10.12
Rome, GA	-	x	-	100	0.00	-0.37	-0.48	-0.52	-0.59	-0.68	-0.88	0.00	-0.37	-0.48	-0.52	-0.59	-0.68	-0.88
Sacramento Metro, CA	x	-	50	-	0.00	-7.11	-9.12	-9.97	-11.26	-13.06	-16.94	0.00	-7.13	-9.14	-10.00	-11.29	-13.08	-16.95
San Diego, CA	x	-	100	-	0.00	-9.97	-12.78	-13.98	-15.78	-18.30	-23.75	0.00	-10.00	-12.81	-14.01	-15.82	-18.33	-23.78
San Francisco Bay Area, CA	x	-	100	-	0.00	-20.84	-26.74	-28.99	-32.72	-37.90	-47.63	0.00	-20.90	-26.81	-29.07	-32.79	-37.98	-47.68
San Joaquin Valley, CA	x	x	50	100	0.00	-14.49	-18.57	-20.31	-22.93	-26.58	-34.45	0.00	-14.53	-18.62	-20.36	-22.99	-26.64	-34.48
Sheboygan, WI	x	-	100	-	0.00	-0.40	-0.51	-0.55	-0.63	-0.73	-0.95	0.00	-0.40	-0.51	-0.56	-0.63	-0.73	-0.95
Springfield (Western MA), MA	x	-	100	-	0.00	-3.04	-3.90	-4.27	-4.82	-5.58	-7.25	0.00	-3.05	-3.91	-4.28	-4.83	-5.60	-7.26
St. Louis, MO-IL	x	x	100	100	0.00	-10.15	-13.01	-14.25	-16.09	-18.66	-24.34	0.00	-10.18	-13.04	-14.29	-16.13	-18.70	-24.37
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.35	-0.45	-0.50	-0.56	-0.65	-0.84	0.00	-0.35	-0.45	-0.50	-0.56	-0.65	-0.84
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-2.09	-2.68	-2.93	-3.31	-3.84	-4.98	0.00	-2.10	-2.69	-2.94	-3.32	-3.85	-4.99
Washington, DC-MD-VA	x	x	100	100	0.00	-16.09	-20.63	-22.59	-25.51	-29.57	-38.51	0.00	-16.15	-20.69	-22.65	-25.57	-29.64	-38.55
Wheeling, WV-OH	-	x	-	100	0.00	-0.56	-0.72	-0.78	-0.88	-1.02	-1.33	0.00	-0.56	-0.72	-0.78	-0.89	-1.03	-1.33
York, PA	-	x	-	100	0.00	-1.30	-1.67	-1.82	-2.06	-2.39	-3.10	0.00	-1.30	-1.67	-1.83	-2.06	-2.39	-3.10

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-66
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-12.94	-15.67	-16.13	-17.89	-19.44	-24.81	0.00	-22.63	-26.09	-26.64	-28.84	-30.30	-32.08
Allegan Co., MI	x	-	100	-	0.00	-1.41	-1.71	-1.76	-1.96	-2.13	-2.71	0.00	-2.47	-2.85	-2.91	-3.15	-3.31	-3.51
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-1.37	-1.66	-1.71	-1.90	-2.06	-2.63	0.00	-2.40	-2.76	-2.82	-3.06	-3.21	-3.40
Atlanta, GA	x	x	100	100	0.00	-74.93	-90.78	-93.43	-103.59	-112.57	-143.59	0.00	-131.09	-151.11	-154.28	-167.04	-175.47	-185.74
Baltimore, MD	x	x	100	100	0.00	-28.51	-34.53	-35.56	-39.43	-42.85	-54.76	0.00	-49.86	-57.47	-58.70	-63.55	-66.77	-70.78
Baton Rouge, LA	x	-	100	-	0.00	-6.73	-8.15	-8.39	-9.30	-10.11	-12.90	0.00	-11.77	-13.56	-13.85	-14.99	-15.75	-16.68
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-4.04	-4.90	-5.04	-5.59	-6.08	-7.77	0.00	-7.07	-8.15	-8.32	-9.01	-9.47	-10.04
Birmingham, AL	-	x	-	100	0.00	-10.12	-12.26	-12.61	-13.99	-15.20	-19.35	0.00	-17.71	-20.42	-20.84	-22.56	-23.69	-25.04
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-44.62	-54.06	-55.65	-61.71	-67.06	-85.63	0.00	-78.06	-89.98	-91.89	-99.48	-104.51	-110.72
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-6.02	-7.30	-7.47	-8.28	-8.99	-11.22	0.00	-10.56	-12.18	-12.38	-13.40	-14.06	-14.62
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-10.67	-12.92	-13.30	-14.75	-16.03	-20.47	0.00	-18.66	-21.51	-21.96	-23.78	-24.98	-26.46
Canton-Massillon, OH	-	x	-	100	0.00	-3.05	-3.70	-3.80	-4.22	-4.58	-5.85	0.00	-5.34	-6.15	-6.28	-6.80	-7.14	-7.57
Charleston, WV	-	x	-	100	0.00	-2.80	-3.39	-3.49	-3.87	-4.20	-5.36	0.00	-4.89	-5.64	-5.76	-6.23	-6.55	-6.93
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-17.96	-21.83	-22.16	-24.55	-26.59	-32.25	0.00	-31.59	-36.47	-36.89	-39.91	-41.80	-42.44
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-5.15	-6.24	-6.42	-7.12	-7.74	-9.85	0.00	-9.02	-10.39	-10.61	-11.49	-12.06	-12.75
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-68.34	-82.89	-84.90	-94.12	-102.16	-128.15	0.00	-119.77	-138.14	-140.60	-152.17	-159.70	-166.71
Chico, CA	x	-	100	-	0.00	-1.92	-2.32	-2.39	-2.65	-2.88	-3.68	0.00	-3.36	-3.87	-3.95	-4.28	-4.49	-4.76
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-17.92	-21.72	-22.31	-24.74	-26.87	-34.05	0.00	-31.38	-36.18	-36.89	-39.93	-41.93	-44.14
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-1.64	-1.98	-2.04	-2.26	-2.46	-3.14	0.00	-2.86	-3.30	-3.37	-3.65	-3.83	-4.06
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-25.34	-30.69	-31.60	-35.04	-38.07	-48.60	0.00	-44.32	-51.09	-52.17	-56.48	-59.34	-62.85
Columbus, OH	x	x	100	100	0.00	-17.50	-21.20	-21.82	-24.19	-26.29	-33.53	0.00	-30.61	-35.28	-36.03	-39.00	-40.97	-43.38
Dallas-Fort Worth, TX	x	-	100	-	0.00	-74.32	-90.03	-92.67	-102.75	-111.66	-142.48	0.00	-130.01	-149.86	-153.02	-165.67	-174.04	-184.28
Dayton-Springfield, OH	-	x	-	100	0.00	-7.70	-9.33	-9.60	-10.65	-11.57	-14.76	0.00	-13.47	-15.53	-15.86	-17.17	-18.03	-19.10
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-33.31	-40.35	-41.53	-46.05	-50.04	-63.83	0.00	-58.27	-67.17	-68.58	-74.25	-78.00	-82.56
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-47.00	-56.94	-58.61	-64.98	-70.62	-90.13	0.00	-82.22	-94.77	-96.77	-104.77	-110.07	-116.56
Door Co., WI	x	-	100	-	0.00	-0.31	-0.38	-0.39	-0.43	-0.47	-0.60	0.00	-0.55	-0.63	-0.64	-0.70	-0.73	-0.78
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	0.00	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03
Evansville, IN	-	x	-	100	0.00	-3.17	-3.85	-3.92	-4.34	-4.71	-5.76	0.00	-5.57	-6.43	-6.52	-7.05	-7.39	-7.55
Greater Connecticut, CT	x	-	100	-	0.00	-17.47	-21.16	-21.79	-24.17	-26.27	-33.61	0.00	-30.55	-35.21	-35.97	-38.95	-40.92	-43.43
Greene Co., PA	x	-	100	-	0.00	-0.37	-0.45	-0.46	-0.52	-0.56	-0.71	0.00	-0.65	-0.75	-0.77	-0.83	-0.87	-0.92
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-7.88	-9.55	-9.83	-10.90	-11.85	-15.12	0.00	-13.79	-15.90	-16.24	-17.58	-18.47	-19.55

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Emission Changes a/ by Nonattainment Area

Diesel PM 10 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-7.04	-8.53	-8.78	-9.73	-10.58	-13.50	0.00	-12.32	-14.20	-14.50	-15.70	-16.49	-17.46
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.05	-0.06	-0.06	-0.06	-0.07	-0.09	0.00	-0.08	-0.10	-0.10	-0.10	-0.11	-0.11
Hickory, NC	-	x	-	100	0.00	-1.89	-2.29	-2.36	-2.62	-2.84	-3.63	0.00	-3.31	-3.81	-3.89	-4.22	-4.43	-4.70
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-51.72	-62.66	-64.49	-71.51	-77.71	-99.16	0.00	-90.48	-104.29	-106.49	-115.29	-121.12	-128.25
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-3.30	-4.04	-3.96	-4.38	-4.71	-4.96	0.00	-5.87	-6.80	-6.73	-7.26	-7.55	-6.87
Imperial Co., CA	x	-	100	-	0.00	-2.43	-2.94	-3.03	-3.36	-3.65	-4.66	0.00	-4.25	-4.90	-5.00	-5.41	-5.69	-6.02
Indianapolis, IN	-	x	-	100	0.00	-16.30	-19.75	-20.32	-22.54	-24.49	-31.25	0.00	-28.52	-32.87	-33.56	-36.34	-38.17	-40.42
Jamestown, NY	x	-	100	-	0.00	-1.42	-1.72	-1.77	-1.96	-2.13	-2.72	0.00	-2.48	-2.86	-2.92	-3.16	-3.32	-3.51
Jefferson Co., NY	x	-	100	-	0.00	-1.41	-1.71	-1.76	-1.95	-2.12	-2.71	0.00	-2.47	-2.85	-2.91	-3.15	-3.31	-3.51
Johnstown, PA	-	x	-	100	0.00	-1.14	-1.38	-1.42	-1.57	-1.71	-2.19	0.00	-1.99	-2.29	-2.34	-2.54	-2.66	-2.83
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-1.42	-1.72	-1.80	-2.00	-2.18	-2.97	0.00	-2.48	-2.85	-2.94	-3.19	-3.37	-3.76
Knoxville, TN	x	x	100	100	0.00	-10.89	-13.20	-13.58	-15.06	-16.36	-20.86	0.00	-19.06	-21.97	-22.43	-24.28	-25.51	-26.99
Lancaster, PA	-	x	-	100	0.00	-4.17	-5.05	-5.20	-5.76	-6.26	-7.99	0.00	-7.29	-8.40	-8.58	-9.29	-9.76	-10.34
Las Vegas, NV	x	-	100	-	0.00	-15.89	-19.25	-19.80	-21.95	-23.85	-30.34	0.00	-27.80	-32.05	-32.70	-35.41	-37.19	-39.27
Libby, MT	-	x	-	100	0.00	-0.07	-0.08	-0.09	-0.09	-0.10	-0.13	0.00	-0.12	-0.14	-0.14	-0.15	-0.16	-0.17
Liberty-Clairton, PA	-	x	-	100	0.00	-0.13	-0.16	-0.16	-0.18	-0.19	-0.26	0.00	-0.22	-0.26	-0.27	-0.29	-0.30	-0.33
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-151.38	-183.39	-188.73	-209.27	-227.40	-290.02	0.00	-264.84	-305.28	-311.68	-337.44	-354.48	-375.16
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-7.74	-9.37	-9.67	-10.72	-11.65	-14.97	0.00	-13.53	-15.59	-15.94	-17.26	-18.14	-19.32
Louisville, KY-IN	-	x	-	100	0.00	-10.49	-12.72	-13.04	-14.46	-15.70	-19.77	0.00	-18.38	-21.20	-21.59	-23.37	-24.53	-25.68
Macon, GA	-	x	-	100	0.00	-1.95	-2.37	-2.42	-2.69	-2.92	-3.66	0.00	-3.42	-3.95	-4.02	-4.35	-4.56	-4.76
Manitowoc Co., WI	x	-		-	0.00	-1.03	-1.25	-1.28	-1.42	-1.55	-1.98	0.00	-1.80	-2.07	-2.12	-2.29	-2.41	-2.56
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-1.13	-1.37	-1.41	-1.57	-1.70	-2.18	0.00	-1.98	-2.29	-2.33	-2.53	-2.66	-2.81
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-4.51	-5.47	-5.63	-6.24	-6.78	-8.65	0.00	-7.90	-9.10	-9.30	-10.06	-10.57	-11.19
Memphis, TN-AR	x	-	100	-	0.00	-9.55	-11.57	-11.91	-13.20	-14.35	-18.31	0.00	-16.70	-19.25	-19.66	-21.29	-22.36	-23.68
Milwaukee-Racine, WI	x	-	100	-	0.00	-16.99	-20.58	-21.18	-23.49	-25.53	-32.60	0.00	-29.71	-34.25	-34.98	-37.87	-39.79	-42.15
Nevada (Western Part), CA	x	-	100	-	0.00	-1.02	-1.23	-1.27	-1.41	-1.53	-1.95	0.00	-1.78	-2.05	-2.09	-2.27	-2.38	-2.52
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-140.18	-169.81	-174.81	-193.84	-210.65	-268.97	0.00	-245.21	-282.65	-288.64	-312.50	-328.30	-347.81
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-1.48	-1.79	-1.84	-2.04	-2.21	-2.81	0.00	-2.58	-2.98	-3.04	-3.29	-3.45	-3.64
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-69.06	-83.66	-86.15	-95.53	-103.82	-132.69	0.00	-120.80	-139.24	-142.21	-153.97	-161.77	-171.52

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Diesel PM 10 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-42.65	-51.71	-53.05	-58.81	-63.86	-80.55	0.00	-74.71	-86.15	-87.77	-95.00	-99.74	-104.58
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-18.29	-22.16	-22.80	-25.28	-27.47	-35.01	0.00	-32.00	-36.89	-37.66	-40.77	-42.82	-45.30
Poughkeepsie, NY	x	x	100	100	0.00	-12.84	-15.56	-16.02	-17.76	-19.30	-24.63	0.00	-22.47	-25.90	-26.45	-28.63	-30.08	-31.85
Providence (All RI), RI	x	-	100	-	0.00	-8.87	-10.75	-11.07	-12.27	-13.33	-17.02	0.00	-15.52	-17.89	-18.27	-19.78	-20.78	-22.01
Reading, PA	-	x	-	100	0.00	-3.78	-4.58	-4.71	-5.23	-5.68	-7.25	0.00	-6.61	-7.62	-7.78	-8.42	-8.85	-9.37
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-9.02	-10.93	-11.26	-12.49	-13.58	-17.39	0.00	-15.78	-18.19	-18.59	-20.12	-21.15	-22.47
Rochester, NY	x	-	100	-	0.00	-12.52	-15.17	-15.61	-17.31	-18.81	-24.01	0.00	-21.90	-25.25	-25.78	-27.91	-29.32	-31.05
Rome, GA	-	x	-	100	0.00	-1.08	-1.31	-1.35	-1.50	-1.63	-2.08	0.00	-1.90	-2.19	-2.23	-2.42	-2.54	-2.69
Sacramento Metro, CA	x	-	50	-	0.00	-22.59	-27.37	-28.17	-31.24	-33.94	-43.31	0.00	-39.52	-45.56	-46.52	-50.36	-52.91	-56.02
San Diego, CA	x	-	100	-	0.00	-29.11	-35.26	-36.29	-40.24	-43.73	-55.80	0.00	-50.92	-58.69	-59.93	-64.88	-68.16	-72.17
San Francisco Bay Area, CA	x	-	100	-	0.00	-61.61	-74.79	-76.30	-84.57	-91.72	-113.45	0.00	-108.12	-124.76	-126.66	-137.05	-143.71	-148.29
San Joaquin Valley, CA	x	x	50	100	0.00	-47.58	-57.66	-59.29	-65.75	-71.43	-90.89	0.00	-83.27	-95.99	-97.96	-106.05	-111.39	-117.66
Sheboygan, WI	x	-	100	-	0.00	-1.18	-1.42	-1.47	-1.63	-1.77	-2.26	0.00	-2.06	-2.37	-2.42	-2.62	-2.75	-2.92
Springfield (Western MA), MA	x	-	100	-	0.00	-9.07	-10.98	-11.30	-12.54	-13.62	-17.38	0.00	-15.86	-18.28	-18.67	-20.21	-21.23	-22.48
St. Louis, MO-IL	x	x	100	100	0.00	-29.97	-36.30	-37.41	-41.49	-45.10	-57.84	0.00	-52.41	-60.40	-61.73	-66.84	-70.24	-74.68
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.99	-1.20	-1.24	-1.37	-1.49	-1.91	0.00	-1.74	-2.00	-2.05	-2.22	-2.33	-2.46
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-6.17	-7.47	-7.69	-8.53	-9.26	-11.82	0.00	-10.79	-12.43	-12.70	-13.75	-14.44	-15.29
Washington, DC-MD-VA	x	x	100	100	0.00	-49.52	-59.98	-61.79	-68.52	-74.47	-95.33	0.00	-86.61	-99.82	-101.98	-110.42	-116.02	-123.17
Wheeling, WV-OH	-	x	-	100	0.00	-1.59	-1.93	-1.98	-2.20	-2.39	-3.05	0.00	-2.78	-3.21	-3.28	-3.55	-3.73	-3.94
York, PA	-	x	-	100	0.00	-4.09	-4.96	-5.10	-5.66	-6.15	-7.85	0.00	-7.16	-8.25	-8.42	-9.12	-9.58	-10.15

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-67
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-19.99	-23.94	-24.26	-26.78	-28.64	-36.29	0.00	-45.46	-51.26	-51.79	-55.46	-57.04	-55.07
Allegan Co., MI	x	-	100	-	0.00	-2.18	-2.61	-2.65	-2.93	-3.13	-3.96	0.00	-4.97	-5.60	-5.66	-6.06	-6.23	-6.02
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-2.26	-2.70	-2.74	-3.02	-3.23	-4.10	0.00	-5.13	-5.78	-5.84	-6.26	-6.44	-6.22
Atlanta, GA	x	x	100	100	0.00	-127.59	-152.76	-154.80	-170.88	-182.75	-231.48	0.00	-290.15	-327.15	-330.49	-353.92	-364.01	-351.32
Baltimore, MD	x	x	100	100	0.00	-43.85	-52.49	-53.22	-58.75	-62.83	-79.73	0.00	-99.68	-112.39	-113.57	-121.62	-125.11	-120.90
Baton Rouge, LA	x	-	100	-	0.00	-10.54	-12.62	-12.79	-14.12	-15.10	-19.14	0.00	-23.96	-27.02	-27.30	-29.23	-30.07	-29.03
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-6.07	-7.26	-7.36	-8.13	-8.70	-11.04	0.00	-13.79	-15.55	-15.71	-16.83	-17.31	-16.74
Birmingham, AL	-	x	-	100	0.00	-15.28	-18.29	-18.52	-20.45	-21.86	-27.64	0.00	-34.75	-39.18	-39.57	-42.37	-43.57	-41.99
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-66.27	-79.34	-80.42	-88.78	-94.95	-120.38	0.00	-150.69	-169.90	-171.66	-183.83	-189.08	-182.62
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-9.23	-11.07	-11.15	-12.30	-13.14	-16.30	0.00	-21.05	-23.74	-23.91	-25.60	-26.29	-25.00
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-15.69	-18.79	-19.04	-21.02	-22.48	-28.51	0.00	-35.68	-40.23	-40.65	-43.53	-44.77	-43.24
Canton-Massillon, OH	-	x	-	100	0.00	-4.51	-5.39	-5.47	-6.03	-6.45	-8.18	0.00	-10.25	-11.55	-11.67	-12.50	-12.85	-12.41
Charleston, WV	-	x	-	100	0.00	-4.04	-4.83	-4.90	-5.41	-5.78	-7.33	0.00	-9.18	-10.35	-10.46	-11.20	-11.52	-11.12
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-30.26	-36.34	-36.40	-40.17	-42.82	-52.08	0.00	-69.20	-78.11	-78.43	-83.93	-86.12	-80.70
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-7.79	-9.33	-9.47	-10.45	-11.18	-14.25	0.00	-17.71	-19.96	-20.18	-21.62	-22.24	-21.56
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-104.54	-125.38	-126.18	-139.26	-148.65	-183.84	0.00	-238.52	-269.12	-270.87	-289.95	-297.79	-282.44
Chico, CA	x	-	100	-	0.00	-2.94	-3.52	-3.57	-3.94	-4.21	-5.34	0.00	-6.68	-7.54	-7.61	-8.15	-8.39	-8.10
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-27.47	-32.91	-33.28	-36.74	-39.27	-49.41	0.00	-62.54	-70.53	-71.17	-76.21	-78.35	-75.24
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-2.36	-2.82	-2.86	-3.16	-3.38	-4.28	0.00	-5.36	-6.04	-6.11	-6.54	-6.73	-6.50
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-37.17	-44.49	-45.10	-49.78	-53.24	-67.49	0.00	-84.51	-95.28	-96.27	-103.09	-106.04	-102.40
Columbus, OH	x	x	100	100	0.00	-27.57	-33.01	-33.45	-36.93	-39.49	-50.03	0.00	-62.70	-70.69	-71.41	-76.48	-78.66	-75.92
Dallas-Fort Worth, TX	x	-	100	-	0.00	-123.02	-147.28	-149.26	-164.77	-176.21	-223.28	0.00	-279.74	-315.41	-318.65	-341.24	-350.98	-338.82
Dayton-Springfield, OH	-	x	-	100	0.00	-11.32	-13.55	-13.73	-15.16	-16.21	-20.55	0.00	-25.74	-29.02	-29.32	-31.40	-32.29	-31.18
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-53.28	-63.79	-64.63	-71.35	-76.30	-96.62	0.00	-121.16	-136.61	-138.00	-147.78	-151.99	-146.66
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-70.09	-83.92	-85.05	-93.88	-100.41	-127.25	0.00	-159.38	-179.70	-181.56	-194.43	-199.98	-193.08
Door Co., WI	x	-	100	-	0.00	-0.46	-0.55	-0.56	-0.61	-0.66	-0.83	0.00	-1.04	-1.18	-1.19	-1.27	-1.31	-1.26
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	0.00	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05
Evansville, IN	-	x	-	100	0.00	-4.80	-5.77	-5.78	-6.38	-6.80	-8.28	0.00	-10.99	-12.40	-12.45	-13.32	-13.67	-12.82
Greater Connecticut, CT	x	-	100	-	0.00	-26.52	-31.75	-32.20	-35.54	-38.02	-48.30	0.00	-60.29	-67.97	-68.69	-73.57	-75.68	-73.20
Greene Co., PA	x	-	100	-	0.00	-0.53	-0.63	-0.64	-0.71	-0.76	-0.96	0.00	-1.20	-1.35	-1.37	-1.46	-1.51	-1.45
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-12.00	-14.37	-14.56	-16.07	-17.19	-21.78	0.00	-27.29	-30.77	-31.08	-33.29	-34.24	-33.05

Table B2-67
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-10.56	-12.64	-12.81	-14.14	-15.13	-19.17	0.00	-24.01	-27.08	-27.35	-29.29	-30.13	-29.09
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.07	-0.08	-0.08	-0.09	-0.10	-0.12	0.00	-0.16	-0.18	-0.18	-0.19	-0.20	-0.19
Hickory, NC	-	x	-	100	0.00	-2.93	-3.51	-3.56	-3.93	-4.20	-5.33	0.00	-6.66	-7.51	-7.59	-8.13	-8.36	-8.08
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-80.92	-96.88	-98.18	-108.38	-115.91	-146.88	0.00	-184.01	-207.48	-209.61	-224.47	-230.87	-222.88
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-4.85	-5.88	-5.67	-6.24	-6.59	-6.87	0.00	-11.29	-12.79	-12.59	-13.44	-13.68	-11.56
Imperial Co., CA	x	-	100	-	0.00	-4.08	-4.89	-4.95	-5.47	-5.85	-7.41	0.00	-9.28	-10.47	-10.57	-11.32	-11.65	-11.24
Indianapolis, IN	-	x	-	100	0.00	-25.66	-30.73	-31.14	-34.37	-36.76	-46.58	0.00	-58.36	-65.80	-66.48	-71.19	-73.22	-70.68
Jamestown, NY	x	-	100	-	0.00	-2.08	-2.49	-2.52	-2.79	-2.98	-3.78	0.00	-4.73	-5.33	-5.39	-5.77	-5.93	-5.73
Jefferson Co., NY	x	-	100	-	0.00	-2.22	-2.66	-2.70	-2.98	-3.19	-4.04	0.00	-5.06	-5.70	-5.76	-6.17	-6.35	-6.13
Johnstown, PA	-	x	-	100	0.00	-1.63	-1.95	-1.98	-2.18	-2.34	-2.97	0.00	-3.70	-4.18	-4.22	-4.52	-4.65	-4.50
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-2.49	-2.96	-3.08	-3.41	-3.67	-5.06	0.00	-5.60	-6.29	-6.45	-6.92	-7.15	-7.36
Knoxville, TN	x	x	100	100	0.00	-16.79	-20.10	-20.37	-22.48	-24.05	-30.44	0.00	-38.19	-43.06	-43.49	-46.57	-47.90	-46.22
Lancaster, PA	-	x	-	100	0.00	-6.27	-7.51	-7.61	-8.40	-8.98	-11.38	0.00	-14.26	-16.08	-16.24	-17.40	-17.89	-17.27
Las Vegas, NV	x	-	100	-	0.00	-27.60	-33.05	-33.45	-36.93	-39.48	-49.81	0.00	-62.79	-70.81	-71.49	-76.55	-78.71	-75.75
Libby, MT	-	x	-	100	0.00	-0.10	-0.12	-0.13	-0.14	-0.15	-0.19	0.00	-0.24	-0.27	-0.27	-0.29	-0.30	-0.29
Liberty-Clairton, PA	-	x	-	100	0.00	-0.18	-0.21	-0.22	-0.24	-0.26	-0.34	0.00	-0.41	-0.46	-0.47	-0.50	-0.51	-0.51
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-240.88	-288.41	-292.19	-322.55	-344.93	-436.63	0.00	-547.81	-617.68	-623.93	-668.15	-687.18	-662.90
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-12.65	-15.13	-15.39	-16.99	-18.19	-23.31	0.00	-28.72	-32.37	-32.77	-35.10	-36.12	-35.16
Louisville, KY-IN	-	x	-	100	0.00	-15.47	-18.54	-18.71	-20.66	-22.07	-27.59	0.00	-35.24	-39.75	-40.08	-42.91	-44.10	-42.15
Macon, GA	-	x	-	100	0.00	-2.88	-3.46	-3.48	-3.85	-4.11	-5.11	0.00	-6.57	-7.41	-7.47	-8.00	-8.21	-7.83
Manitowoc Co., WI	x	-		-	0.00	-1.51	-1.81	-1.83	-2.02	-2.17	-2.76	0.00	-3.43	-3.87	-3.91	-4.19	-4.31	-4.18
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-1.89	-2.27	-2.30	-2.54	-2.71	-3.44	0.00	-4.31	-4.86	-4.91	-5.26	-5.41	-5.22
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-7.70	-9.21	-9.34	-10.31	-11.02	-13.97	0.00	-17.50	-19.73	-19.93	-21.35	-21.96	-21.20
Memphis, TN-AR	x	-	100	-	0.00	-14.15	-16.94	-17.17	-18.96	-20.27	-25.69	0.00	-32.18	-36.29	-36.66	-39.26	-40.38	-38.98
Milwaukee-Racine, WI	x	-	100	-	0.00	-25.29	-30.27	-30.68	-33.87	-36.23	-45.94	0.00	-57.49	-64.82	-65.49	-70.14	-72.14	-69.69
Nevada (Western Part), CA	x	-	100	-	0.00	-1.60	-1.92	-1.94	-2.14	-2.29	-2.91	0.00	-3.64	-4.10	-4.14	-4.44	-4.56	-4.41
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-209.03	-250.24	-253.65	-280.00	-299.47	-379.70	0.00	-475.28	-535.87	-541.43	-579.81	-596.38	-576.00
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-2.13	-2.56	-2.59	-2.86	-3.05	-3.85	0.00	-4.86	-5.48	-5.53	-5.92	-6.09	-5.85
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-106.20	-127.13	-128.90	-142.30	-152.20	-193.17	0.00	-241.44	-272.22	-275.08	-294.59	-303.03	-292.89

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High Scenario Alternative CAFE Standards
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Diesel PM 10 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-72.71	-87.12	-88.00	-97.13	-103.78	-129.99	0.00	-165.60	-186.78	-188.36	-201.67	-207.28	-198.42
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-26.30	-31.49	-31.90	-35.21	-37.66	-47.66	0.00	-59.81	-67.44	-68.12	-72.95	-75.02	-72.36
Poughkeepsie, NY	x	x	100	100	0.00	-19.95	-23.89	-24.21	-26.72	-28.58	-36.22	0.00	-45.37	-51.15	-51.68	-55.34	-56.92	-54.96
Providence (All RI), RI	x	-	100	-	0.00	-13.16	-15.76	-15.97	-17.63	-18.85	-23.90	0.00	-29.93	-33.74	-34.09	-36.51	-37.55	-36.26
Reading, PA	-	x	-	100	0.00	-5.88	-7.04	-7.13	-7.87	-8.42	-10.67	0.00	-13.37	-15.07	-15.23	-16.31	-16.77	-16.19
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-16.82	-20.13	-20.43	-22.56	-24.13	-30.75	0.00	-38.22	-43.08	-43.57	-46.66	-48.01	-46.53
Rochester, NY	x	-	100	-	0.00	-18.72	-22.41	-22.71	-25.07	-26.81	-33.98	0.00	-42.56	-47.99	-48.48	-51.92	-53.40	-51.56
Rome, GA	-	x	-	100	0.00	-1.60	-1.92	-1.95	-2.15	-2.30	-2.91	0.00	-3.65	-4.11	-4.15	-4.45	-4.57	-4.42
Sacramento Metro, CA	x	-	50	-	0.00	-36.46	-43.64	-44.24	-48.83	-52.23	-66.22	0.00	-82.89	-93.46	-94.43	-101.12	-104.01	-100.45
San Diego, CA	x	-	100	-	0.00	-43.00	-51.48	-52.17	-57.59	-61.59	-78.04	0.00	-97.78	-110.25	-111.38	-119.28	-122.68	-118.43
San Francisco Bay Area, CA	x	-	100	-	0.00	-92.31	-110.75	-111.26	-122.78	-131.01	-161.00	0.00	-210.78	-237.86	-239.18	-256.00	-262.83	-248.15
San Joaquin Valley, CA	x	x	50	100	0.00	-79.16	-94.80	-95.96	-105.93	-113.25	-142.91	0.00	-180.11	-203.10	-205.06	-219.58	-225.79	-217.32
Sheboygan, WI	x	-	100	-	0.00	-1.77	-2.12	-2.15	-2.37	-2.53	-3.22	0.00	-4.02	-4.53	-4.58	-4.90	-5.04	-4.88
Springfield (Western MA), MA	x	-	100	-	0.00	-13.67	-16.37	-16.59	-18.31	-19.58	-24.81	0.00	-31.09	-35.05	-35.41	-37.92	-39.00	-37.65
St. Louis, MO-IL	x	x	100	100	0.00	-44.93	-53.77	-54.57	-60.24	-64.46	-82.09	0.00	-102.09	-115.09	-116.37	-124.63	-128.22	-124.25
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-1.41	-1.69	-1.72	-1.89	-2.03	-2.57	0.00	-3.22	-3.63	-3.66	-3.92	-4.03	-3.89
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-9.20	-11.02	-11.16	-12.32	-13.18	-16.70	0.00	-20.93	-23.59	-23.84	-25.53	-26.25	-25.34
Washington, DC-MD-VA	x	x	100	100	0.00	-77.98	-93.33	-94.67	-104.51	-111.80	-142.11	0.00	-177.23	-199.81	-201.96	-216.29	-222.51	-215.31
Wheeling, WV-OH	-	x	-	100	0.00	-2.30	-2.75	-2.78	-3.07	-3.29	-4.17	0.00	-5.22	-5.88	-5.95	-6.37	-6.55	-6.32
York, PA	-	x	-	100	0.00	-6.52	-7.80	-7.91	-8.73	-9.33	-11.83	0.00	-14.82	-16.71	-16.88	-18.07	-18.59	-17.95

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-68
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-26.98	-32.02	-32.27	-35.51	-37.53	-47.91	0.00	-72.10	-80.40	-81.00	-86.26	-87.77	-80.97
Allegan Co., MI	x	-	100	-	0.00	-2.94	-3.48	-3.51	-3.86	-4.08	-5.21	0.00	-7.84	-8.75	-8.81	-9.39	-9.55	-8.81
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-3.45	-4.09	-4.13	-4.54	-4.80	-6.13	0.00	-9.22	-10.28	-10.35	-11.03	-11.22	-10.35
Atlanta, GA	x	x	100	100	0.00	-214.61	-254.70	-256.69	-282.42	-298.48	-380.94	0.00	-573.53	-639.55	-644.28	-686.13	-698.07	-643.86
Baltimore, MD	x	x	100	100	0.00	-58.66	-69.61	-70.18	-77.22	-81.62	-104.34	0.00	-156.71	-174.74	-176.08	-187.52	-190.80	-176.18
Baton Rouge, LA	x	-	100	-	0.00	-14.84	-17.61	-17.75	-19.53	-20.64	-26.36	0.00	-39.65	-44.22	-44.55	-47.44	-48.27	-44.53
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-7.73	-9.17	-9.25	-10.17	-10.75	-13.75	0.00	-20.64	-23.02	-23.19	-24.70	-25.13	-23.22
Birmingham, AL	-	x	-	100	0.00	-20.01	-23.76	-23.93	-26.33	-27.82	-35.44	0.00	-53.50	-59.67	-60.09	-63.99	-65.10	-59.97
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-83.04	-98.54	-99.33	-109.29	-115.51	-147.54	0.00	-221.88	-247.42	-249.27	-265.47	-270.10	-249.25
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-12.23	-14.53	-14.57	-16.03	-16.92	-21.21	0.00	-32.78	-36.57	-36.75	-39.12	-39.76	-36.24
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-19.16	-22.74	-22.92	-25.22	-26.65	-34.04	0.00	-51.19	-57.08	-57.51	-61.25	-62.32	-57.51
Canton-Massillon, OH	-	x	-	100	0.00	-5.54	-6.58	-6.63	-7.29	-7.71	-9.84	0.00	-14.81	-16.52	-16.64	-17.72	-18.03	-16.63
Charleston, WV	-	x	-	100	0.00	-4.76	-5.65	-5.70	-6.27	-6.62	-8.45	0.00	-12.72	-14.19	-14.30	-15.22	-15.49	-14.29
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-48.82	-58.04	-58.10	-63.91	-67.39	-83.99	0.00	-130.96	-146.13	-146.72	-156.19	-158.68	-144.05
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-10.12	-11.99	-12.15	-13.37	-14.16	-18.42	0.00	-26.95	-30.04	-30.34	-32.32	-32.93	-30.77
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-140.73	-167.61	-166.72	-183.35	-192.97	-235.12	0.00	-378.85	-422.96	-423.43	-450.60	-457.16	-408.94
Chico, CA	x	-	100	-	0.00	-3.89	-4.62	-4.65	-5.12	-5.41	-6.91	0.00	-10.39	-11.59	-11.68	-12.43	-12.65	-11.67
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-37.85	-44.95	-45.21	-49.74	-52.54	-66.63	0.00	-101.27	-112.95	-113.68	-121.05	-123.11	-113.06
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-2.76	-3.28	-3.30	-3.63	-3.84	-4.91	0.00	-7.38	-8.23	-8.29	-8.83	-8.98	-8.29
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-45.23	-53.67	-54.10	-59.52	-62.91	-80.34	0.00	-120.85	-134.76	-135.77	-144.59	-147.11	-135.74
Columbus, OH	x	x	100	100	0.00	-39.32	-46.67	-47.04	-51.75	-54.69	-69.81	0.00	-105.09	-117.19	-118.06	-125.72	-127.91	-117.98
Dallas-Fort Worth, TX	x	-	100	-	0.00	-194.94	-231.36	-233.17	-256.55	-271.14	-346.12	0.00	-520.94	-580.91	-585.23	-623.24	-634.10	-584.93
Dayton-Springfield, OH	-	x	-	100	0.00	-13.79	-16.37	-16.50	-18.15	-19.19	-24.49	0.00	-36.86	-41.11	-41.41	-44.10	-44.87	-41.39
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-78.43	-93.09	-93.79	-103.19	-109.05	-139.04	0.00	-209.64	-233.78	-235.48	-250.77	-255.12	-235.15
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-88.34	-104.84	-105.67	-116.26	-122.88	-156.89	0.00	-236.07	-263.24	-265.21	-282.43	-287.36	-265.11
Door Co., WI	x	-	100	-	0.00	-0.56	-0.66	-0.67	-0.73	-0.78	-0.99	0.00	-1.49	-1.66	-1.68	-1.78	-1.82	-1.68
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.02	-0.03	-0.03	-0.03	-0.03	-0.04	0.00	-0.06	-0.07	-0.07	-0.07	-0.08	-0.07
Evansville, IN	-	x	-	100	0.00	-6.23	-7.41	-7.40	-8.14	-8.57	-10.57	0.00	-16.74	-18.68	-18.73	-19.94	-20.24	-18.25
Greater Connecticut, CT	x	-	100	-	0.00	-34.49	-40.92	-41.27	-45.41	-48.00	-61.43	0.00	-92.12	-102.72	-103.52	-110.25	-112.19	-103.66
Greene Co., PA	x	-	100	-	0.00	-0.60	-0.71	-0.71	-0.79	-0.83	-1.06	0.00	-1.60	-1.78	-1.79	-1.91	-1.94	-1.79
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-15.68	-18.61	-18.75	-20.63	-21.81	-27.84	0.00	-41.90	-46.72	-47.07	-50.12	-51.00	-47.04

Table B2-68
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Diesel PM 10 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-13.41	-15.92	-16.04	-17.65	-18.65	-23.82	0.00	-35.84	-39.96	-40.26	-42.88	-43.62	-40.25
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.09	-0.10	-0.10	-0.11	-0.12	-0.14	0.00	-0.23	-0.26	-0.26	-0.28	-0.28	-0.25
Hickory, NC	-	x	-	100	0.00	-3.97	-4.71	-4.75	-5.22	-5.52	-7.06	0.00	-10.60	-11.82	-11.91	-12.68	-12.90	-11.92
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-115.40	-136.95	-138.03	-151.87	-160.50	-204.90	0.00	-308.38	-343.87	-346.43	-368.93	-375.36	-346.26
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-5.94	-7.15	-6.86	-7.53	-7.84	-8.25	0.00	-16.32	-18.28	-17.99	-19.11	-19.24	-15.75
Imperial Co., CA	x	-	100	-	0.00	-6.50	-7.72	-7.78	-8.56	-9.05	-11.55	0.00	-17.38	-19.38	-19.52	-20.79	-21.15	-19.51
Indianapolis, IN	-	x	-	100	0.00	-36.68	-43.53	-43.87	-48.27	-51.02	-65.13	0.00	-98.02	-109.31	-110.12	-117.27	-119.31	-110.06
Jamestown, NY	x	-	100	-	0.00	-2.53	-3.00	-3.02	-3.33	-3.52	-4.49	0.00	-6.75	-7.53	-7.59	-8.08	-8.22	-7.59
Jefferson Co., NY	x	-	100	-	0.00	-3.11	-3.69	-3.72	-4.10	-4.33	-5.53	0.00	-8.31	-9.27	-9.34	-9.95	-10.12	-9.34
Johnstown, PA	-	x	-	100	0.00	-1.89	-2.24	-2.26	-2.49	-2.63	-3.37	0.00	-5.04	-5.62	-5.67	-6.04	-6.14	-5.69
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-4.29	-5.05	-5.28	-5.81	-6.22	-8.92	0.00	-11.23	-12.48	-12.81	-13.67	-14.02	-14.05
Knoxville, TN	x	x	100	100	0.00	-22.56	-26.78	-26.98	-29.69	-31.37	-40.02	0.00	-60.30	-67.24	-67.74	-72.13	-73.39	-67.67
Lancaster, PA	-	x	-	100	0.00	-8.01	-9.50	-9.58	-10.54	-11.14	-14.22	0.00	-21.40	-23.86	-24.04	-25.60	-26.05	-24.03
Las Vegas, NV	x	-	100	-	0.00	-46.96	-55.76	-56.10	-61.72	-65.19	-82.69	0.00	-125.63	-140.12	-141.03	-150.18	-152.73	-140.29
Libby, MT	-	x	-	100	0.00	-0.13	-0.16	-0.16	-0.18	-0.19	-0.24	0.00	-0.36	-0.40	-0.40	-0.43	-0.44	-0.40
Liberty-Clairton, PA	-	x	-	100	0.00	-0.20	-0.23	-0.24	-0.26	-0.28	-0.38	0.00	-0.52	-0.58	-0.59	-0.63	-0.64	-0.62
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-353.18	-419.23	-422.25	-464.58	-490.90	-625.31	0.00	-944.15	-1,052.90	-1,060.40	-1,129.23	-1,148.75	-1,058.15
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-19.27	-22.83	-23.15	-25.48	-26.99	-35.21	0.00	-51.30	-57.17	-57.78	-61.55	-62.71	-58.72
Louisville, KY-IN	-	x	-	100	0.00	-19.00	-22.58	-22.67	-24.94	-26.33	-33.17	0.00	-50.89	-56.77	-57.09	-60.79	-61.79	-56.51
Macon, GA	-	x	-	100	0.00	-3.55	-4.22	-4.22	-4.65	-4.90	-6.14	0.00	-9.51	-10.61	-10.66	-11.34	-11.53	-10.50
Manitowoc Co., WI	x	-		-	0.00	-1.84	-2.18	-2.20	-2.42	-2.56	-3.28	0.00	-4.90	-5.47	-5.51	-5.87	-5.97	-5.53
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-2.99	-3.55	-3.58	-3.94	-4.16	-5.32	0.00	-7.99	-8.91	-8.98	-9.56	-9.73	-8.98
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-12.71	-15.08	-15.20	-16.72	-17.67	-22.56	0.00	-33.95	-37.86	-38.14	-40.62	-41.33	-38.12
Memphis, TN-AR	x	-	100	-	0.00	-17.54	-20.81	-20.98	-23.08	-24.39	-31.14	0.00	-46.87	-52.26	-52.65	-56.07	-57.05	-52.63
Milwaukee-Racine, WI	x	-	100	-	0.00	-31.70	-37.62	-37.93	-41.73	-44.10	-56.34	0.00	-84.71	-94.46	-95.17	-101.35	-103.12	-95.18
Nevada (Western Part), CA	x	-	100	-	0.00	-2.23	-2.65	-2.67	-2.94	-3.11	-3.98	0.00	-5.97	-6.66	-6.71	-7.14	-7.27	-6.71
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-262.44	-311.45	-313.95	-345.43	-365.09	-466.33	0.00	-701.27	-781.98	-787.86	-839.04	-853.68	-787.81
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-2.52	-2.99	-3.01	-3.31	-3.50	-4.45	0.00	-6.74	-7.52	-7.57	-8.06	-8.20	-7.54
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-142.44	-169.03	-170.43	-187.53	-198.22	-253.43	0.00	-380.55	-424.35	-427.59	-455.38	-463.35	-427.88

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Diesel PM 10 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-119.16	-141.54	-142.20	-156.44	-165.17	-208.53	0.00	-319.01	-355.83	-357.92	-381.10	-387.47	-354.80
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-30.75	-36.50	-36.77	-40.46	-42.76	-54.52	0.00	-82.19	-91.66	-92.32	-98.32	-100.02	-92.20
Poughkeepsie, NY	x	x	100	100	0.00	-27.17	-32.24	-32.50	-35.75	-37.79	-48.24	0.00	-72.60	-80.95	-81.56	-86.85	-88.37	-81.52
Providence (All RI), RI	x	-	100	-	0.00	-16.33	-19.38	-19.54	-21.50	-22.72	-29.01	0.00	-43.64	-48.67	-49.03	-52.22	-53.13	-49.02
Reading, PA	-	x	-	100	0.00	-8.02	-9.52	-9.59	-10.55	-11.15	-14.24	0.00	-21.43	-23.90	-24.07	-25.64	-26.08	-24.06
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-32.95	-39.07	-39.48	-43.44	-45.94	-59.14	0.00	-87.92	-98.02	-98.86	-105.30	-107.19	-99.44
Rochester, NY	x	-	100	-	0.00	-23.62	-28.03	-28.25	-31.09	-32.85	-41.95	0.00	-63.12	-70.39	-70.91	-75.51	-76.83	-70.88
Rome, GA	-	x	-	100	0.00	-1.98	-2.35	-2.37	-2.60	-2.75	-3.51	0.00	-5.29	-5.90	-5.94	-6.33	-6.44	-5.94
Sacramento Metro, CA	x	-	50	-	0.00	-54.26	-64.39	-64.93	-71.44	-75.52	-96.57	0.00	-144.97	-161.65	-162.89	-173.48	-176.52	-163.02
San Diego, CA	x	-	100	-	0.00	-52.92	-62.81	-63.30	-69.64	-73.60	-93.95	0.00	-141.42	-157.70	-158.87	-169.19	-172.14	-158.79
San Francisco Bay Area, CA	x	-	100	-	0.00	-117.18	-139.38	-139.33	-153.25	-161.55	-200.43	0.00	-314.57	-351.05	-352.27	-374.98	-380.84	-344.72
San Joaquin Valley, CA	x	x	50	100	0.00	-124.00	-147.24	-148.11	-162.94	-172.11	-218.23	0.00	-331.73	-369.98	-372.38	-396.52	-403.26	-370.33
Sheboygan, WI	x	-	100	-	0.00	-2.26	-2.68	-2.70	-2.97	-3.14	-4.02	0.00	-6.02	-6.72	-6.77	-7.21	-7.34	-6.78
Springfield (Western MA), MA	x	-	100	-	0.00	-17.53	-20.81	-20.97	-23.07	-24.38	-31.13	0.00	-46.85	-52.24	-52.63	-56.05	-57.02	-52.60
St. Louis, MO-IL	x	x	100	100	0.00	-57.53	-68.24	-68.88	-75.79	-80.14	-102.82	0.00	-153.60	-171.26	-172.65	-183.88	-187.15	-173.23
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-1.61	-1.92	-1.93	-2.12	-2.24	-2.87	0.00	-4.31	-4.81	-4.84	-5.16	-5.25	-4.84
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-11.56	-13.71	-13.82	-15.21	-16.07	-20.52	0.00	-30.88	-34.44	-34.69	-36.94	-37.59	-34.67
Washington, DC-MD-VA	x	x	100	100	0.00	-112.98	-134.05	-135.23	-148.79	-157.30	-201.44	0.00	-301.76	-336.47	-339.12	-361.17	-367.53	-339.77
Wheeling, WV-OH	-	x	-	100	0.00	-2.70	-3.20	-3.22	-3.55	-3.75	-4.79	0.00	-7.20	-8.03	-8.09	-8.62	-8.77	-8.09
York, PA	-	x	-	100	0.00	-9.32	-11.06	-11.15	-12.27	-12.97	-16.56	0.00	-24.91	-27.78	-27.98	-29.80	-30.32	-27.98

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-69
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.32	0.41	0.59	0.71	1.02	3.20	0.00	0.32	0.41	0.59	0.71	1.02	3.20
Allegan Co., MI	x	-	100	-	0.00	0.04	0.04	0.06	0.08	0.11	0.35	0.00	0.04	0.04	0.06	0.08	0.11	0.35
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.03	0.04	0.06	0.07	0.10	0.32	0.00	0.03	0.04	0.06	0.07	0.10	0.32
Atlanta, GA	x	x	100	100	0.00	1.72	2.17	3.13	3.76	5.44	17.04	0.00	1.72	2.17	3.13	3.76	5.44	17.04
Baltimore, MD	x	x	100	100	0.00	0.72	0.90	1.30	1.56	2.26	7.08	0.00	0.72	0.90	1.30	1.56	2.26	7.08
Baton Rouge, LA	x	-	100	-	0.00	-1.40	-1.76	-2.23	-2.53	-2.86	-5.00	0.00	-1.40	-1.76	-2.24	-2.54	-2.86	-5.00
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-3.05	-3.83	-4.92	-5.61	-6.49	-12.36	0.00	-3.06	-3.84	-4.93	-5.62	-6.50	-12.37
Birmingham, AL	-	x	-	100	0.00	0.26	0.33	0.48	0.57	0.83	2.59	0.00	0.26	0.33	0.48	0.57	0.83	2.59
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	1.16	1.46	2.11	2.54	3.67	11.52	0.00	1.16	1.46	2.11	2.54	3.67	11.52
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.16	0.20	0.29	0.34	0.50	1.56	0.00	0.16	0.20	0.29	0.34	0.50	1.56
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.28	0.35	0.51	0.61	0.88	2.77	0.00	0.28	0.35	0.51	0.61	0.88	2.77
Canton-Massillon, OH	-	x	-	100	0.00	-0.12	-0.16	-0.19	-0.20	-0.19	-0.08	0.00	-0.13	-0.16	-0.19	-0.20	-0.19	-0.08
Charleston, WV	-	x	-	100	0.00	0.07	0.09	0.14	0.16	0.24	0.74	0.00	0.07	0.09	0.14	0.16	0.24	0.74
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.45	0.57	0.82	0.99	1.43	4.48	0.00	0.45	0.57	0.82	0.99	1.43	4.48
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.13	0.17	0.24	0.29	0.42	1.33	0.00	0.13	0.17	0.24	0.29	0.42	1.33
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-0.51	-0.64	-0.48	-0.36	0.65	7.83	0.00	-0.52	-0.65	-0.49	-0.37	0.65	7.83
Chico, CA	x	-	100	-	0.00	0.05	0.06	0.09	0.11	0.15	0.48	0.00	0.05	0.06	0.09	0.11	0.15	0.48
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.46	0.58	0.84	1.01	1.46	4.59	0.00	0.46	0.58	0.84	1.01	1.46	4.59
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.04	0.06	0.08	0.10	0.14	0.43	0.00	0.04	0.06	0.08	0.10	0.14	0.43
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.67	0.84	1.21	1.46	2.11	6.61	0.00	0.67	0.84	1.21	1.46	2.11	6.61
Columbus, OH	x	x	100	100	0.00	0.43	0.54	0.78	0.94	1.36	4.27	0.00	0.43	0.54	0.78	0.94	1.36	4.27
Dallas-Fort Worth, TX	x	-	100	-	0.00	1.75	2.20	3.18	3.82	5.52	17.32	0.00	1.75	2.20	3.18	3.82	5.52	17.32
Dayton-Springfield, OH	-	x	-	100	0.00	0.20	0.25	0.37	0.44	0.64	2.00	0.00	0.20	0.25	0.37	0.44	0.64	2.00
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	0.55	0.69	1.04	1.28	1.99	6.90	0.00	0.55	0.69	1.04	1.28	1.99	6.90
Detroit-Ann Arbor, MI	x	x	100	100	0.00	0.94	1.18	1.76	2.14	3.24	10.88	0.00	0.94	1.18	1.76	2.14	3.24	10.88
Door Co., WI	x	-	100	-	0.00	0.01	0.01	0.01	0.02	0.03	0.08	0.00	0.01	0.01	0.01	0.02	0.03	0.08
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.09	0.11	0.16	0.19	0.27	0.86	0.00	0.09	0.11	0.16	0.19	0.27	0.86
Greater Connecticut, CT	x	-	100	-	0.00	0.44	0.56	0.80	0.97	1.40	4.38	0.00	0.44	0.56	0.80	0.97	1.40	4.38
Greene Co., PA	x	-	100	-	0.00	0.01	0.01	0.02	0.02	0.03	0.10	0.00	0.01	0.01	0.02	0.02	0.03	0.10
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.20	0.25	0.36	0.44	0.63	1.98	0.00	0.20	0.25	0.36	0.44	0.63	1.98

Table B2-69
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.18	0.23	0.33	0.40	0.57	1.80	0.00	0.18	0.23	0.33	0.40	0.57	1.80
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Hickory, NC	-	x	-	100	0.00	0.05	0.06	0.09	0.10	0.15	0.47	0.00	0.05	0.06	0.09	0.10	0.15	0.47
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-5.16	-6.48	-8.10	-9.13	-9.87	-14.63	0.00	-5.18	-6.50	-8.12	-9.15	-9.89	-14.65
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-0.51	-0.64	-0.81	-0.91	-1.00	-1.55	0.00	-0.51	-0.64	-0.81	-0.91	-1.00	-1.55
Imperial Co., CA	x	-	100	-	0.00	0.06	0.07	0.10	0.12	0.18	0.55	0.00	0.06	0.07	0.10	0.12	0.18	0.55
Indianapolis, IN	-	x	-	100	0.00	0.40	0.51	0.73	0.88	1.27	3.99	0.00	0.40	0.51	0.73	0.88	1.27	3.99
Jamestown, NY	x	-	100	-	0.00	0.04	0.05	0.07	0.08	0.12	0.37	0.00	0.04	0.05	0.07	0.08	0.12	0.37
Jefferson Co., NY	x	-	100	-	0.00	0.03	0.04	0.06	0.08	0.11	0.34	0.00	0.03	0.04	0.06	0.08	0.11	0.34
Johnstown, PA	-	x	-	100	0.00	0.03	0.04	0.06	0.07	0.10	0.30	0.00	0.03	0.04	0.06	0.07	0.10	0.30
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.03	0.04	0.05	0.06	0.09	0.29	0.00	0.03	0.04	0.05	0.06	0.09	0.29
Knoxville, TN	x	x	100	100	0.00	0.27	0.34	0.50	0.60	0.86	2.71	0.00	0.27	0.34	0.50	0.60	0.86	2.71
Lancaster, PA	-	x	-	100	0.00	0.11	0.13	0.19	0.23	0.34	1.06	0.00	0.11	0.13	0.19	0.23	0.34	1.06
Las Vegas, NV	x	-	100	-	0.00	0.35	0.45	0.64	0.77	1.12	3.51	0.00	0.35	0.45	0.64	0.77	1.12	3.51
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	0.23	0.30	1.11	1.66	4.20	21.95	0.00	0.22	0.29	1.10	1.65	4.19	21.95
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.18	0.23	0.33	0.40	0.58	1.81	0.00	0.18	0.23	0.33	0.40	0.58	1.81
Louisville, KY-IN	-	x	-	100	0.00	0.28	0.35	0.51	0.61	0.89	2.78	0.00	0.28	0.35	0.51	0.61	0.89	2.78
Macon, GA	-	x	-	100	0.00	0.05	0.07	0.10	0.11	0.17	0.52	0.00	0.05	0.07	0.10	0.11	0.17	0.52
Manitowoc Co., WI	x	-		-	0.00	0.03	0.03	0.05	0.06	0.08	0.27	0.00	0.03	0.03	0.05	0.06	0.08	0.27
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.03	0.03	0.05	0.06	0.08	0.26	0.00	0.03	0.03	0.05	0.06	0.08	0.26
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.10	0.13	0.19	0.22	0.32	1.02	0.00	0.10	0.13	0.19	0.22	0.32	1.02
Memphis, TN-AR	x	-	100	-	0.00	-0.26	-0.32	-0.36	-0.39	-0.30	0.32	0.00	-0.26	-0.32	-0.37	-0.39	-0.31	0.32
Milwaukee-Racine, WI	x	-	100	-	0.00	0.44	0.55	0.80	0.96	1.39	4.37	0.00	0.44	0.55	0.80	0.96	1.39	4.37
Nevada (Western Part), CA	x	-	100	-	0.00	0.02	0.03	0.05	0.05	0.08	0.25	0.00	0.02	0.03	0.05	0.05	0.08	0.25
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	2.74	3.45	5.15	6.28	9.54	32.16	0.00	2.74	3.45	5.15	6.27	9.53	32.16
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.04	0.05	0.07	0.09	0.13	0.39	0.00	0.04	0.05	0.07	0.09	0.13	0.39
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-1.59	-1.99	-2.23	-2.36	-1.70	3.07	0.00	-1.59	-2.00	-2.24	-2.37	-1.71	3.06

Table B2-69
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.98	1.24	1.79	2.15	3.11	9.75	0.00	0.98	1.24	1.79	2.15	3.11	9.75
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.49	0.62	0.89	1.08	1.56	4.88	0.00	0.49	0.62	0.89	1.08	1.56	4.88
Poughkeepsie, NY	x	x	100	100	0.00	0.32	0.40	0.58	0.70	1.01	3.16	0.00	0.32	0.40	0.58	0.70	1.01	3.16
Providence (All RI), RI	x	-	100	-	0.00	0.23	0.29	0.42	0.50	0.73	2.29	0.00	0.23	0.29	0.42	0.50	0.73	2.29
Reading, PA	-	x	-	100	0.00	0.09	0.12	0.17	0.20	0.30	0.93	0.00	0.09	0.12	0.17	0.20	0.30	0.93
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.19	0.23	0.34	0.41	0.59	1.85	0.00	0.19	0.23	0.34	0.41	0.59	1.85
Rochester, NY	x	-	100	-	0.00	0.32	0.41	0.59	0.71	1.02	3.21	0.00	0.32	0.41	0.59	0.71	1.02	3.21
Rome, GA	-	x	-	100	0.00	0.03	0.04	0.05	0.06	0.09	0.28	0.00	0.03	0.04	0.05	0.06	0.09	0.28
Sacramento Metro, CA	x	-	50	-	0.00	0.54	0.68	0.99	1.19	1.72	5.39	0.00	0.54	0.68	0.99	1.19	1.72	5.39
San Diego, CA	x	-	100	-	0.00	0.76	0.96	1.38	1.66	2.40	7.54	0.00	0.76	0.96	1.38	1.66	2.40	7.54
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.19	-0.23	0.03	0.21	1.26	8.66	0.00	-0.19	-0.23	0.02	0.21	1.26	8.65
San Joaquin Valley, CA	x	x	50	100	0.00	0.80	1.01	1.51	1.85	2.83	9.67	0.00	0.80	1.00	1.51	1.85	2.83	9.67
Sheboygan, WI	x	-	100	-	0.00	0.03	0.04	0.05	0.07	0.09	0.30	0.00	0.03	0.04	0.05	0.07	0.09	0.30
Springfield (Western MA), MA	x	-	100	-	0.00	0.23	0.29	0.42	0.51	0.73	2.30	0.00	0.23	0.29	0.42	0.51	0.73	2.30
St. Louis, MO-IL	x	x	100	100	0.00	-0.09	-0.11	0.01	0.09	0.58	3.97	0.00	-0.09	-0.11	0.01	0.09	0.57	3.97
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.03	-0.04	-0.04	-0.04	-0.04	0.03	0.00	-0.03	-0.04	-0.04	-0.04	-0.04	0.03
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.15	0.19	0.28	0.33	0.49	1.55	0.00	0.15	0.19	0.28	0.33	0.49	1.55
Washington, DC-MD-VA	x	x	100	100	0.00	1.22	1.54	2.22	2.67	3.86	12.11	0.00	1.22	1.54	2.22	2.67	3.86	12.11
Wheeling, WV-OH	-	x	-	100	0.00	0.04	0.05	0.08	0.09	0.13	0.42	0.00	0.04	0.05	0.08	0.09	0.13	0.42
York, PA	-	x	-	100	0.00	0.10	0.12	0.18	0.22	0.31	0.98	0.00	0.10	0.12	0.18	0.22	0.31	0.98

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
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Table B2-70
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	1.08	1.12	1.50	1.95	2.57	8.87	0.00	1.31	1.36	1.80	2.31	3.01	9.26
Allegan Co., MI	x	-	100	-	0.00	0.12	0.12	0.16	0.21	0.28	0.97	0.00	0.14	0.15	0.20	0.25	0.33	1.01
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.11	0.12	0.16	0.21	0.27	0.94	0.00	0.14	0.14	0.19	0.24	0.32	0.98
Atlanta, GA	x	x	100	100	0.00	6.28	6.48	8.72	11.32	14.90	51.40	0.00	7.59	7.91	10.42	13.41	17.45	53.67
Baltimore, MD	x	x	100	100	0.00	2.38	2.46	3.31	4.29	5.65	19.50	0.00	2.88	3.00	3.95	5.09	6.62	20.36
Baton Rouge, LA	x	-	100	-	0.00	-4.33	-5.13	-6.13	-6.70	-7.31	-11.78	0.00	-7.39	-8.40	-9.50	-10.21	-10.81	-14.09
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-9.52	-11.15	-13.45	-14.92	-16.61	-30.23	0.00	-15.85	-17.92	-20.45	-22.26	-23.99	-35.18
Birmingham, AL	-	x	-	100	0.00	0.85	0.88	1.18	1.53	2.02	6.96	0.00	1.03	1.07	1.41	1.82	2.36	7.27
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	3.74	3.85	5.19	6.73	8.86	30.56	0.00	4.51	4.70	6.19	7.97	10.38	31.91
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.52	0.54	0.73	0.94	1.24	4.27	0.00	0.63	0.66	0.87	1.12	1.45	4.46
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.89	0.92	1.24	1.61	2.12	7.30	0.00	1.08	1.12	1.48	1.91	2.48	7.63
Canton-Massillon, OH	-	x	-	100	0.00	-0.38	-0.48	-0.55	-0.55	-0.52	-0.05	0.00	-0.75	-0.87	-0.94	-0.94	-0.91	-0.29
Charleston, WV	-	x	-	100	0.00	0.23	0.24	0.33	0.42	0.56	1.92	0.00	0.28	0.29	0.39	0.50	0.65	2.00
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	1.63	1.68	2.26	2.93	3.86	13.30	0.00	1.96	2.05	2.70	3.47	4.52	13.89
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.43	0.45	0.60	0.78	1.03	3.54	0.00	0.52	0.55	0.72	0.92	1.20	3.70
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-1.26	-2.26	-1.91	-0.65	1.34	24.25	0.00	-4.67	-5.89	-5.46	-4.09	-1.71	22.70
Chico, CA	x	-	100	-	0.00	0.16	0.17	0.22	0.29	0.38	1.32	0.00	0.19	0.20	0.27	0.34	0.45	1.37
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	1.52	1.57	2.11	2.74	3.60	12.43	0.00	1.83	1.91	2.52	3.24	4.22	12.98
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.14	0.14	0.19	0.25	0.32	1.12	0.00	0.17	0.17	0.23	0.29	0.38	1.17
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	2.12	2.19	2.95	3.82	5.03	17.36	0.00	2.56	2.67	3.52	4.53	5.89	18.12
Columbus, OH	x	x	100	100	0.00	1.47	1.51	2.04	2.64	3.48	12.00	0.00	1.77	1.85	2.43	3.13	4.07	12.53
Dallas-Fort Worth, TX	x	-	100	-	0.00	6.23	6.43	8.65	11.22	14.77	50.95	0.00	7.52	7.84	10.33	13.29	17.30	53.20
Dayton-Springfield, OH	-	x	-	100	0.00	0.65	0.67	0.90	1.16	1.53	5.28	0.00	0.78	0.81	1.07	1.38	1.79	5.51
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	1.97	1.92	2.72	3.73	5.17	20.10	0.00	2.01	1.98	2.88	4.04	5.68	20.68
Detroit-Ann Arbor, MI	x	x	100	100	0.00	3.06	3.04	4.23	5.71	7.79	29.28	0.00	3.31	3.33	4.66	6.36	8.72	30.25
Door Co., WI	x	-	100	-	0.00	0.03	0.03	0.04	0.05	0.06	0.21	0.00	0.03	0.03	0.04	0.06	0.07	0.22
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Evansville, IN	-	x	-	100	0.00	0.28	0.29	0.39	0.51	0.67	2.32	0.00	0.34	0.36	0.47	0.61	0.79	2.42
Greater Connecticut, CT	x	-	100	-	0.00	1.46	1.50	2.02	2.63	3.46	11.92	0.00	1.76	1.83	2.42	3.11	4.05	12.45
Greene Co., PA	x	-	100	-	0.00	0.03	0.03	0.04	0.06	0.07	0.26	0.00	0.04	0.04	0.05	0.07	0.09	0.27
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.66	0.68	0.92	1.19	1.57	5.41	0.00	0.80	0.83	1.10	1.41	1.84	5.64

Table B2-70
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.59	0.61	0.82	1.06	1.40	4.83	0.00	0.71	0.74	0.98	1.26	1.64	5.04
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.01	0.01	0.01	0.01	0.03
Hickory, NC	-	x	-	100	0.00	0.16	0.16	0.22	0.28	0.37	1.29	0.00	0.19	0.20	0.26	0.34	0.44	1.35
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-15.85	-19.06	-22.47	-23.98	-25.36	-32.08	0.00	-28.04	-32.10	-35.82	-37.79	-38.98	-40.89
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-1.59	-1.90	-2.26	-2.43	-2.60	-3.63	0.00	-2.78	-3.18	-3.56	-3.78	-3.94	-4.50
Imperial Co., CA	x	-	100	-	0.00	0.20	0.21	0.28	0.37	0.48	1.66	0.00	0.25	0.26	0.34	0.43	0.57	1.74
Indianapolis, IN	-	x	-	100	0.00	1.37	1.41	1.90	2.46	3.24	11.18	0.00	1.65	1.72	2.27	2.92	3.79	11.67
Jamestown, NY	x	-	100	-	0.00	0.12	0.12	0.16	0.21	0.28	0.97	0.00	0.14	0.15	0.20	0.25	0.33	1.01
Jefferson Co., NY	x	-	100	-	0.00	0.12	0.12	0.16	0.21	0.28	0.97	0.00	0.14	0.15	0.20	0.25	0.33	1.01
Johnstown, PA	-	x	-	100	0.00	0.09	0.10	0.13	0.17	0.22	0.78	0.00	0.11	0.12	0.16	0.20	0.26	0.81
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.11	0.11	0.15	0.19	0.25	0.87	0.00	0.13	0.13	0.18	0.23	0.30	0.91
Knoxville, TN	x	x	100	100	0.00	0.91	0.94	1.27	1.65	2.17	7.48	0.00	1.10	1.15	1.52	1.95	2.54	7.81
Lancaster, PA	-	x	-	100	0.00	0.35	0.36	0.48	0.63	0.83	2.86	0.00	0.42	0.44	0.58	0.75	0.97	2.98
Las Vegas, NV	x	-	100	-	0.00	1.34	1.38	1.86	2.41	3.17	10.95	0.00	1.62	1.68	2.22	2.86	3.72	11.43
Libby, MT	-	x	-	100	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Liberty-Clairton, PA	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.08	0.00	0.01	0.01	0.02	0.02	0.03	0.09
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	1.83	0.43	2.29	5.76	10.92	67.52	0.00	-2.58	-4.24	-2.10	1.78	7.80	66.52
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.64	0.66	0.89	1.16	1.52	5.25	0.00	0.77	0.81	1.06	1.37	1.78	5.48
Louisville, KY-IN	-	x	-	100	0.00	0.90	0.93	1.25	1.62	2.13	7.35	0.00	1.08	1.13	1.49	1.92	2.50	7.68
Macon, GA	-	x	-	100	0.00	0.17	0.17	0.23	0.30	0.40	1.38	0.00	0.20	0.21	0.28	0.36	0.47	1.44
Manitowoc Co., WI	x	-		-	0.00	0.09	0.09	0.12	0.15	0.20	0.70	0.00	0.10	0.11	0.14	0.18	0.24	0.73
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.09	0.10	0.13	0.17	0.22	0.78	0.00	0.11	0.12	0.16	0.20	0.26	0.81
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.38	0.39	0.53	0.68	0.90	3.10	0.00	0.46	0.48	0.63	0.81	1.05	3.23
Memphis, TN-AR	x	-	100	-	0.00	-0.78	-1.01	-1.11	-1.04	-0.89	1.27	0.00	-1.63	-1.93	-2.03	-1.97	-1.76	0.75
Milwaukee-Racine, WI	x	-	100	-	0.00	1.42	1.47	1.97	2.56	3.37	11.63	0.00	1.72	1.79	2.36	3.03	3.95	12.14
Nevada (Western Part), CA	x	-	100	-	0.00	0.09	0.09	0.12	0.15	0.20	0.70	0.00	0.10	0.11	0.14	0.18	0.24	0.73
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	8.95	8.86	12.36	16.75	22.91	86.68	0.00	9.58	9.59	13.52	18.56	25.55	89.49
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.12	0.13	0.17	0.22	0.30	1.02	0.00	0.15	0.16	0.21	0.27	0.35	1.06
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-4.61	-6.15	-6.64	-5.96	-4.65	12.48	0.00	-10.15	-12.06	-12.55	-11.88	-10.22	9.23

Table B2-70
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	3.64	3.76	5.06	6.56	8.64	29.80	0.00	4.40	4.58	6.04	7.77	10.12	31.11
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	1.54	1.58	2.13	2.77	3.64	12.56	0.00	1.85	1.93	2.55	3.28	4.26	13.12
Poughkeepsie, NY	x	x	100	100	0.00	1.08	1.11	1.49	1.94	2.55	8.80	0.00	1.30	1.35	1.78	2.30	2.99	9.19
Providence (All RI), RI	x	-	100	-	0.00	0.74	0.77	1.03	1.34	1.76	6.08	0.00	0.90	0.94	1.23	1.59	2.06	6.35
Reading, PA	-	x	-	100	0.00	0.32	0.33	0.44	0.57	0.75	2.59	0.00	0.38	0.40	0.53	0.68	0.88	2.71
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.75	0.78	1.04	1.35	1.78	6.15	0.00	0.91	0.95	1.25	1.60	2.09	6.42
Rochester, NY	x	-	100	-	0.00	1.05	1.08	1.46	1.89	2.49	8.58	0.00	1.27	1.32	1.74	2.24	2.91	8.96
Rome, GA	-	x	-	100	0.00	0.09	0.09	0.13	0.16	0.22	0.74	0.00	0.11	0.11	0.15	0.19	0.25	0.78
Sacramento Metro, CA	x	-	50	-	0.00	1.89	1.95	2.63	3.41	4.49	15.49	0.00	2.29	2.38	3.14	4.04	5.26	16.17
San Diego, CA	x	-	100	-	0.00	2.44	2.52	3.39	4.39	5.78	19.96	0.00	2.95	3.07	4.04	5.21	6.77	20.84
San Francisco Bay Area, CA	x	-	100	-	0.00	-0.39	-1.18	-0.67	0.62	2.60	24.92	0.00	-3.02	-3.98	-3.38	-1.96	0.38	23.90
San Joaquin Valley, CA	x	x	50	100	0.00	3.03	3.00	4.19	5.68	7.78	29.52	0.00	3.23	3.23	4.57	6.29	8.67	30.47
Sheboygan, WI	x	-	100	-	0.00	0.10	0.10	0.14	0.18	0.23	0.80	0.00	0.12	0.12	0.16	0.21	0.27	0.84
Springfield (Western MA), MA	x	-	100	-	0.00	0.76	0.78	1.05	1.37	1.80	6.22	0.00	0.92	0.96	1.26	1.62	2.11	6.49
St. Louis, MO-IL	x	x	100	100	0.00	-0.19	-0.56	-0.32	0.26	1.17	11.41	0.00	-1.41	-1.85	-1.58	-0.93	0.14	10.93
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.09	-0.12	-0.13	-0.13	-0.11	0.10	0.00	-0.19	-0.22	-0.24	-0.23	-0.21	0.04
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.49	0.50	0.68	0.89	1.18	4.15	0.00	0.58	0.60	0.80	1.05	1.37	4.32
Washington, DC-MD-VA	x	x	100	100	0.00	4.13	4.26	5.73	7.44	9.79	33.78	0.00	4.98	5.20	6.85	8.81	11.47	35.27
Wheeling, WV-OH	-	x	-	100	0.00	0.13	0.14	0.19	0.24	0.32	1.09	0.00	0.16	0.17	0.22	0.28	0.37	1.14
York, PA	-	x	-	100	0.00	0.34	0.35	0.48	0.62	0.81	2.80	0.00	0.41	0.43	0.57	0.73	0.95	2.93

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-71
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	1.66	1.66	2.23	2.90	3.72	12.94	0.00	2.32	2.39	3.09	3.94	4.97	14.14
Allegan Co., MI	x	-	100	-	0.00	0.18	0.18	0.24	0.32	0.41	1.41	0.00	0.25	0.26	0.34	0.43	0.54	1.54
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.19	0.19	0.25	0.33	0.42	1.46	0.00	0.26	0.27	0.35	0.44	0.56	1.59
Atlanta, GA	x	x	100	100	0.00	10.60	10.60	14.22	18.49	23.77	82.66	0.00	14.84	15.26	19.72	25.15	31.77	90.31
Baltimore, MD	x	x	100	100	0.00	3.63	3.63	4.87	6.34	8.14	28.32	0.00	5.08	5.23	6.76	8.62	10.89	30.94
Baton Rouge, LA	x	-	100	-	0.00	-6.80	-7.94	-9.35	-10.14	-10.98	-17.45	0.00	-14.89	-16.58	-18.24	-19.41	-20.23	-23.41
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-14.96	-17.24	-20.50	-22.61	-24.94	-44.95	0.00	-31.73	-35.20	-39.07	-42.06	-44.50	-57.86
Birmingham, AL	-	x	-	100	0.00	1.27	1.27	1.71	2.22	2.85	9.93	0.00	1.78	1.83	2.37	3.02	3.82	10.85
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	5.50	5.50	7.37	9.59	12.33	42.87	0.00	7.70	7.92	10.23	13.04	16.48	46.83
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.79	0.79	1.06	1.38	1.78	6.18	0.00	1.11	1.14	1.47	1.88	2.37	6.75
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	1.30	1.30	1.75	2.27	2.92	10.15	0.00	1.82	1.87	2.42	3.09	3.90	11.09
Canton-Massillon, OH	-	x	-	100	0.00	-0.63	-0.78	-0.87	-0.87	-0.85	-0.25	0.00	-1.58	-1.79	-1.90	-1.92	-1.86	-0.84
Charleston, WV	-	x	-	100	0.00	0.34	0.34	0.45	0.58	0.75	2.61	0.00	0.47	0.48	0.62	0.80	1.00	2.86
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	2.68	2.68	3.59	4.67	6.01	20.89	0.00	3.75	3.86	4.98	6.35	8.03	22.82
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.64	0.64	0.86	1.12	1.44	5.00	0.00	0.90	0.92	1.19	1.52	1.92	5.46
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-2.18	-3.84	-3.24	-1.28	1.35	34.95	0.00	-10.88	-13.04	-12.20	-9.94	-6.29	31.84
Chico, CA	x	-	100	-	0.00	0.24	0.24	0.33	0.43	0.55	1.90	0.00	0.34	0.35	0.45	0.58	0.73	2.08
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	2.31	2.31	3.10	4.03	5.18	18.00	0.00	3.23	3.32	4.29	5.48	6.92	19.66
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.20	0.20	0.26	0.34	0.44	1.53	0.00	0.27	0.28	0.36	0.46	0.59	1.67
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	3.08	3.08	4.14	5.38	6.92	24.05	0.00	4.32	4.44	5.74	7.32	9.24	26.27
Columbus, OH	x	x	100	100	0.00	2.29	2.29	3.07	3.99	5.14	17.86	0.00	3.21	3.30	4.26	5.43	6.86	19.51
Dallas-Fort Worth, TX	x	-	100	-	0.00	10.22	10.21	13.70	17.82	22.91	79.66	0.00	14.30	14.71	19.00	24.23	30.62	87.03
Dayton-Springfield, OH	-	x	-	100	0.00	0.94	0.94	1.26	1.64	2.11	7.33	0.00	1.32	1.35	1.75	2.23	2.82	8.01
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	3.14	2.95	4.17	5.76	7.75	30.45	0.00	3.49	3.38	4.90	6.89	9.43	32.54
Detroit-Ann Arbor, MI	x	x	100	100	0.00	4.45	4.24	5.92	8.06	10.73	41.03	0.00	5.26	5.19	7.27	9.96	13.35	44.05
Door Co., WI	x	-	100	-	0.00	0.04	0.04	0.05	0.07	0.09	0.30	0.00	0.05	0.05	0.07	0.09	0.11	0.32
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Evansville, IN	-	x	-	100	0.00	0.42	0.42	0.57	0.74	0.95	3.31	0.00	0.59	0.61	0.79	1.01	1.27	3.62
Greater Connecticut, CT	x	-	100	-	0.00	2.19	2.19	2.94	3.82	4.92	17.10	0.00	3.07	3.16	4.08	5.20	6.57	18.68
Greene Co., PA	x	-	100	-	0.00	0.04	0.04	0.06	0.08	0.10	0.34	0.00	0.06	0.06	0.08	0.10	0.13	0.37
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	1.00	1.00	1.34	1.74	2.23	7.77	0.00	1.39	1.43	1.85	2.36	2.99	8.49

Table B2-71
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.88	0.88	1.18	1.53	1.97	6.84	0.00	1.23	1.26	1.63	2.08	2.63	7.47
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.00	0.01	0.01	0.01	0.01	0.02	0.05
Hickory, NC	-	x	-	100	0.00	0.24	0.24	0.33	0.42	0.54	1.89	0.00	0.34	0.35	0.45	0.58	0.73	2.07
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-24.93	-29.60	-34.34	-36.35	-38.29	-47.63	0.00	-56.99	-63.86	-69.38	-72.60	-74.03	-69.95
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-2.53	-2.99	-3.49	-3.73	-3.99	-5.63	0.00	-5.68	-6.34	-6.93	-7.31	-7.53	-7.87
Imperial Co., CA	x	-	100	-	0.00	0.34	0.34	0.45	0.59	0.76	2.64	0.00	0.47	0.49	0.63	0.80	1.02	2.89
Indianapolis, IN	-	x	-	100	0.00	2.13	2.13	2.86	3.72	4.78	16.62	0.00	2.98	3.07	3.96	5.06	6.39	18.16
Jamestown, NY	x	-	100	-	0.00	0.17	0.17	0.23	0.30	0.39	1.35	0.00	0.24	0.25	0.32	0.41	0.52	1.47
Jefferson Co., NY	x	-	100	-	0.00	0.18	0.18	0.25	0.32	0.41	1.44	0.00	0.26	0.27	0.34	0.44	0.55	1.57
Johnstown, PA	-	x	-	100	0.00	0.13	0.13	0.18	0.23	0.30	1.05	0.00	0.19	0.19	0.25	0.32	0.40	1.15
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.18	0.18	0.24	0.31	0.39	1.37	0.00	0.25	0.25	0.33	0.42	0.53	1.50
Knoxville, TN	x	x	100	100	0.00	1.40	1.40	1.87	2.44	3.13	10.89	0.00	1.95	2.01	2.60	3.31	4.18	11.89
Lancaster, PA	-	x	-	100	0.00	0.52	0.52	0.70	0.91	1.17	4.06	0.00	0.73	0.75	0.97	1.24	1.56	4.44
Las Vegas, NV	x	-	100	-	0.00	2.31	2.31	3.10	4.03	5.17	18.00	0.00	3.23	3.32	4.29	5.47	6.92	19.66
Libby, MT	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.07	0.00	0.01	0.01	0.02	0.02	0.03	0.07
Liberty-Clairton, PA	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.11	0.00	0.02	0.02	0.03	0.03	0.04	0.12
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	3.00	0.48	3.53	9.07	16.20	102.39	0.00	-7.70	-10.74	-6.81	-0.13	9.36	102.20
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	1.03	1.03	1.38	1.80	2.31	8.04	0.00	1.44	1.48	1.92	2.44	3.09	8.78
Louisville, KY-IN	-	x	-	100	0.00	1.31	1.31	1.76	2.29	2.94	10.24	0.00	1.84	1.89	2.44	3.11	3.93	11.19
Macon, GA	-	x	-	100	0.00	0.25	0.25	0.33	0.43	0.55	1.92	0.00	0.34	0.35	0.46	0.58	0.74	2.10
Manitowoc Co., WI	x	-		-	0.00	0.12	0.12	0.17	0.22	0.28	0.97	0.00	0.17	0.18	0.23	0.30	0.37	1.06
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.16	0.16	0.21	0.27	0.35	1.23	0.00	0.22	0.23	0.29	0.37	0.47	1.34
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.64	0.64	0.86	1.11	1.43	4.98	0.00	0.89	0.92	1.19	1.52	1.92	5.44
Memphis, TN-AR	x	-	100	-	0.00	-1.30	-1.66	-1.81	-1.71	-1.53	1.35	0.00	-3.54	-4.05	-4.21	-4.13	-3.83	0.07
Milwaukee-Racine, WI	x	-	100	-	0.00	2.10	2.10	2.81	3.66	4.70	16.35	0.00	2.93	3.02	3.90	4.97	6.28	17.86
Nevada (Western Part), CA	x	-	100	-	0.00	0.13	0.13	0.18	0.23	0.30	1.03	0.00	0.19	0.19	0.25	0.31	0.40	1.13
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	12.97	12.32	17.27	23.61	31.52	121.41	0.00	15.11	14.82	20.95	28.91	38.97	130.16
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.18	0.18	0.24	0.31	0.40	1.39	0.00	0.25	0.26	0.33	0.42	0.54	1.52
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-7.48	-9.89	-10.51	-9.39	-7.73	17.13	0.00	-21.85	-25.17	-25.76	-24.68	-22.08	9.49

Table B2-71
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	6.15	6.15	8.25	10.73	13.80	47.98	0.00	8.61	8.86	11.45	14.59	18.44	52.41
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	2.19	2.19	2.93	3.82	4.91	17.06	0.00	3.06	3.15	4.07	5.19	6.56	18.64
Poughkeepsie, NY	x	x	100	100	0.00	1.66	1.66	2.22	2.89	3.71	12.92	0.00	2.32	2.39	3.08	3.93	4.96	14.11
Providence (All RI), RI	x	-	100	-	0.00	1.09	1.09	1.46	1.91	2.45	8.52	0.00	1.53	1.57	2.03	2.59	3.27	9.30
Reading, PA	-	x	-	100	0.00	0.49	0.49	0.65	0.85	1.09	3.81	0.00	0.68	0.70	0.91	1.16	1.46	4.16
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	1.38	1.38	1.86	2.41	3.10	10.79	0.00	1.94	1.99	2.57	3.28	4.15	11.79
Rochester, NY	x	-	100	-	0.00	1.55	1.55	2.08	2.71	3.48	12.12	0.00	2.18	2.24	2.89	3.69	4.66	13.24
Rome, GA	-	x	-	100	0.00	0.13	0.13	0.18	0.23	0.30	1.04	0.00	0.19	0.19	0.25	0.32	0.40	1.13
Sacramento Metro, CA	x	-	50	-	0.00	3.02	3.02	4.06	5.28	6.78	23.58	0.00	4.23	4.35	5.63	7.17	9.06	25.77
San Diego, CA	x	-	100	-	0.00	3.57	3.57	4.79	6.23	8.01	27.85	0.00	5.00	5.14	6.64	8.47	10.70	30.42
San Francisco Bay Area, CA	x	-	100	-	0.00	-1.06	-2.40	-1.68	0.20	2.69	33.95	0.00	-7.84	-9.57	-8.59	-6.39	-2.98	31.94
San Joaquin Valley, CA	x	x	50	100	0.00	5.09	4.87	6.79	9.23	12.27	46.79	0.00	6.06	5.99	8.37	11.43	15.30	50.25
Sheboygan, WI	x	-	100	-	0.00	0.15	0.15	0.20	0.25	0.33	1.14	0.00	0.20	0.21	0.27	0.35	0.44	1.24
Springfield (Western MA), MA	x	-	100	-	0.00	1.14	1.13	1.52	1.98	2.55	8.85	0.00	1.59	1.63	2.11	2.69	3.40	9.67
St. Louis, MO-IL	x	x	100	100	0.00	-0.50	-1.13	-0.80	0.07	1.21	15.56	0.00	-3.64	-4.44	-3.99	-2.98	-1.42	14.62
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.16	-0.20	-0.22	-0.21	-0.20	0.05	0.00	-0.41	-0.47	-0.49	-0.49	-0.47	-0.10
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.73	0.72	0.97	1.27	1.65	5.84	0.00	0.99	1.01	1.32	1.71	2.18	6.36
Washington, DC-MD-VA	x	x	100	100	0.00	6.44	6.44	8.64	11.23	14.44	50.22	0.00	9.02	9.27	11.98	15.28	19.30	54.87
Wheeling, WV-OH	-	x	-	100	0.00	0.19	0.19	0.26	0.33	0.43	1.49	0.00	0.27	0.27	0.35	0.45	0.57	1.62
York, PA	-	x	-	100	0.00	0.54	0.54	0.73	0.94	1.21	4.22	0.00	0.76	0.78	1.01	1.28	1.62	4.61

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-72
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	2.21	2.18	2.91	3.76	4.78	16.55	0.00	3.52	3.63	4.60	5.76	7.13	19.00
Allegan Co., MI	x	-	100	-	0.00	0.24	0.24	0.32	0.41	0.52	1.80	0.00	0.38	0.40	0.50	0.63	0.78	2.07
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.28	0.28	0.37	0.48	0.61	2.11	0.00	0.45	0.46	0.59	0.74	0.91	2.43
Atlanta, GA	x	x	100	100	0.00	17.58	17.35	23.15	29.94	38.03	131.75	0.00	28.03	28.90	36.62	45.81	56.76	151.19
Baltimore, MD	x	x	100	100	0.00	4.79	4.73	6.31	8.16	10.36	35.91	0.00	7.64	7.88	9.98	12.49	15.47	41.21
Baton Rouge, LA	x	-	100	-	0.00	-9.56	-11.04	-12.85	-13.89	-14.98	-23.73	0.00	-24.35	-26.84	-29.11	-30.85	-31.89	-34.45
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-21.06	-24.02	-28.26	-31.06	-34.08	-61.38	0.00	-51.92	-57.03	-62.40	-66.85	-70.06	-84.98
Birmingham, AL	-	x	-	100	0.00	1.65	1.62	2.17	2.80	3.56	12.33	0.00	2.62	2.70	3.43	4.29	5.31	14.15
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	6.79	6.70	8.94	11.57	14.69	50.91	0.00	10.83	11.17	14.15	17.70	21.93	58.42
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	1.03	1.02	1.36	1.76	2.23	7.73	0.00	1.64	1.70	2.15	2.69	3.33	8.87
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	1.57	1.55	2.06	2.67	3.39	11.74	0.00	2.50	2.58	3.26	4.08	5.06	13.48
Canton-Massillon, OH	-	x	-	100	0.00	-0.95	-1.15	-1.29	-1.31	-1.32	-0.89	0.00	-2.71	-3.02	-3.19	-3.26	-3.21	-1.96
Charleston, WV	-	x	-	100	0.00	0.39	0.38	0.51	0.66	0.84	2.92	0.00	0.62	0.64	0.81	1.02	1.26	3.35
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	4.16	4.10	5.48	7.08	9.00	31.17	0.00	6.63	6.84	8.66	10.84	13.43	35.77
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.80	0.79	1.05	1.36	1.73	6.00	0.00	1.28	1.32	1.67	2.09	2.58	6.89
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-3.30	-5.60	-4.74	-2.14	1.17	45.13	0.00	-18.56	-21.67	-20.31	-17.28	-12.17	41.26
Chico, CA	x	-	100	-	0.00	0.32	0.31	0.42	0.54	0.69	2.39	0.00	0.51	0.52	0.66	0.83	1.03	2.74
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	3.14	3.09	4.13	5.34	6.78	23.49	0.00	5.00	5.15	6.53	8.17	10.12	26.96
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.23	0.22	0.30	0.38	0.49	1.69	0.00	0.36	0.37	0.47	0.59	0.73	1.94
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	3.70	3.65	4.87	6.30	8.01	27.73	0.00	5.90	6.08	7.71	9.64	11.95	31.83
Columbus, OH	x	x	100	100	0.00	3.22	3.18	4.24	5.49	6.97	24.14	0.00	5.14	5.30	6.71	8.39	10.40	27.70
Dallas-Fort Worth, TX	x	-	100	-	0.00	15.97	15.75	21.02	27.19	34.53	119.63	0.00	25.45	26.24	33.25	41.60	51.54	137.29
Dayton-Springfield, OH	-	x	-	100	0.00	1.13	1.11	1.49	1.92	2.44	8.46	0.00	1.80	1.86	2.35	2.94	3.65	9.71
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	4.63	4.29	6.04	8.28	10.96	42.71	0.00	5.84	5.73	8.09	11.05	14.76	47.80
Detroit-Ann Arbor, MI	x	x	100	100	0.00	5.31	4.95	6.94	9.46	12.49	48.32	0.00	6.83	6.73	9.40	12.76	16.94	54.16
Door Co., WI	x	-	100	-	0.00	0.05	0.05	0.06	0.08	0.10	0.34	0.00	0.07	0.08	0.10	0.12	0.15	0.39
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Evansville, IN	-	x	-	100	0.00	0.54	0.53	0.71	0.92	1.17	4.05	0.00	0.86	0.89	1.12	1.41	1.74	4.64
Greater Connecticut, CT	x	-	100	-	0.00	2.81	2.78	3.70	4.79	6.08	21.07	0.00	4.48	4.62	5.86	7.33	9.08	24.18
Greene Co., PA	x	-	100	-	0.00	0.05	0.05	0.06	0.08	0.11	0.37	0.00	0.08	0.08	0.10	0.13	0.16	0.42
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	1.28	1.27	1.69	2.19	2.78	9.62	0.00	2.05	2.11	2.67	3.35	4.14	11.04

Table B2-72
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	1.10	1.08	1.45	1.87	2.37	8.23	0.00	1.75	1.80	2.29	2.86	3.54	9.44
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.01	0.01	0.01	0.01	0.02	0.06	0.00	0.01	0.01	0.02	0.02	0.03	0.07
Hickory, NC	-	x	-	100	0.00	0.32	0.32	0.43	0.55	0.70	2.43	0.00	0.52	0.53	0.67	0.84	1.05	2.79
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-34.95	-41.11	-47.11	-49.68	-52.11	-64.50	0.00	-93.27	-103.33	-110.73	-115.58	-117.08	-103.79
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-3.65	-4.24	-4.91	-5.27	-5.64	-8.35	0.00	-9.44	-10.42	-11.26	-11.88	-12.20	-12.45
Imperial Co., CA	x	-	100	-	0.00	0.53	0.53	0.70	0.91	1.15	3.99	0.00	0.85	0.88	1.11	1.39	1.72	4.58
Indianapolis, IN	-	x	-	100	0.00	3.00	2.96	3.95	5.12	6.50	22.51	0.00	4.79	4.94	6.26	7.83	9.70	25.83
Jamestown, NY	x	-	100	-	0.00	0.21	0.20	0.27	0.35	0.45	1.55	0.00	0.33	0.34	0.43	0.54	0.67	1.78
Jefferson Co., NY	x	-	100	-	0.00	0.25	0.25	0.33	0.43	0.55	1.91	0.00	0.41	0.42	0.53	0.66	0.82	2.19
Johnstown, PA	-	x	-	100	0.00	0.15	0.15	0.20	0.26	0.33	1.15	0.00	0.24	0.25	0.32	0.40	0.49	1.32
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.27	0.27	0.36	0.47	0.59	2.05	0.00	0.44	0.45	0.57	0.71	0.88	2.35
Knoxville, TN	x	x	100	100	0.00	1.85	1.83	2.44	3.15	4.00	13.86	0.00	2.95	3.04	3.85	4.82	5.97	15.91
Lancaster, PA	-	x	-	100	0.00	0.66	0.65	0.86	1.12	1.42	4.91	0.00	1.05	1.08	1.37	1.71	2.12	5.64
Las Vegas, NV	x	-	100	-	0.00	3.89	3.84	5.12	6.62	8.41	29.14	0.00	6.20	6.39	8.10	10.13	12.55	33.44
Libby, MT	-	x	-	100	0.00	0.01	0.01	0.01	0.02	0.02	0.08	0.00	0.02	0.02	0.02	0.03	0.04	0.09
Liberty-Clairton, PA	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.03	0.11	0.00	0.02	0.02	0.03	0.04	0.05	0.12
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	5.13	1.50	6.16	14.03	23.74	144.70	0.00	-12.04	-16.26	-9.73	0.18	14.27	150.04
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	1.52	1.50	2.00	2.58	3.28	11.37	0.00	2.42	2.49	3.16	3.95	4.90	13.05
Louisville, KY-IN	-	x	-	100	0.00	1.59	1.57	2.09	2.71	3.44	11.92	0.00	2.54	2.62	3.31	4.15	5.14	13.68
Macon, GA	-	x	-	100	0.00	0.30	0.30	0.39	0.51	0.65	2.25	0.00	0.48	0.49	0.62	0.78	0.97	2.58
Manitowoc Co., WI	x	-		-	0.00	0.15	0.15	0.20	0.25	0.32	1.12	0.00	0.24	0.25	0.31	0.39	0.48	1.28
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.24	0.24	0.32	0.42	0.53	1.83	0.00	0.39	0.40	0.51	0.64	0.79	2.10
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	1.04	1.03	1.37	1.77	2.25	7.80	0.00	1.66	1.71	2.17	2.71	3.36	8.95
Memphis, TN-AR	x	-	100	-	0.00	-2.03	-2.52	-2.76	-2.69	-2.56	0.19	0.00	-6.17	-6.93	-7.20	-7.21	-6.89	-2.11
Milwaukee-Racine, WI	x	-	100	-	0.00	2.59	2.56	3.41	4.42	5.61	19.43	0.00	4.13	4.26	5.40	6.76	8.37	22.30
Nevada (Western Part), CA	x	-	100	-	0.00	0.18	0.18	0.24	0.31	0.39	1.37	0.00	0.29	0.30	0.38	0.48	0.59	1.57
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	15.34	14.23	20.05	27.49	36.42	142.22	0.00	19.27	18.89	26.72	36.60	48.94	159.10
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.21	0.21	0.27	0.35	0.45	1.56	0.00	0.33	0.34	0.43	0.54	0.67	1.79
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-11.21	-14.46	-15.32	-14.03	-12.16	17.57	0.00	-37.18	-42.03	-42.86	-41.81	-38.37	4.85

Table B2-72
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

Formaldehyde 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	9.94	9.81	13.09	16.93	21.50	74.50	0.00	15.85	16.34	20.71	25.91	32.10	85.50
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	2.52	2.49	3.32	4.30	5.46	18.91	0.00	4.02	4.15	5.26	6.57	8.14	21.70
Poughkeepsie, NY	x	x	100	100	0.00	2.22	2.20	2.93	3.79	4.81	16.67	0.00	3.55	3.66	4.63	5.80	7.18	19.13
Providence (All RI), RI	x	-	100	-	0.00	1.34	1.32	1.76	2.28	2.89	10.02	0.00	2.13	2.20	2.78	3.48	4.32	11.50
Reading, PA	-	x	-	100	0.00	0.66	0.65	0.86	1.12	1.42	4.92	0.00	1.05	1.08	1.37	1.71	2.12	5.65
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	2.66	2.62	3.50	4.53	5.75	19.93	0.00	4.24	4.37	5.54	6.93	8.58	22.87
Rochester, NY	x	-	100	-	0.00	1.93	1.91	2.55	3.29	4.18	14.49	0.00	3.08	3.18	4.03	5.04	6.24	16.63
Rome, GA	-	x	-	100	0.00	0.16	0.16	0.21	0.28	0.35	1.21	0.00	0.26	0.27	0.34	0.42	0.52	1.39
Sacramento Metro, CA	x	-	50	-	0.00	4.43	4.37	5.83	7.55	9.58	33.20	0.00	7.06	7.28	9.23	11.55	14.30	38.10
San Diego, CA	x	-	100	-	0.00	4.33	4.28	5.71	7.38	9.37	32.48	0.00	6.91	7.12	9.03	11.29	13.99	37.27
San Francisco Bay Area, CA	x	-	100	-	0.00	-2.72	-4.58	-3.89	-1.79	0.88	36.44	0.00	-15.13	-17.66	-16.57	-14.12	-9.99	33.25
San Joaquin Valley, CA	x	x	50	100	0.00	8.13	7.71	10.65	14.32	18.72	70.45	0.00	11.15	11.16	15.11	20.01	26.05	79.42
Sheboygan, WI	x	-	100	-	0.00	0.18	0.18	0.24	0.31	0.40	1.38	0.00	0.29	0.30	0.38	0.48	0.59	1.58
Springfield (Western MA), MA	x	-	100	-	0.00	1.44	1.42	1.89	2.45	3.11	10.76	0.00	2.29	2.36	2.99	3.74	4.63	12.35
St. Louis, MO-IL	x	x	100	100	0.00	-1.23	-2.09	-1.76	-0.78	0.46	17.02	0.00	-6.94	-8.11	-7.59	-6.45	-4.53	15.58
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.25	-0.31	-0.34	-0.35	-0.34	-0.18	0.00	-0.73	-0.81	-0.86	-0.87	-0.85	-0.47
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.89	0.87	1.17	1.53	1.96	6.93	0.00	1.38	1.41	1.81	2.30	2.88	7.91
Washington, DC-MD-VA	x	x	100	100	0.00	9.20	9.08	12.11	15.67	19.90	68.95	0.00	14.67	15.13	19.17	23.98	29.71	79.13
Wheeling, WV-OH	-	x	-	100	0.00	0.22	0.22	0.29	0.38	0.48	1.65	0.00	0.35	0.36	0.46	0.58	0.71	1.90
York, PA	-	x	-	100	0.00	0.76	0.75	1.00	1.30	1.65	5.72	0.00	1.22	1.25	1.59	1.99	2.46	6.56

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-73
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-3.92	-5.28	-9.03	-10.11	-11.59	-26.11	0.00	-3.94	-5.30	-9.05	-10.13	-11.61	-26.13
Allegan Co., MI	x	-	100	-	0.00	-0.43	-0.58	-0.99	-1.11	-1.27	-2.86	0.00	-0.43	-0.58	-0.99	-1.11	-1.27	-2.86
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.39	-0.53	-0.90	-1.01	-1.15	-2.60	0.00	-0.39	-0.53	-0.90	-1.01	-1.16	-2.60
Atlanta, GA	x	x	100	100	0.00	-20.82	-28.05	-47.96	-53.74	-61.59	-138.79	0.00	-20.92	-28.16	-48.07	-53.85	-61.71	-138.87
Baltimore, MD	x	x	100	100	0.00	-8.69	-11.70	-19.99	-22.39	-25.67	-57.81	0.00	-8.73	-11.75	-20.03	-22.44	-25.72	-57.84
Baton Rouge, LA	x	-	100	-	0.00	-77.87	-98.62	-124.77	-142.22	-163.88	-300.53	0.00	-78.10	-98.87	-125.03	-142.49	-164.16	-300.72
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-153.98	-194.79	-244.75	-279.11	-321.66	-586.39	0.00	-154.43	-195.27	-245.25	-279.63	-322.20	-586.75
Birmingham, AL	-	x	-	100	0.00	-3.15	-4.25	-7.27	-8.14	-9.33	-21.05	0.00	-3.17	-4.26	-7.29	-8.16	-9.35	-21.06
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-14.11	-19.01	-32.48	-36.39	-41.71	-93.97	0.00	-14.18	-19.09	-32.56	-36.47	-41.79	-94.02
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-1.81	-2.45	-4.24	-4.75	-5.44	-12.34	0.00	-1.82	-2.46	-4.25	-4.76	-5.45	-12.35
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-3.39	-4.57	-7.81	-8.75	-10.03	-22.59	0.00	-3.41	-4.59	-7.83	-8.77	-10.05	-22.61
Canton-Massillon, OH	-	x	-	100	0.00	-10.87	-13.83	-17.91	-20.39	-23.48	-43.93	0.00	-10.91	-13.86	-17.95	-20.42	-23.52	-43.95
Charleston, WV	-	x	-	100	0.00	-0.91	-1.22	-2.09	-2.34	-2.68	-6.05	0.00	-0.91	-1.23	-2.09	-2.35	-2.69	-6.05
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-4.82	-6.55	-11.57	-12.94	-14.83	-34.01	0.00	-4.84	-6.57	-11.60	-12.97	-14.86	-34.03
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-1.59	-2.14	-3.68	-4.12	-4.73	-10.68	0.00	-1.60	-2.15	-3.69	-4.13	-4.74	-10.69
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-131.55	-168.10	-223.74	-254.20	-292.62	-559.58	0.00	-131.97	-168.56	-224.21	-254.70	-293.13	-559.92
Chico, CA	x	-	100	-	0.00	-0.59	-0.79	-1.35	-1.51	-1.73	-3.90	0.00	-0.59	-0.79	-1.35	-1.52	-1.74	-3.91
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-5.53	-7.45	-12.79	-14.32	-16.41	-37.06	0.00	-5.55	-7.48	-12.82	-14.35	-16.45	-37.08
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.53	-0.72	-1.22	-1.37	-1.57	-3.54	0.00	-0.53	-0.72	-1.23	-1.37	-1.57	-3.54
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-8.09	-10.90	-18.63	-20.87	-23.92	-53.89	0.00	-8.13	-10.94	-18.67	-20.92	-23.97	-53.93
Columbus, OH	x	x	100	100	0.00	-5.22	-7.04	-12.03	-13.48	-15.45	-34.81	0.00	-5.25	-7.06	-12.06	-13.51	-15.48	-34.83
Dallas-Fort Worth, TX	x	-	100	-	0.00	-21.18	-28.53	-48.76	-54.63	-62.61	-141.08	0.00	-21.28	-28.64	-48.88	-54.75	-62.73	-141.16
Dayton-Springfield, OH	-	x	-	100	0.00	-2.45	-3.30	-5.65	-6.33	-7.25	-16.34	0.00	-2.46	-3.32	-5.66	-6.34	-7.26	-16.34
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-22.56	-29.34	-42.78	-48.34	-55.55	-113.61	0.00	-22.64	-29.43	-42.87	-48.44	-55.65	-113.68
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-28.34	-37.06	-55.50	-62.61	-71.92	-149.75	0.00	-28.45	-37.18	-55.62	-62.74	-72.05	-149.84
Door Co., WI	x	-	100	-	0.00	-0.10	-0.13	-0.23	-0.26	-0.29	-0.66	0.00	-0.10	-0.13	-0.23	-0.26	-0.29	-0.66
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.03	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.03
Evansville, IN	-	x	-	100	0.00	-0.95	-1.29	-2.27	-2.54	-2.91	-6.64	0.00	-0.96	-1.30	-2.27	-2.54	-2.91	-6.64
Greater Connecticut, CT	x	-	100	-	0.00	-5.39	-7.26	-12.40	-13.89	-15.92	-35.84	0.00	-5.42	-7.29	-12.43	-13.92	-15.95	-35.86
Greene Co., PA	x	-	100	-	0.00	-0.12	-0.17	-0.28	-0.32	-0.36	-0.82	0.00	-0.12	-0.17	-0.28	-0.32	-0.36	-0.82
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-2.42	-3.27	-5.58	-6.26	-7.17	-16.15	0.00	-2.44	-3.28	-5.60	-6.27	-7.18	-16.16

Table B2-73
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NOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-2.20	-2.96	-5.06	-5.67	-6.50	-14.64	0.00	-2.21	-2.97	-5.07	-5.68	-6.51	-14.65
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.01	-0.02	-0.03	-0.04	-0.04	-0.10	0.00	-0.01	-0.02	-0.03	-0.04	-0.04	-0.10
Hickory, NC	-	x	-	100	0.00	-0.57	-0.77	-1.31	-1.47	-1.69	-3.80	0.00	-0.57	-0.77	-1.32	-1.48	-1.69	-3.80
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-328.23	-416.29	-531.03	-604.98	-697.00	-1,287.24	0.00	-329.22	-417.36	-532.13	-606.13	-698.18	-1,288.04
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-31.07	-39.39	-50.15	-57.14	-65.84	-121.41	0.00	-31.16	-39.49	-50.26	-57.25	-65.95	-121.48
Imperial Co., CA	x	-	100	-	0.00	-0.68	-0.91	-1.56	-1.74	-2.00	-4.50	0.00	-0.68	-0.91	-1.56	-1.75	-2.00	-4.51
Indianapolis, IN	-	x	-	100	0.00	-4.88	-6.57	-11.23	-12.59	-14.43	-32.51	0.00	-4.90	-6.60	-11.26	-12.61	-14.45	-32.52
Jamestown, NY	x	-	100	-	0.00	-0.45	-0.61	-1.04	-1.16	-1.33	-3.01	0.00	-0.45	-0.61	-1.04	-1.17	-1.34	-3.01
Jefferson Co., NY	x	-	100	-	0.00	-0.42	-0.57	-0.97	-1.08	-1.24	-2.79	0.00	-0.42	-0.57	-0.97	-1.08	-1.24	-2.80
Johnstown, PA	-	x	-	100	0.00	-0.37	-0.50	-0.85	-0.96	-1.10	-2.47	0.00	-0.37	-0.50	-0.86	-0.96	-1.10	-2.47
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.39	-0.52	-0.87	-0.98	-1.12	-2.50	0.00	-0.39	-0.53	-0.88	-0.98	-1.13	-2.50
Knoxville, TN	x	x	100	100	0.00	-3.31	-4.46	-7.62	-8.54	-9.79	-22.06	0.00	-3.32	-4.48	-7.64	-8.56	-9.81	-22.07
Lancaster, PA	-	x	-	100	0.00	-1.30	-1.75	-2.98	-3.34	-3.83	-8.63	0.00	-1.30	-1.75	-2.99	-3.35	-3.84	-8.64
Las Vegas, NV	x	-	100	-	0.00	-4.27	-5.76	-9.85	-11.04	-12.65	-28.53	0.00	-4.29	-5.78	-9.88	-11.06	-12.68	-28.54
Libby, MT	-	x	-	100	0.00	-0.02	-0.03	-0.05	-0.05	-0.06	-0.14	0.00	-0.02	-0.03	-0.05	-0.05	-0.06	-0.14
Liberty-Clairton, PA	-	x	-	100	0.00	-0.04	-0.06	-0.10	-0.11	-0.13	-0.29	0.00	-0.04	-0.06	-0.10	-0.11	-0.13	-0.29
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-213.15	-273.21	-369.82	-419.73	-483.01	-935.87	0.00	-213.85	-273.97	-370.61	-420.56	-483.86	-936.45
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-2.23	-3.00	-5.12	-5.74	-6.58	-14.81	0.00	-2.24	-3.01	-5.13	-5.75	-6.59	-14.82
Louisville, KY-IN	-	x	-	100	0.00	-3.30	-4.46	-7.68	-8.60	-9.86	-22.30	0.00	-3.32	-4.48	-7.70	-8.62	-9.88	-22.32
Macon, GA	-	x	-	100	0.00	-0.61	-0.83	-1.43	-1.60	-1.83	-4.14	0.00	-0.62	-0.83	-1.43	-1.60	-1.83	-4.15
Manitowoc Co., WI	x	-		-	0.00	-0.33	-0.44	-0.75	-0.85	-0.97	-2.18	0.00	-0.33	-0.44	-0.76	-0.85	-0.97	-2.18
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.32	-0.43	-0.73	-0.82	-0.94	-2.12	0.00	-0.32	-0.43	-0.73	-0.82	-0.94	-2.12
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-1.24	-1.67	-2.86	-3.20	-3.67	-8.28	0.00	-1.25	-1.68	-2.87	-3.21	-3.68	-8.28
Memphis, TN-AR	x	-	100	-	0.00	-27.44	-34.94	-45.62	-51.89	-59.76	-112.52	0.00	-27.52	-35.03	-45.72	-51.99	-59.86	-112.59
Milwaukee-Racine, WI	x	-	100	-	0.00	-5.35	-7.21	-12.31	-13.79	-15.81	-35.61	0.00	-5.38	-7.23	-12.34	-13.82	-15.84	-35.63
Nevada (Western Part), CA	x	-	100	-	0.00	-0.30	-0.41	-0.70	-0.78	-0.89	-2.01	0.00	-0.30	-0.41	-0.70	-0.78	-0.90	-2.01
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-87.18	-113.86	-169.66	-191.47	-219.94	-456.43	0.00	-87.51	-114.23	-170.04	-191.87	-220.35	-456.71
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.48	-0.64	-1.10	-1.23	-1.41	-3.18	0.00	-0.48	-0.64	-1.10	-1.23	-1.41	-3.19
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-181.89	-231.72	-303.15	-344.80	-397.05	-748.85	0.00	-182.47	-232.33	-303.79	-345.47	-397.73	-749.31

Table B2-73
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-11.62	-15.68	-26.98	-30.22	-34.64	-78.32	0.00	-11.68	-15.75	-27.05	-30.29	-34.70	-78.37
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-5.95	-8.02	-13.72	-15.37	-17.62	-39.71	0.00	-5.98	-8.05	-13.75	-15.40	-17.65	-39.73
Poughkeepsie, NY	x	x	100	100	0.00	-3.87	-5.21	-8.91	-9.98	-11.44	-25.78	0.00	-3.89	-5.23	-8.93	-10.00	-11.46	-25.79
Providence (All RI), RI	x	-	100	-	0.00	-2.80	-3.77	-6.45	-7.22	-8.28	-18.65	0.00	-2.81	-3.79	-6.46	-7.24	-8.30	-18.67
Reading, PA	-	x	-	100	0.00	-1.14	-1.53	-2.62	-2.93	-3.36	-7.57	0.00	-1.14	-1.54	-2.62	-2.94	-3.37	-7.58
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-2.27	-3.06	-5.22	-5.84	-6.70	-15.08	0.00	-2.28	-3.07	-5.23	-5.86	-6.71	-15.09
Rochester, NY	x	-	100	-	0.00	-3.92	-5.28	-9.03	-10.12	-11.59	-26.12	0.00	-3.94	-5.30	-9.05	-10.14	-11.62	-26.14
Rome, GA	-	x	-	100	0.00	-0.34	-0.46	-0.79	-0.88	-1.01	-2.28	0.00	-0.34	-0.46	-0.79	-0.89	-1.02	-2.28
Sacramento Metro, CA	x	-	50	-	0.00	-6.58	-8.86	-15.15	-16.97	-19.45	-43.84	0.00	-6.61	-8.90	-15.19	-17.01	-19.49	-43.87
San Diego, CA	x	-	100	-	0.00	-9.22	-12.42	-21.23	-23.78	-27.26	-61.42	0.00	-9.26	-12.47	-21.28	-23.84	-27.31	-61.45
San Francisco Bay Area, CA	x	-	100	-	0.00	-108.81	-139.25	-186.86	-212.19	-244.23	-470.03	0.00	-109.17	-139.64	-187.26	-212.61	-244.65	-470.32
San Joaquin Valley, CA	x	x	50	100	0.00	-28.45	-37.08	-54.71	-61.78	-70.98	-146.33	0.00	-28.56	-37.20	-54.83	-61.90	-71.11	-146.41
Sheboygan, WI	x	-	100	-	0.00	-0.37	-0.49	-0.84	-0.94	-1.08	-2.43	0.00	-0.37	-0.50	-0.84	-0.95	-1.08	-2.43
Springfield (Western MA), MA	x	-	100	-	0.00	-2.81	-3.79	-6.48	-7.26	-8.32	-18.75	0.00	-2.83	-3.81	-6.49	-7.28	-8.34	-18.76
St. Louis, MO-IL	x	x	100	100	0.00	-50.94	-65.17	-87.36	-99.21	-114.19	-219.58	0.00	-51.10	-65.35	-87.55	-99.41	-114.39	-219.72
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-3.04	-3.87	-5.05	-5.75	-6.62	-12.45	0.00	-3.05	-3.88	-5.06	-5.76	-6.63	-12.46
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-2.31	-3.09	-5.05	-5.67	-6.51	-14.32	0.00	-2.32	-3.10	-5.07	-5.69	-6.52	-14.33
Washington, DC-MD-VA	x	x	100	100	0.00	-14.92	-20.09	-34.28	-38.40	-44.02	-99.09	0.00	-14.99	-20.17	-34.36	-38.49	-44.10	-99.15
Wheeling, WV-OH	-	x	-	100	0.00	-0.52	-0.70	-1.19	-1.33	-1.53	-3.44	0.00	-0.52	-0.70	-1.19	-1.33	-1.53	-3.44
York, PA	-	x	-	100	0.00	-1.20	-1.62	-2.77	-3.10	-3.55	-8.01	0.00	-1.21	-1.63	-2.77	-3.11	-3.56	-8.01

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-74
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-23.50	-26.27	-45.50	-52.04	-64.28	-184.99	0.00	-30.55	-33.42	-53.09	-60.03	-72.01	-182.32
Allegan Co., MI	x	-	100	-	0.00	-2.57	-2.87	-4.98	-5.69	-7.03	-20.23	0.00	-3.34	-3.65	-5.81	-6.56	-7.87	-19.94
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-2.49	-2.78	-4.82	-5.51	-6.81	-19.59	0.00	-3.24	-3.54	-5.62	-6.36	-7.63	-19.31
Atlanta, GA	x	x	100	100	0.00	-136.13	-152.21	-263.65	-301.53	-372.50	-1,072.16	0.00	-176.98	-193.56	-307.59	-347.81	-417.23	-1,056.63
Baltimore, MD	x	x	100	100	0.00	-51.74	-57.86	-100.15	-114.54	-141.48	-406.99	0.00	-67.31	-73.63	-116.91	-132.18	-158.53	-401.17
Baton Rouge, LA	x	-	100	-	0.00	-248.55	-292.44	-352.54	-392.34	-437.15	-793.84	0.00	-415.60	-471.31	-538.11	-587.85	-633.44	-925.89
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-483.18	-569.51	-676.38	-751.72	-832.93	-1,462.39	0.00	-814.35	-924.40	-1,044.45	-1,139.49	-1,222.47	-1,730.23
Birmingham, AL	-	x	-	100	0.00	-18.40	-20.57	-35.66	-40.79	-50.40	-145.14	0.00	-23.91	-26.15	-41.59	-47.03	-56.43	-143.01
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-81.03	-90.61	-156.88	-179.42	-221.63	-637.72	0.00	-105.38	-115.26	-183.08	-207.01	-248.30	-628.54
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-11.05	-12.34	-21.55	-24.65	-30.51	-88.36	0.00	-14.26	-15.57	-24.99	-28.28	-34.01	-86.91
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-19.37	-21.66	-37.50	-42.88	-52.97	-152.42	0.00	-25.19	-27.55	-43.76	-49.48	-59.35	-150.23
Canton-Massillon, OH	-	x	-	100	0.00	-36.40	-42.60	-53.68	-59.97	-67.88	-134.73	0.00	-59.40	-67.16	-79.19	-86.85	-94.81	-151.53
Charleston, WV	-	x	-	100	0.00	-5.08	-5.68	-9.84	-11.25	-13.90	-39.99	0.00	-6.60	-7.22	-11.48	-12.98	-15.57	-39.41
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-33.38	-37.21	-65.66	-75.18	-93.25	-272.01	0.00	-42.68	-46.55	-75.62	-85.67	-103.32	-266.96
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-9.37	-10.47	-18.15	-20.76	-25.65	-73.86	0.00	-12.17	-13.31	-21.17	-23.94	-28.72	-72.78
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-469.96	-546.53	-723.51	-811.75	-933.93	-2,015.29	0.00	-744.96	-839.04	-1,027.84	-1,132.36	-1,254.42	-2,194.08
Chico, CA	x	-	100	-	0.00	-3.48	-3.90	-6.75	-7.72	-9.53	-27.44	0.00	-4.53	-4.96	-7.87	-8.90	-10.68	-27.04
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-32.66	-36.51	-63.40	-72.52	-89.64	-258.51	0.00	-42.37	-46.32	-73.83	-83.51	-100.25	-254.61
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-2.97	-3.32	-5.75	-6.58	-8.13	-23.38	0.00	-3.86	-4.23	-6.71	-7.59	-9.10	-23.04
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-46.01	-51.45	-89.09	-101.89	-125.86	-362.18	0.00	-59.84	-65.45	-103.96	-117.55	-141.00	-356.96
Columbus, OH	x	x	100	100	0.00	-31.78	-35.54	-61.55	-70.40	-86.97	-250.30	0.00	-41.32	-45.20	-71.82	-81.21	-97.41	-246.68
Dallas-Fort Worth, TX	x	-	100	-	0.00	-134.99	-150.93	-261.40	-298.96	-369.31	-1,062.86	0.00	-175.52	-191.96	-305.00	-344.88	-413.69	-1,047.51
Dayton-Springfield, OH	-	x	-	100	0.00	-13.99	-15.64	-27.09	-30.98	-38.27	-110.14	0.00	-18.19	-19.89	-31.61	-35.74	-42.87	-108.55
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-100.25	-114.54	-172.50	-195.46	-233.48	-593.92	0.00	-145.89	-162.37	-222.58	-248.21	-285.69	-609.46
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-127.64	-145.32	-224.12	-254.38	-305.73	-796.80	0.00	-182.50	-202.60	-284.19	-317.66	-368.21	-810.97
Door Co., WI	x	-	100	-	0.00	-0.57	-0.63	-1.10	-1.26	-1.55	-4.47	0.00	-0.74	-0.81	-1.28	-1.45	-1.74	-4.40
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.02	-0.03	-0.05	-0.05	-0.07	-0.19	0.00	-0.03	-0.03	-0.05	-0.06	-0.07	-0.19
Evansville, IN	-	x	-	100	0.00	-5.88	-6.55	-11.53	-13.20	-16.36	-47.63	0.00	-7.53	-8.22	-13.30	-15.07	-18.16	-46.77
Greater Connecticut, CT	x	-	100	-	0.00	-31.69	-35.44	-61.31	-70.12	-86.60	-249.03	0.00	-41.24	-45.11	-71.59	-80.94	-97.06	-245.49
Greene Co., PA	x	-	100	-	0.00	-0.68	-0.76	-1.31	-1.50	-1.85	-5.33	0.00	-0.88	-0.96	-1.53	-1.73	-2.07	-5.25
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-14.32	-16.01	-27.74	-31.72	-39.18	-112.77	0.00	-18.62	-20.37	-32.36	-36.59	-43.89	-111.14

Table B2-74
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-12.79	-14.30	-24.76	-28.32	-34.98	-100.67	0.00	-16.63	-18.19	-28.89	-32.67	-39.19	-99.22
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.09	-0.10	-0.17	-0.19	-0.24	-0.69	0.00	-0.11	-0.12	-0.20	-0.22	-0.27	-0.68
Hickory, NC	-	x	-	100	0.00	-3.43	-3.84	-6.64	-7.60	-9.38	-26.99	0.00	-4.46	-4.88	-7.75	-8.77	-10.51	-26.60
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-1,068.00	-1,254.04	-1,537.41	-1,713.59	-1,920.98	-3,615.15	0.00	-1,769.58	-2,004.47	-2,316.32	-2,534.20	-2,744.31	-4,154.41
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-100.32	-117.87	-143.76	-160.16	-179.21	-333.67	0.00	-166.69	-188.88	-217.46	-237.81	-257.13	-385.14
Imperial Co., CA	x	-	100	-	0.00	-4.41	-4.93	-8.54	-9.77	-12.07	-34.73	0.00	-5.74	-6.27	-9.97	-11.27	-13.52	-34.23
Indianapolis, IN	-	x	-	100	0.00	-29.61	-33.11	-57.33	-65.57	-81.00	-233.13	0.00	-38.50	-42.10	-66.90	-75.65	-90.74	-229.76
Jamestown, NY	x	-	100	-	0.00	-2.57	-2.88	-4.98	-5.70	-7.04	-20.25	0.00	-3.35	-3.66	-5.81	-6.57	-7.88	-19.96
Jefferson Co., NY	x	-	100	-	0.00	-2.56	-2.87	-4.96	-5.68	-7.01	-20.18	0.00	-3.34	-3.65	-5.79	-6.55	-7.86	-19.89
Johnstown, PA	-	x	-	100	0.00	-2.06	-2.31	-3.99	-4.56	-5.64	-16.21	0.00	-2.68	-2.94	-4.66	-5.27	-6.32	-15.98
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-2.51	-2.81	-4.74	-5.41	-6.65	-18.73	0.00	-3.34	-3.66	-5.64	-6.36	-7.57	-18.58
Knoxville, TN	x	x	100	100	0.00	-19.79	-22.13	-38.34	-43.85	-54.18	-155.95	0.00	-25.73	-28.14	-44.73	-50.58	-60.67	-153.69
Lancaster, PA	-	x	-	100	0.00	-7.57	-8.46	-14.66	-16.76	-20.71	-59.60	0.00	-9.84	-10.77	-17.10	-19.34	-23.20	-58.74
Las Vegas, NV	x	-	100	-	0.00	-28.90	-32.30	-56.02	-64.07	-79.17	-228.04	0.00	-37.53	-41.04	-65.30	-73.85	-88.62	-224.68
Libby, MT	-	x	-	100	0.00	-0.12	-0.14	-0.24	-0.28	-0.34	-0.98	0.00	-0.16	-0.18	-0.28	-0.32	-0.38	-0.97
Liberty-Clairton, PA	-	x	-	100	0.00	-0.23	-0.26	-0.44	-0.50	-0.62	-1.77	0.00	-0.30	-0.33	-0.52	-0.59	-0.70	-1.75
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-799.36	-926.02	-1,262.34	-1,419.66	-1,648.34	-3,714.26	0.00	-1,244.35	-1,398.12	-1,754.06	-1,937.67	-2,165.26	-3,978.89
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-14.01	-15.68	-27.08	-30.96	-38.22	-109.78	0.00	-18.27	-19.99	-31.65	-35.78	-42.89	-108.27
Louisville, KY-IN	-	x	-	100	0.00	-19.18	-21.43	-37.30	-42.67	-52.78	-152.47	0.00	-24.82	-27.13	-43.36	-49.06	-58.94	-150.08
Macon, GA	-	x	-	100	0.00	-3.57	-3.99	-6.96	-7.96	-9.85	-28.48	0.00	-4.62	-5.05	-8.08	-9.14	-10.99	-28.03
Manitowoc Co., WI	x	-		-	0.00	-1.86	-2.08	-3.60	-4.12	-5.09	-14.62	0.00	-2.43	-2.66	-4.21	-4.76	-5.71	-14.41
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-2.06	-2.30	-3.99	-4.56	-5.63	-16.20	0.00	-2.68	-2.93	-4.65	-5.26	-6.31	-15.97
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-8.20	-9.17	-15.88	-18.16	-22.43	-64.57	0.00	-10.66	-11.66	-18.53	-20.95	-25.13	-63.63
Memphis, TN-AR	x	-	100	-	0.00	-93.44	-109.16	-139.49	-156.04	-177.45	-361.21	0.00	-151.26	-170.83	-203.57	-223.55	-245.07	-402.21
Milwaukee-Racine, WI	x	-	100	-	0.00	-30.84	-34.49	-59.71	-68.29	-84.35	-242.70	0.00	-40.11	-43.88	-69.68	-78.79	-94.51	-239.21
Nevada (Western Part), CA	x	-	100	-	0.00	-1.85	-2.06	-3.57	-4.09	-5.05	-14.52	0.00	-2.40	-2.63	-4.17	-4.71	-5.65	-14.31
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-388.98	-443.21	-679.89	-771.40	-925.85	-2,400.10	0.00	-558.43	-620.30	-865.52	-966.94	-1,119.02	-2,447.18
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-2.69	-3.00	-5.21	-5.96	-7.36	-21.22	0.00	-3.49	-3.81	-6.07	-6.86	-8.24	-20.91
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-626.43	-731.25	-939.91	-1,051.95	-1,198.69	-2,465.01	0.00	-1,010.57	-1,140.81	-1,365.59	-1,500.41	-1,647.68	-2,733.83

Table B2-74
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-77.90	-87.04	-151.42	-173.22	-214.19	-618.49	0.00	-100.88	-110.26	-176.11	-199.23	-239.30	-608.92
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-33.24	-37.16	-64.39	-73.64	-90.98	-261.92	0.00	-43.20	-47.24	-75.10	-84.93	-101.89	-258.11
Poughkeepsie, NY	x	x	100	100	0.00	-23.33	-26.08	-45.17	-51.66	-63.82	-183.66	0.00	-30.33	-33.18	-52.71	-59.60	-71.49	-181.00
Providence (All RI), RI	x	-	100	-	0.00	-16.12	-18.02	-31.20	-35.69	-44.08	-126.86	0.00	-20.96	-22.92	-36.41	-41.17	-49.39	-125.03
Reading, PA	-	x	-	100	0.00	-6.86	-7.68	-13.29	-15.20	-18.78	-54.04	0.00	-8.93	-9.76	-15.51	-17.54	-21.04	-53.26
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-16.36	-18.30	-31.64	-36.18	-44.68	-128.44	0.00	-21.30	-23.30	-36.96	-41.78	-50.10	-126.63
Rochester, NY	x	-	100	-	0.00	-22.74	-25.43	-44.04	-50.36	-62.21	-179.04	0.00	-29.57	-32.34	-51.38	-58.10	-69.69	-176.46
Rome, GA	-	x	-	100	0.00	-1.97	-2.20	-3.81	-4.36	-5.39	-15.50	0.00	-2.56	-2.80	-4.45	-5.03	-6.03	-15.27
Sacramento Metro, CA	x	-	50	-	0.00	-41.03	-45.88	-79.46	-90.88	-112.27	-323.11	0.00	-53.36	-58.35	-92.72	-104.84	-125.76	-318.44
San Diego, CA	x	-	100	-	0.00	-52.87	-59.11	-102.38	-117.09	-144.64	-416.28	0.00	-68.74	-75.18	-119.45	-135.07	-162.02	-410.27
San Francisco Bay Area, CA	x	-	100	-	0.00	-393.70	-457.19	-611.90	-687.14	-793.30	-1,740.52	0.00	-619.93	-697.60	-862.12	-950.74	-1,056.64	-1,883.10
San Joaquin Valley, CA	x	x	50	100	0.00	-133.47	-152.11	-233.05	-264.40	-317.24	-821.37	0.00	-191.79	-213.07	-296.95	-331.70	-383.73	-837.83
Sheboygan, WI	x	-	100	-	0.00	-2.13	-2.38	-4.12	-4.72	-5.82	-16.74	0.00	-2.77	-3.04	-4.82	-5.44	-6.53	-16.51
Springfield (Western MA), MA	x	-	100	-	0.00	-16.47	-18.41	-31.89	-36.47	-45.05	-129.67	0.00	-21.41	-23.42	-37.21	-42.07	-50.47	-127.79
St. Louis, MO-IL	x	x	100	100	0.00	-183.68	-213.36	-285.03	-320.03	-369.26	-807.97	0.00	-289.55	-325.88	-402.14	-443.40	-492.53	-875.05
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-10.26	-11.99	-15.26	-17.07	-19.38	-39.18	0.00	-16.65	-18.81	-22.34	-24.53	-26.86	-43.75
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-12.38	-13.92	-23.34	-26.64	-32.66	-91.68	0.00	-16.57	-18.20	-27.86	-31.40	-37.31	-91.08
Washington, DC-MD-VA	x	x	100	100	0.00	-89.82	-100.45	-173.75	-198.70	-245.39	-705.58	0.00	-116.91	-127.89	-202.91	-229.41	-275.08	-695.58
Wheeling, WV-OH	-	x	-	100	0.00	-2.89	-3.23	-5.60	-6.40	-7.91	-22.75	0.00	-3.76	-4.11	-6.53	-7.38	-8.86	-22.42
York, PA	-	x	-	100	0.00	-7.43	-8.31	-14.39	-16.45	-20.32	-58.49	0.00	-9.66	-10.57	-16.79	-18.98	-22.77	-57.65

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-75
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-55.00	-55.23	-97.42	-115.18	-143.73	-453.89	0.00	-69.99	-69.52	-115.01	-135.78	-166.20	-436.43
Allegan Co., MI	x	-	100	-	0.00	-6.01	-6.03	-10.64	-12.58	-15.70	-49.58	0.00	-7.65	-7.59	-12.56	-14.83	-18.16	-47.68
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-6.20	-6.23	-10.98	-12.99	-16.20	-51.16	0.00	-7.89	-7.84	-12.97	-15.31	-18.74	-49.20
Atlanta, GA	x	x	100	100	0.00	-351.10	-352.55	-621.95	-735.39	-917.68	-2,898.26	0.00	-446.73	-443.67	-734.18	-866.80	-1,061.00	-2,786.66
Baltimore, MD	x	x	100	100	0.00	-120.47	-120.99	-213.33	-252.22	-314.70	-993.52	0.00	-153.43	-152.42	-252.00	-297.47	-364.04	-955.44
Baton Rouge, LA	x	-	100	-	0.00	-399.21	-459.48	-552.25	-613.25	-680.25	-1,268.83	0.00	-841.09	-931.65	-1,043.50	-1,131.78	-1,202.15	-1,609.10
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-762.08	-883.26	-1,038.05	-1,147.38	-1,260.64	-2,210.47	0.00	-1,640.42	-1,823.12	-2,013.81	-2,175.80	-2,294.42	-2,908.84
Birmingham, AL	-	x	-	100	0.00	-42.10	-42.27	-74.61	-88.22	-110.11	-347.90	0.00	-53.52	-53.13	-88.01	-103.92	-127.23	-334.44
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-182.22	-182.99	-322.73	-381.58	-476.13	-1,503.44	0.00	-231.97	-230.41	-381.11	-449.91	-550.64	-1,445.69
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-25.85	-25.89	-45.95	-54.37	-67.94	-215.53	0.00	-32.53	-32.20	-53.82	-63.65	-78.11	-206.81
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-43.15	-43.33	-76.42	-90.35	-112.74	-355.98	0.00	-54.93	-54.56	-90.24	-106.53	-130.38	-342.31
Canton-Massillon, OH	-	x	-	100	0.00	-60.74	-68.65	-87.37	-98.11	-111.33	-236.75	0.00	-120.79	-132.55	-154.27	-169.05	-183.00	-278.45
Charleston, WV	-	x	-	100	0.00	-11.11	-11.15	-19.67	-23.26	-29.02	-91.66	0.00	-14.13	-14.04	-23.22	-27.42	-33.56	-88.13
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-86.16	-86.11	-153.69	-182.00	-227.70	-725.17	0.00	-107.34	-105.94	-178.74	-211.71	-260.40	-694.57
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-21.33	-21.43	-37.74	-44.62	-55.65	-175.53	0.00	-27.23	-27.07	-44.66	-52.70	-64.46	-168.88
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-833.80	-921.93	-1,253.17	-1,424.33	-1,654.58	-3,954.76	0.00	-1,542.23	-1,670.83	-2,045.09	-2,269.71	-2,513.54	-4,364.70
Chico, CA	x	-	100	-	0.00	-8.09	-8.12	-14.32	-16.93	-21.13	-66.73	0.00	-10.29	-10.22	-16.91	-19.96	-24.43	-64.16
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-76.05	-76.30	-134.88	-159.53	-199.16	-629.95	0.00	-96.41	-95.65	-158.81	-187.60	-229.83	-605.28
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-6.48	-6.51	-11.48	-13.58	-16.94	-53.49	0.00	-8.25	-8.20	-13.56	-16.01	-19.59	-51.44
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-102.20	-102.63	-181.02	-214.03	-267.07	-843.34	0.00	-130.09	-129.22	-213.75	-252.34	-308.85	-810.93
Columbus, OH	x	x	100	100	0.00	-75.86	-76.17	-134.38	-158.89	-198.27	-626.17	0.00	-96.53	-95.87	-158.63	-187.29	-229.24	-602.07
Dallas-Fort Worth, TX	x	-	100	-	0.00	-338.43	-339.84	-599.47	-708.80	-884.48	-2,793.22	0.00	-430.68	-427.75	-707.73	-835.55	-1,022.71	-2,685.75
Dayton-Springfield, OH	-	x	-	100	0.00	-31.14	-31.27	-55.16	-65.22	-81.38	-257.00	0.00	-39.63	-39.36	-65.12	-76.88	-94.10	-247.12
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-208.90	-219.61	-344.02	-400.09	-484.97	-1,383.85	0.00	-321.79	-335.77	-471.90	-540.30	-630.57	-1,395.96
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-259.02	-270.59	-431.09	-502.60	-611.96	-1,775.21	0.00	-389.24	-403.82	-579.01	-665.65	-781.98	-1,776.55
Door Co., WI	x	-	100	-	0.00	-1.26	-1.27	-2.24	-2.64	-3.30	-10.41	0.00	-1.61	-1.60	-2.64	-3.12	-3.81	-10.01
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.05	-0.05	-0.10	-0.11	-0.14	-0.45	0.00	-0.07	-0.07	-0.11	-0.13	-0.16	-0.43
Evansville, IN	-	x	-	100	0.00	-13.67	-13.66	-24.38	-28.87	-36.12	-115.01	0.00	-17.04	-16.82	-28.36	-33.59	-41.32	-110.17
Greater Connecticut, CT	x	-	100	-	0.00	-72.79	-73.12	-128.87	-152.36	-190.09	-599.96	0.00	-92.77	-92.17	-152.31	-179.77	-219.97	-577.04
Greene Co., PA	x	-	100	-	0.00	-1.45	-1.46	-2.57	-3.04	-3.79	-11.98	0.00	-1.85	-1.84	-3.04	-3.58	-4.39	-11.52
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-33.01	-33.15	-58.48	-69.14	-86.28	-272.48	0.00	-42.01	-41.73	-69.04	-81.51	-99.76	-261.99

Table B2-75 High Scenario Alternative CAFE Standards Emission Changes a/ by Nonattainment Area NOx 2025																		
Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-29.05	-29.17	-51.45	-60.83	-75.91	-239.71	0.00	-36.97	-36.72	-60.75	-71.72	-87.78	-230.49
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.20	-0.20	-0.35	-0.42	-0.52	-1.67	0.00	-0.25	-0.24	-0.41	-0.49	-0.60	-1.60
Hickory, NC	-	x	-	100	0.00	-8.05	-8.08	-14.25	-16.85	-21.03	-66.38	0.00	-10.25	-10.18	-16.84	-19.88	-24.32	-63.84
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-1,748.50	-1,997.32	-2,458.83	-2,743.54	-3,073.25	-6,081.00	0.00	-3,597.79	-3,970.13	-4,516.47	-4,919.26	-5,266.36	-7,450.62
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-162.34	-186.02	-226.78	-252.55	-281.79	-544.78	0.00	-337.30	-372.79	-421.37	-458.16	-488.92	-676.51
Imperial Co., CA	x	-	100	-	0.00	-11.23	-11.28	-19.89	-23.52	-29.35	-92.68	0.00	-14.29	-14.19	-23.48	-27.72	-33.94	-89.12
Indianapolis, IN	-	x	-	100	0.00	-70.60	-70.89	-125.06	-147.87	-184.52	-582.71	0.00	-89.85	-89.23	-147.64	-174.31	-213.35	-560.29
Jamestown, NY	x	-	100	-	0.00	-5.72	-5.74	-10.13	-11.98	-14.94	-47.19	0.00	-7.28	-7.23	-11.96	-14.12	-17.28	-45.38
Jefferson Co., NY	x	-	100	-	0.00	-6.11	-6.14	-10.83	-12.80	-15.98	-50.44	0.00	-7.78	-7.73	-12.79	-15.10	-18.48	-48.50
Johnstown, PA	-	x	-	100	0.00	-4.47	-4.49	-7.91	-9.35	-11.67	-36.82	0.00	-5.70	-5.66	-9.35	-11.04	-13.51	-35.42
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-6.31	-6.42	-10.98	-12.93	-16.03	-49.47	0.00	-8.47	-8.53	-13.47	-15.78	-19.07	-48.07
Knoxville, TN	x	x	100	100	0.00	-46.22	-46.41	-81.89	-96.83	-120.83	-381.66	0.00	-58.80	-58.39	-96.65	-114.11	-139.68	-366.95
Lancaster, PA	-	x	-	100	0.00	-17.25	-17.32	-30.56	-36.13	-45.08	-142.37	0.00	-21.95	-21.81	-36.08	-42.59	-52.13	-136.89
Las Vegas, NV	x	-	100	-	0.00	-76.20	-76.48	-135.09	-159.75	-199.40	-630.31	0.00	-96.75	-96.03	-159.22	-188.04	-230.28	-605.80
Libby, MT	-	x	-	100	0.00	-0.29	-0.29	-0.51	-0.60	-0.75	-2.36	0.00	-0.36	-0.36	-0.60	-0.71	-0.86	-2.27
Liberty-Clairton, PA	-	x	-	100	0.00	-0.48	-0.48	-0.84	-0.99	-1.23	-3.84	0.00	-0.62	-0.62	-1.00	-1.18	-1.44	-3.71
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-1,484.60	-1,620.72	-2,286.31	-2,615.21	-3,074.95	-7,760.96	0.00	-2,627.74	-2,823.34	-3,567.26	-3,989.39	-4,476.95	-8,325.04
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-34.45	-34.65	-60.90	-71.97	-89.74	-282.67	0.00	-44.12	-43.90	-72.22	-85.18	-104.11	-272.12
Louisville, KY-IN	-	x	-	100	0.00	-43.06	-43.17	-76.45	-90.44	-112.96	-357.77	0.00	-54.40	-53.91	-89.79	-106.13	-130.12	-343.54
Macon, GA	-	x	-	100	0.00	-8.05	-8.07	-14.31	-16.93	-21.15	-67.06	0.00	-10.15	-10.05	-16.78	-19.84	-24.34	-64.37
Manitowoc Co., WI	x	-		-	0.00	-4.14	-4.16	-7.32	-8.65	-10.79	-34.05	0.00	-5.28	-5.25	-8.66	-10.22	-12.50	-32.76
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-5.21	-5.23	-9.22	-10.91	-13.61	-42.96	0.00	-6.63	-6.59	-10.89	-12.86	-15.74	-41.31
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-21.17	-21.26	-37.50	-44.34	-55.33	-174.74	0.00	-26.94	-26.76	-44.27	-52.27	-63.98	-168.02
Memphis, TN-AR	x	-	100	-	0.00	-158.15	-177.68	-230.26	-259.47	-296.41	-652.89	0.00	-308.50	-337.41	-397.91	-437.52	-476.55	-753.06
Milwaukee-Racine, WI	x	-	100	-	0.00	-69.51	-69.80	-123.10	-145.55	-181.62	-573.45	0.00	-88.50	-87.91	-145.38	-171.63	-210.05	-551.43
Nevada (Western Part), CA	x	-	100	-	0.00	-4.40	-4.41	-7.78	-9.20	-11.48	-36.25	0.00	-5.60	-5.56	-9.19	-10.85	-13.28	-34.86
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-785.33	-821.98	-1,302.84	-1,517.83	-1,845.61	-5,327.55	0.00	-1,189.12	-1,235.87	-1,761.15	-2,022.15	-2,370.78	-5,344.22
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-5.90	-5.92	-10.46	-12.36	-15.43	-48.80	0.00	-7.48	-7.43	-12.32	-14.55	-17.82	-46.90
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-1,076.70	-1,205.50	-1,578.66	-1,782.31	-2,043.78	-4,588.91	0.00	-2,076.68	-2,266.78	-2,694.23	-2,968.31	-3,244.72	-5,237.68

Table B2-75
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-202.04	-202.60	-358.62	-424.22	-529.77	-1,677.25	0.00	-255.51	-253.31	-421.51	-498.11	-610.57	-1,610.85
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-72.42	-72.71	-128.30	-151.70	-189.32	-598.02	0.00	-92.10	-91.46	-151.40	-178.76	-218.84	-574.95
Poughkeepsie, NY	x	x	100	100	0.00	-54.88	-55.11	-97.21	-114.94	-143.42	-452.93	0.00	-69.85	-69.37	-114.77	-135.50	-165.85	-435.51
Providence (All RI), RI	x	-	100	-	0.00	-36.19	-36.35	-64.11	-75.80	-94.58	-298.67	0.00	-46.07	-45.76	-75.70	-89.36	-109.38	-287.19
Reading, PA	-	x	-	100	0.00	-16.17	-16.24	-28.64	-33.87	-42.26	-133.45	0.00	-20.58	-20.44	-33.82	-39.92	-48.86	-128.32
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-46.05	-46.27	-81.48	-96.31	-120.14	-378.93	0.00	-58.78	-58.43	-96.40	-113.76	-139.14	-364.56
Rochester, NY	x	-	100	-	0.00	-51.48	-51.70	-91.19	-107.83	-134.55	-424.90	0.00	-65.52	-65.08	-107.67	-127.11	-155.58	-408.55
Rome, GA	-	x	-	100	0.00	-4.41	-4.43	-7.81	-9.24	-11.53	-36.40	0.00	-5.61	-5.57	-9.22	-10.89	-13.33	-35.00
Sacramento Metro, CA	x	-	50	-	0.00	-100.24	-100.66	-177.54	-209.91	-261.93	-827.08	0.00	-127.60	-126.75	-209.65	-247.50	-302.92	-795.31
San Diego, CA	x	-	100	-	0.00	-118.30	-118.79	-209.54	-247.76	-309.17	-976.38	0.00	-150.54	-149.51	-247.38	-292.06	-357.48	-938.81
San Francisco Bay Area, CA	x	-	100	-	0.00	-699.51	-770.97	-1,057.91	-1,204.39	-1,403.49	-3,403.72	0.00	-1,279.73	-1,383.64	-1,706.87	-1,897.97	-2,108.91	-3,727.84
San Joaquin Valley, CA	x	x	50	100	0.00	-292.07	-304.81	-486.89	-567.87	-691.90	-2,012.07	0.00	-437.20	-453.17	-651.83	-749.84	-881.78	-2,011.19
Sheboygan, WI	x	-	100	-	0.00	-4.85	-4.87	-8.58	-10.15	-12.66	-39.95	0.00	-6.18	-6.14	-10.15	-11.98	-14.65	-38.43
Springfield (Western MA), MA	x	-	100	-	0.00	-37.61	-37.76	-66.62	-78.76	-98.29	-310.39	0.00	-47.86	-47.53	-78.65	-92.85	-113.65	-298.45
St. Louis, MO-IL	x	x	100	100	0.00	-325.70	-359.22	-491.94	-559.86	-651.98	-1,576.42	0.00	-597.24	-646.01	-795.61	-884.33	-981.92	-1,729.27
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-17.14	-19.30	-24.81	-27.92	-31.79	-68.94	0.00	-33.72	-36.94	-43.30	-47.54	-51.63	-80.21
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-27.17	-27.58	-47.35	-55.79	-69.19	-214.09	0.00	-36.24	-36.48	-57.86	-67.81	-82.08	-207.81
Washington, DC-MD-VA	x	x	100	100	0.00	-213.90	-214.88	-378.67	-447.67	-558.51	-1,762.52	0.00	-272.69	-270.97	-447.62	-528.31	-646.39	-1,695.27
Wheeling, WV-OH	-	x	-	100	0.00	-6.31	-6.34	-11.18	-13.22	-16.50	-52.11	0.00	-8.04	-7.98	-13.20	-15.59	-19.08	-50.11
York, PA	-	x	-	100	0.00	-17.92	-18.00	-31.74	-37.53	-46.83	-147.89	0.00	-22.81	-22.66	-37.48	-44.25	-54.16	-142.21

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-76
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-106.28	-99.54	-167.80	-205.74	-261.35	-866.05	0.00	-124.59	-114.39	-194.74	-243.61	-309.94	-811.20
Allegan Co., MI	x	-	100	-	0.00	-11.56	-10.83	-18.26	-22.39	-28.44	-94.24	0.00	-13.56	-12.45	-21.19	-26.51	-33.72	-88.27
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-13.58	-12.72	-21.44	-26.28	-33.39	-110.62	0.00	-15.92	-14.62	-24.88	-31.13	-39.60	-103.62
Atlanta, GA	x	x	100	100	0.00	-845.63	-792.02	-1,335.15	-1,637.10	-2,079.67	-6,891.77	0.00	-991.10	-909.92	-1,549.31	-1,938.24	-2,466.08	-6,455.12
Baltimore, MD	x	x	100	100	0.00	-230.68	-216.10	-364.16	-446.48	-567.13	-1,878.84	0.00	-270.66	-248.59	-422.90	-528.94	-672.83	-1,760.10
Baton Rouge, LA	x	-	100	-	0.00	-577.45	-652.19	-780.93	-869.44	-965.38	-1,864.93	0.00	-1,385.80	-1,514.64	-1,682.07	-1,823.79	-1,929.91	-2,474.40
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-1,075.34	-1,231.37	-1,434.50	-1,581.54	-1,729.00	-3,043.34	0.00	-2,687.89	-2,955.67	-3,226.77	-3,471.95	-3,631.11	-4,315.54
Birmingham, AL	-	x	-	100	0.00	-79.04	-74.01	-124.81	-153.05	-194.45	-644.60	0.00	-92.52	-84.90	-144.71	-181.08	-230.45	-603.64
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-326.90	-306.20	-516.10	-632.79	-803.82	-2,663.41	0.00	-383.32	-351.99	-599.09	-749.41	-953.39	-2,494.86
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-49.16	-45.94	-77.74	-95.40	-121.32	-403.24	0.00	-56.97	-52.09	-89.50	-112.22	-143.14	-377.03
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-75.41	-70.64	-119.06	-145.98	-185.43	-614.40	0.00	-88.43	-81.21	-138.21	-172.88	-219.94	-575.53
Canton-Massillon, OH	-	x	-	100	0.00	-89.61	-98.47	-124.40	-141.03	-160.98	-359.24	0.00	-197.62	-213.08	-245.68	-270.71	-293.43	-431.50
Charleston, WV	-	x	-	100	0.00	-18.76	-17.57	-29.62	-36.31	-46.13	-152.87	0.00	-21.99	-20.19	-34.37	-43.00	-54.71	-143.18
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-197.56	-184.49	-312.55	-383.67	-488.07	-1,623.89	0.00	-228.09	-208.22	-358.91	-450.37	-574.92	-1,517.46
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-38.96	-36.58	-61.39	-75.20	-95.42	-315.07	0.00	-46.26	-42.68	-71.90	-89.71	-113.81	-295.72
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-1,340.47	-1,414.96	-1,929.13	-2,239.25	-2,645.38	-6,855.71	0.00	-2,586.46	-2,721.67	-3,349.71	-3,788.84	-4,261.34	-7,463.38
Chico, CA	x	-	100	-	0.00	-15.32	-14.35	-24.19	-29.66	-37.68	-124.85	0.00	-17.96	-16.49	-28.07	-35.12	-44.68	-116.94
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-150.26	-140.62	-237.37	-291.15	-370.00	-1,227.50	0.00	-175.37	-160.76	-274.65	-343.88	-437.94	-1,148.98
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-10.87	-10.18	-17.16	-21.05	-26.73	-88.58	0.00	-12.75	-11.71	-19.92	-24.92	-31.71	-82.98
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-178.08	-166.80	-281.15	-344.72	-437.90	-1,451.00	0.00	-208.79	-191.72	-326.34	-408.23	-519.36	-1,359.15
Columbus, OH	x	x	100	100	0.00	-154.94	-145.12	-244.63	-299.95	-381.04	-1,262.71	0.00	-181.60	-166.73	-283.88	-355.14	-451.85	-1,182.72
Dallas-Fort Worth, TX	x	-	100	-	0.00	-767.95	-719.28	-1,212.47	-1,486.67	-1,888.55	-6,258.20	0.00	-900.17	-826.48	-1,407.09	-1,760.27	-2,239.58	-5,861.82
Dayton-Springfield, OH	-	x	-	100	0.00	-54.34	-50.90	-85.79	-105.19	-133.63	-442.82	0.00	-63.70	-58.48	-99.57	-124.56	-158.47	-414.77
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-396.68	-390.22	-604.36	-726.25	-899.24	-2,756.07	0.00	-583.91	-576.75	-831.51	-993.17	-1,198.09	-2,703.56
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-440.79	-432.78	-672.54	-808.86	-1,002.62	-3,083.71	0.00	-643.55	-634.22	-919.32	-1,099.87	-1,329.48	-3,018.60
Door Co., WI	x	-	100	-	0.00	-2.20	-2.06	-3.47	-4.25	-5.40	-17.91	0.00	-2.58	-2.37	-4.03	-5.04	-6.41	-16.78
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.10	-0.09	-0.15	-0.19	-0.24	-0.80	0.00	-0.11	-0.10	-0.17	-0.22	-0.28	-0.74
Evansville, IN	-	x	-	100	0.00	-25.50	-23.78	-40.38	-49.59	-63.12	-210.37	0.00	-29.25	-26.64	-46.16	-58.00	-74.15	-196.39
Greater Connecticut, CT	x	-	100	-	0.00	-135.47	-126.92	-213.84	-262.16	-332.98	-1,102.94	0.00	-159.05	-146.12	-248.45	-310.70	-395.16	-1,033.34
Greene Co., PA	x	-	100	-	0.00	-2.35	-2.20	-3.71	-4.55	-5.78	-19.17	0.00	-2.76	-2.53	-4.31	-5.39	-6.86	-17.95
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-61.76	-57.85	-97.51	-119.56	-151.89	-503.32	0.00	-72.40	-66.47	-113.16	-141.57	-180.12	-471.44

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Emission Changes a/ by Nonattainment Area

NOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-52.82	-49.47	-83.39	-102.25	-129.89	-430.40	0.00	-61.92	-56.86	-96.79	-121.08	-154.04	-403.15
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.37	-0.34	-0.59	-0.72	-0.92	-3.08	0.00	-0.41	-0.37	-0.66	-0.83	-1.07	-2.87
Hickory, NC	-	x	-	100	0.00	-15.60	-14.62	-24.63	-30.20	-38.36	-127.07	0.00	-18.31	-16.81	-28.60	-35.77	-45.50	-119.04
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-2,593.63	-2,888.15	-3,555.99	-3,997.11	-4,504.34	-9,427.92	0.00	-5,962.00	-6,472.48	-7,324.13	-8,006.50	-8,577.26	-11,829.45
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-234.04	-262.95	-318.13	-355.46	-396.90	-791.03	0.00	-552.88	-602.82	-674.01	-732.98	-779.14	-1,026.81
Imperial Co., CA	x	-	100	-	0.00	-25.62	-23.99	-40.45	-49.59	-63.00	-208.77	0.00	-30.03	-27.57	-46.94	-58.72	-74.71	-195.54
Indianapolis, IN	-	x	-	100	0.00	-144.50	-135.34	-228.15	-279.74	-355.36	-1,177.58	0.00	-169.38	-155.51	-264.76	-331.22	-421.41	-1,102.99
Jamestown, NY	x	-	100	-	0.00	-9.95	-9.32	-15.71	-19.27	-24.47	-81.09	0.00	-11.67	-10.72	-18.24	-22.82	-29.03	-75.96
Jefferson Co., NY	x	-	100	-	0.00	-12.24	-11.47	-19.33	-23.70	-30.11	-99.76	0.00	-14.36	-13.19	-22.44	-28.07	-35.71	-93.45
Johnstown, PA	-	x	-	100	0.00	-7.40	-6.93	-11.67	-14.31	-18.17	-60.16	0.00	-8.70	-8.00	-13.58	-16.97	-21.58	-56.38
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-14.40	-13.75	-22.42	-27.28	-34.33	-110.61	0.00	-18.55	-17.60	-27.85	-34.18	-42.57	-105.33
Knoxville, TN	x	x	100	100	0.00	-88.95	-83.31	-140.45	-172.21	-218.78	-725.06	0.00	-104.22	-95.67	-162.94	-203.86	-259.39	-679.09
Lancaster, PA	-	x	-	100	0.00	-31.54	-29.54	-49.80	-61.06	-77.56	-257.02	0.00	-36.97	-33.95	-57.79	-72.30	-91.98	-240.74
Las Vegas, NV	x	-	100	-	0.00	-186.37	-174.42	-294.42	-361.11	-458.90	-1,522.40	0.00	-217.55	-199.43	-340.68	-426.55	-543.20	-1,425.04
Libby, MT	-	x	-	100	0.00	-0.53	-0.49	-0.83	-1.02	-1.30	-4.30	0.00	-0.62	-0.57	-0.97	-1.21	-1.54	-4.03
Liberty-Clairton, PA	-	x	-	100	0.00	-0.72	-0.68	-1.14	-1.39	-1.76	-5.76	0.00	-0.88	-0.82	-1.36	-1.69	-2.12	-5.43
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-2,546.24	-2,631.53	-3,730.44	-4,378.91	-5,254.49	-14,456.69	0.00	-4,555.14	-4,718.98	-6,047.83	-6,944.48	-7,970.37	-15,152.84
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-73.94	-69.46	-116.50	-142.68	-181.00	-597.34	0.00	-87.97	-81.22	-136.62	-170.40	-216.08	-560.84
Louisville, KY-IN	-	x	-	100	0.00	-75.99	-71.05	-120.11	-147.36	-187.34	-622.21	0.00	-88.33	-80.84	-138.57	-173.65	-221.34	-582.03
Macon, GA	-	x	-	100	0.00	-14.28	-13.34	-22.58	-27.71	-35.24	-117.16	0.00	-16.53	-15.11	-25.98	-32.58	-41.56	-109.53
Manitowoc Co., WI	x	-		-	0.00	-7.19	-6.74	-11.35	-13.92	-17.67	-58.51	0.00	-8.46	-7.77	-13.20	-16.51	-20.99	-54.83
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-11.77	-11.03	-18.58	-22.79	-28.95	-95.90	0.00	-13.81	-12.68	-21.58	-26.99	-34.33	-89.84
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-50.05	-46.88	-79.03	-96.90	-123.09	-407.89	0.00	-58.67	-53.87	-91.71	-114.73	-145.97	-382.05
Memphis, TN-AR	x	-	100	-	0.00	-236.21	-257.09	-330.83	-377.28	-434.48	-1,010.18	0.00	-505.16	-541.82	-633.74	-702.49	-768.04	-1,180.48
Milwaukee-Racine, WI	x	-	100	-	0.00	-124.78	-116.88	-196.99	-241.53	-306.80	-1,016.53	0.00	-146.33	-134.38	-228.69	-286.06	-363.91	-952.22
Nevada (Western Part), CA	x	-	100	-	0.00	-8.78	-8.23	-13.86	-16.99	-21.58	-71.49	0.00	-10.31	-9.47	-16.10	-20.13	-25.61	-66.97
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-1,328.42	-1,307.64	-2,022.90	-2,430.19	-3,007.91	-9,207.71	0.00	-1,960.89	-1,938.35	-2,789.42	-3,329.82	-4,014.12	-9,038.87
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-9.98	-9.34	-15.77	-19.34	-24.57	-81.50	0.00	-11.66	-10.70	-18.26	-22.86	-29.10	-76.30
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-1,660.52	-1,791.45	-2,344.32	-2,687.62	-3,119.11	-7,506.16	0.00	-3,450.16	-3,681.64	-4,366.17	-4,867.14	-5,364.15	-8,574.04

Table B2-76
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

NOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-475.37	-444.62	-751.26	-921.64	-1,171.56	-3,889.69	0.00	-553.26	-506.62	-867.52	-1,086.83	-1,384.94	-3,639.27
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-121.29	-113.59	-191.52	-234.84	-298.34	-988.81	0.00	-142.07	-130.41	-222.15	-277.95	-353.68	-926.08
Poughkeepsie, NY	x	x	100	100	0.00	-107.01	-100.23	-168.95	-207.15	-263.15	-871.99	0.00	-125.44	-115.18	-196.08	-245.29	-312.07	-816.77
Providence (All RI), RI	x	-	100	-	0.00	-64.32	-60.24	-101.54	-124.50	-158.16	-524.07	0.00	-75.41	-69.24	-117.86	-147.44	-187.57	-490.89
Reading, PA	-	x	-	100	0.00	-31.59	-29.59	-49.87	-61.15	-77.68	-257.40	0.00	-37.03	-34.00	-57.88	-72.40	-92.12	-241.10
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-128.53	-120.51	-202.77	-248.52	-315.54	-1,044.06	0.00	-151.49	-139.38	-236.23	-295.20	-375.12	-978.79
Rochester, NY	x	-	100	-	0.00	-93.03	-87.14	-146.89	-180.10	-228.79	-758.13	0.00	-109.06	-100.14	-170.47	-213.26	-271.32	-710.12
Rome, GA	-	x	-	100	0.00	-7.79	-7.30	-12.31	-15.09	-19.17	-63.51	0.00	-9.14	-8.39	-14.28	-17.87	-22.73	-59.49
Sacramento Metro, CA	x	-	50	-	0.00	-213.35	-199.87	-336.79	-412.92	-524.48	-1,737.47	0.00	-250.36	-229.96	-391.16	-489.22	-622.28	-1,627.71
San Diego, CA	x	-	100	-	0.00	-208.49	-195.28	-329.18	-403.62	-512.73	-1,699.07	0.00	-244.38	-224.37	-382.00	-477.89	-608.02	-1,591.44
San Francisco Bay Area, CA	x	-	100	-	0.00	-1,091.80	-1,153.05	-1,570.58	-1,822.55	-2,152.28	-5,569.17	0.00	-2,110.32	-2,221.41	-2,731.54	-3,088.56	-3,472.09	-6,068.82
San Joaquin Valley, CA	x	x	50	100	0.00	-595.31	-579.30	-914.41	-1,104.02	-1,375.33	-4,297.32	0.00	-836.08	-814.89	-1,212.49	-1,462.11	-1,784.08	-4,167.03
Sheboygan, WI	x	-	100	-	0.00	-8.85	-8.29	-13.97	-17.12	-21.75	-72.02	0.00	-10.40	-9.55	-16.23	-20.30	-25.81	-67.48
Springfield (Western MA), MA	x	-	100	-	0.00	-69.06	-64.68	-109.04	-133.70	-169.84	-562.80	0.00	-80.95	-74.32	-126.54	-158.30	-201.40	-527.15
St. Louis, MO-IL	x	x	100	100	0.00	-509.38	-538.19	-732.48	-849.80	-1,003.20	-2,592.42	0.00	-986.04	-1,038.25	-1,275.70	-1,442.01	-1,620.42	-2,827.41
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-24.93	-27.33	-34.67	-39.36	-45.03	-101.48	0.00	-54.58	-58.78	-68.00	-75.03	-81.49	-121.09
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-48.12	-45.63	-75.32	-91.92	-116.07	-377.93	0.00	-59.96	-56.26	-91.30	-112.81	-141.57	-357.64
Washington, DC-MD-VA	x	x	100	100	0.00	-443.43	-415.50	-699.91	-858.06	-1,089.80	-3,609.27	0.00	-520.87	-478.60	-813.45	-1,017.19	-1,293.57	-3,381.78
Wheeling, WV-OH	-	x	-	100	0.00	-10.62	-9.95	-16.76	-20.56	-26.11	-86.53	0.00	-12.45	-11.43	-19.46	-24.34	-30.97	-81.05
York, PA	-	x	-	100	0.00	-36.71	-34.38	-57.96	-71.06	-90.27	-299.12	0.00	-43.04	-39.52	-67.27	-84.15	-107.06	-280.18

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-77
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.21	0.18	0.72	0.82	0.69	2.47	0.00	0.21	0.18	0.72	0.82	0.69	2.47
Allegan Co., MI	x	-	100	-	0.00	0.02	0.02	0.08	0.09	0.08	0.27	0.00	0.02	0.02	0.08	0.09	0.08	0.27
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.02	0.07	0.08	0.07	0.25	0.00	0.02	0.02	0.07	0.08	0.07	0.25
Atlanta, GA	x	x	100	100	0.00	1.10	0.96	3.84	4.38	3.67	13.14	0.00	1.09	0.95	3.84	4.38	3.67	13.14
Baltimore, MD	x	x	100	100	0.00	0.45	0.40	1.60	1.82	1.52	5.46	0.00	0.45	0.40	1.60	1.82	1.52	5.46
Baton Rouge, LA	x	-	100	-	0.00	-14.25	-17.94	-22.86	-26.13	-30.64	-59.49	0.00	-14.29	-17.98	-22.90	-26.17	-30.69	-59.53
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-28.84	-36.24	-46.54	-53.19	-62.19	-121.56	0.00	-28.92	-36.33	-46.63	-53.29	-62.29	-121.62
Birmingham, AL	-	x	-	100	0.00	0.17	0.15	0.58	0.67	0.56	2.00	0.00	0.17	0.15	0.58	0.67	0.56	2.00
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	0.74	0.65	2.60	2.96	2.48	8.88	0.00	0.74	0.64	2.60	2.96	2.48	8.88
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.10	0.09	0.35	0.40	0.34	1.21	0.00	0.10	0.09	0.35	0.40	0.34	1.21
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.18	0.16	0.62	0.71	0.60	2.14	0.00	0.18	0.15	0.62	0.71	0.60	2.14
Canton-Massillon, OH	-	x	-	100	0.00	-1.82	-2.31	-2.86	-3.26	-3.88	-7.33	0.00	-1.83	-2.32	-2.86	-3.27	-3.88	-7.33
Charleston, WV	-	x	-	100	0.00	0.05	0.04	0.17	0.19	0.16	0.57	0.00	0.05	0.04	0.17	0.19	0.16	0.57
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	0.30	0.27	1.03	1.18	1.00	3.52	0.00	0.30	0.27	1.03	1.18	1.00	3.52
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.09	0.08	0.30	0.34	0.29	1.03	0.00	0.09	0.08	0.30	0.34	0.29	1.03
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-19.81	-25.30	-29.92	-34.21	-41.42	-75.09	0.00	-19.87	-25.37	-29.99	-34.28	-41.50	-75.14
Chico, CA	x	-	100	-	0.00	0.03	0.03	0.11	0.12	0.10	0.37	0.00	0.03	0.03	0.11	0.12	0.10	0.37
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.30	0.26	1.04	1.18	0.99	3.55	0.00	0.30	0.26	1.04	1.18	0.99	3.55
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.03	0.02	0.10	0.11	0.09	0.33	0.00	0.03	0.02	0.10	0.11	0.09	0.33
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	0.42	0.37	1.49	1.70	1.42	5.10	0.00	0.42	0.37	1.49	1.70	1.42	5.10
Columbus, OH	x	x	100	100	0.00	0.27	0.24	0.96	1.10	0.92	3.30	0.00	0.27	0.24	0.96	1.10	0.92	3.29
Dallas-Fort Worth, TX	x	-	100	-	0.00	1.11	0.97	3.91	4.45	3.73	13.35	0.00	1.11	0.97	3.90	4.45	3.73	13.35
Dayton-Springfield, OH	-	x	-	100	0.00	0.13	0.11	0.45	0.52	0.43	1.55	0.00	0.13	0.11	0.45	0.51	0.43	1.55
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-1.90	-2.58	-2.10	-2.40	-3.48	-4.03	0.00	-1.91	-2.59	-2.11	-2.41	-3.49	-4.04
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-1.79	-2.55	-1.43	-1.65	-2.95	-1.56	0.00	-1.80	-2.56	-1.44	-1.66	-2.96	-1.57
Door Co., WI	x	-	100	-	0.00	0.01	0.00	0.02	0.02	0.02	0.06	0.00	0.01	0.00	0.02	0.02	0.02	0.06
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evansville, IN	-	x	-	100	0.00	0.06	0.05	0.20	0.22	0.19	0.67	0.00	0.06	0.05	0.20	0.22	0.19	0.67
Greater Connecticut, CT	x	-	100	-	0.00	0.28	0.25	0.99	1.13	0.94	3.38	0.00	0.28	0.24	0.99	1.12	0.94	3.38
Greene Co., PA	x	-	100	-	0.00	0.01	0.01	0.02	0.03	0.02	0.08	0.00	0.01	0.01	0.02	0.03	0.02	0.08
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.13	0.11	0.45	0.51	0.43	1.53	0.00	0.13	0.11	0.45	0.51	0.43	1.53

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PM 2015

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	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.12	0.10	0.41	0.46	0.39	1.38	0.00	0.12	0.10	0.40	0.46	0.39	1.38
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Hickory, NC	-	x	-	100	0.00	0.03	0.03	0.10	0.12	0.10	0.36	0.00	0.03	0.03	0.10	0.12	0.10	0.36
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-58.35	-73.59	-92.87	-106.15	-125.01	-240.60	0.00	-58.52	-73.76	-93.05	-106.34	-125.20	-240.73
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-5.62	-7.09	-8.97	-10.25	-12.06	-23.26	0.00	-5.64	-7.10	-8.98	-10.27	-12.08	-23.27
Imperial Co., CA	x	-	100	-	0.00	0.04	0.03	0.12	0.14	0.12	0.43	0.00	0.04	0.03	0.12	0.14	0.12	0.43
Indianapolis, IN	-	x	-	100	0.00	0.26	0.22	0.90	1.03	0.86	3.08	0.00	0.26	0.22	0.90	1.02	0.86	3.08
Jamestown, NY	x	-	100	-	0.00	0.02	0.02	0.08	0.09	0.08	0.28	0.00	0.02	0.02	0.08	0.09	0.08	0.28
Jefferson Co., NY	x	-	100	-	0.00	0.02	0.02	0.08	0.09	0.07	0.26	0.00	0.02	0.02	0.08	0.09	0.07	0.26
Johnstown, PA	-	x	-	100	0.00	0.02	0.02	0.07	0.08	0.07	0.23	0.00	0.02	0.02	0.07	0.08	0.07	0.23
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.02	0.02	0.06	0.07	0.06	0.22	0.00	0.02	0.02	0.06	0.07	0.06	0.22
Knoxville, TN	x	x	100	100	0.00	0.17	0.15	0.61	0.70	0.58	2.09	0.00	0.17	0.15	0.61	0.70	0.58	2.09
Lancaster, PA	-	x	-	100	0.00	0.07	0.06	0.24	0.27	0.23	0.82	0.00	0.07	0.06	0.24	0.27	0.23	0.82
Las Vegas, NV	x	-	100	-	0.00	0.23	0.20	0.79	0.90	0.76	2.71	0.00	0.23	0.20	0.79	0.90	0.76	2.71
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Liberty-Clairton, PA	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-29.49	-37.94	-43.26	-49.47	-60.87	-106.51	0.00	-29.58	-38.04	-43.37	-49.58	-60.98	-106.59
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.12	0.10	0.41	0.46	0.39	1.39	0.00	0.12	0.10	0.41	0.46	0.39	1.39
Louisville, KY-IN	-	x	-	100	0.00	0.18	0.16	0.63	0.72	0.60	2.16	0.00	0.18	0.16	0.63	0.72	0.60	2.16
Macon, GA	-	x	-	100	0.00	0.03	0.03	0.12	0.13	0.11	0.40	0.00	0.03	0.03	0.12	0.13	0.11	0.40
Manitowoc Co., WI	x	-		-	0.00	0.02	0.01	0.06	0.07	0.06	0.20	0.00	0.02	0.01	0.06	0.07	0.06	0.20
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.02	0.01	0.06	0.07	0.06	0.20	0.00	0.02	0.01	0.06	0.07	0.06	0.20
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.07	0.06	0.23	0.26	0.22	0.78	0.00	0.07	0.06	0.23	0.26	0.22	0.78
Memphis, TN-AR	x	-	100	-	0.00	-4.46	-5.67	-6.92	-7.92	-9.45	-17.67	0.00	-4.48	-5.68	-6.94	-7.93	-9.47	-17.68
Milwaukee-Racine, WI	x	-	100	-	0.00	0.28	0.24	0.98	1.12	0.94	3.36	0.00	0.28	0.24	0.98	1.12	0.94	3.36
Nevada (Western Part), CA	x	-	100	-	0.00	0.02	0.01	0.06	0.06	0.05	0.19	0.00	0.02	0.01	0.06	0.06	0.05	0.19
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-5.86	-8.24	-5.11	-5.87	-9.90	-6.86	0.00	-5.88	-8.27	-5.14	-5.90	-9.93	-6.88
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.03	0.02	0.09	0.10	0.08	0.30	0.00	0.03	0.02	0.09	0.10	0.08	0.30
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-29.34	-37.26	-45.39	-51.89	-62.03	-115.61	0.00	-29.42	-37.36	-45.48	-51.99	-62.13	-115.68

Table B2-77
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	0.63	0.56	2.21	2.52	2.12	7.55	0.00	0.63	0.55	2.21	2.52	2.11	7.55
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.31	0.27	1.10	1.25	1.05	3.76	0.00	0.31	0.27	1.10	1.25	1.05	3.76
Poughkeepsie, NY	x	x	100	100	0.00	0.20	0.18	0.71	0.81	0.68	2.44	0.00	0.20	0.18	0.71	0.81	0.68	2.44
Providence (All RI), RI	x	-	100	-	0.00	0.15	0.13	0.52	0.59	0.49	1.76	0.00	0.15	0.13	0.52	0.59	0.49	1.76
Reading, PA	-	x	-	100	0.00	0.06	0.05	0.21	0.24	0.20	0.72	0.00	0.06	0.05	0.21	0.24	0.20	0.72
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.12	0.10	0.42	0.47	0.40	1.42	0.00	0.12	0.10	0.42	0.47	0.40	1.42
Rochester, NY	x	-	100	-	0.00	0.21	0.18	0.72	0.82	0.69	2.47	0.00	0.21	0.18	0.72	0.82	0.69	2.47
Rome, GA	-	x	-	100	0.00	0.02	0.02	0.06	0.07	0.06	0.22	0.00	0.02	0.02	0.06	0.07	0.06	0.22
Sacramento Metro, CA	x	-	50	-	0.00	0.35	0.30	1.21	1.38	1.16	4.15	0.00	0.35	0.30	1.21	1.38	1.16	4.15
San Diego, CA	x	-	100	-	0.00	0.48	0.42	1.70	1.94	1.62	5.81	0.00	0.48	0.42	1.70	1.94	1.62	5.81
San Francisco Bay Area, CA	x	-	100	-	0.00	-15.93	-20.41	-23.76	-27.17	-33.12	-59.16	0.00	-15.98	-20.46	-23.82	-27.23	-33.18	-59.20
San Joaquin Valley, CA	x	x	50	100	0.00	-2.14	-2.96	-2.13	-2.45	-3.79	-3.59	0.00	-2.15	-2.97	-2.14	-2.46	-3.80	-3.60
Sheboygan, WI	x	-	100	-	0.00	0.02	0.02	0.07	0.08	0.06	0.23	0.00	0.02	0.02	0.07	0.08	0.06	0.23
Springfield (Western MA), MA	x	-	100	-	0.00	0.15	0.13	0.52	0.59	0.50	1.77	0.00	0.15	0.13	0.52	0.59	0.50	1.77
St. Louis, MO-IL	x	x	100	100	0.00	-7.37	-9.44	-11.00	-12.58	-15.33	-27.40	0.00	-7.39	-9.47	-11.03	-12.61	-15.36	-27.42
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-0.50	-0.63	-0.77	-0.88	-1.05	-1.97	0.00	-0.50	-0.63	-0.77	-0.88	-1.05	-1.97
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.03	0.00	0.24	0.27	0.19	0.91	0.00	0.03	0.00	0.24	0.27	0.18	0.91
Washington, DC-MD-VA	x	x	100	100	0.00	0.78	0.68	2.73	3.11	2.60	9.33	0.00	0.78	0.68	2.73	3.11	2.60	9.33
Wheeling, WV-OH	-	x	-	100	0.00	0.03	0.02	0.10	0.11	0.09	0.33	0.00	0.03	0.02	0.10	0.11	0.09	0.33
York, PA	-	x	-	100	0.00	0.06	0.06	0.22	0.25	0.21	0.76	0.00	0.06	0.05	0.22	0.25	0.21	0.76

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-78
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	0.66	0.69	2.19	2.02	1.98	4.62	0.00	1.36	1.47	3.10	2.91	2.93	6.39
Allegan Co., MI	x	-	100	-	0.00	0.07	0.08	0.24	0.22	0.22	0.50	0.00	0.15	0.16	0.34	0.32	0.32	0.70
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.07	0.07	0.23	0.21	0.21	0.49	0.00	0.14	0.16	0.33	0.31	0.31	0.68
Atlanta, GA	x	x	100	100	0.00	3.86	3.98	12.71	11.69	11.46	26.76	0.00	7.86	8.55	17.95	16.87	17.00	37.05
Baltimore, MD	x	x	100	100	0.00	1.46	1.51	4.82	4.43	4.34	10.14	0.00	2.98	3.24	6.80	6.39	6.44	14.04
Baton Rouge, LA	x	-	100	-	0.00	-44.57	-52.02	-62.21	-69.64	-78.18	-147.28	0.00	-73.39	-82.90	-94.13	-103.20	-111.99	-169.51
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-90.23	-105.25	-126.87	-141.69	-158.87	-299.94	0.00	-148.76	-167.99	-191.79	-209.92	-227.65	-346.00
Birmingham, AL	-	x	-	100	0.00	0.52	0.54	1.72	1.59	1.55	3.63	0.00	1.07	1.16	2.43	2.29	2.31	5.02
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	2.29	2.37	7.55	6.95	6.81	15.90	0.00	4.67	5.08	10.67	10.02	10.10	22.02
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.33	0.34	1.07	0.98	0.96	2.25	0.00	0.66	0.72	1.51	1.42	1.43	3.10
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.55	0.57	1.80	1.66	1.63	3.80	0.00	1.12	1.21	2.55	2.40	2.41	5.26
Canton-Massillon, OH	-	x	-	100	0.00	-5.71	-6.68	-7.76	-8.76	-9.88	-18.46	0.00	-9.36	-10.58	-11.77	-12.99	-14.13	-21.06
Charleston, WV	-	x	-	100	0.00	0.14	0.15	0.47	0.44	0.43	1.00	0.00	0.29	0.32	0.67	0.63	0.63	1.38
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	1.04	1.08	3.35	3.09	3.04	7.06	0.00	2.10	2.29	4.73	4.46	4.50	9.74
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.27	0.28	0.88	0.81	0.79	1.85	0.00	0.54	0.59	1.24	1.16	1.17	2.56
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-61.87	-72.63	-80.45	-92.10	-104.74	-193.15	0.00	-100.65	-113.96	-122.75	-136.85	-149.57	-217.26
Chico, CA	x	-	100	-	0.00	0.10	0.10	0.33	0.30	0.29	0.68	0.00	0.20	0.22	0.46	0.43	0.43	0.95
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	0.94	0.97	3.08	2.84	2.78	6.49	0.00	1.91	2.08	4.35	4.09	4.13	8.98
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.08	0.09	0.28	0.25	0.25	0.58	0.00	0.17	0.19	0.39	0.37	0.37	0.81
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	1.30	1.34	4.29	3.95	3.87	9.03	0.00	2.65	2.88	6.06	5.69	5.74	12.51
Columbus, OH	x	x	100	100	0.00	0.90	0.93	2.97	2.73	2.68	6.25	0.00	1.84	1.99	4.19	3.94	3.97	8.65
Dallas-Fort Worth, TX	x	-	100	-	0.00	3.82	3.95	12.59	11.59	11.36	26.52	0.00	7.79	8.47	17.79	16.72	16.85	36.72
Dayton-Springfield, OH	-	x	-	100	0.00	0.40	0.41	1.30	1.20	1.18	2.75	0.00	0.81	0.88	1.84	1.73	1.75	3.80
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-5.84	-7.04	-5.00	-6.69	-8.22	-13.27	0.00	-8.96	-10.27	-8.12	-10.11	-11.53	-12.59
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-5.62	-6.88	-3.37	-5.32	-6.99	-10.01	0.00	-8.33	-9.61	-5.88	-8.17	-9.66	-7.71
Door Co., WI	x	-	100	-	0.00	0.02	0.02	0.05	0.05	0.05	0.11	0.00	0.03	0.04	0.07	0.07	0.07	0.15
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Evansville, IN	-	x	-	100	0.00	0.18	0.19	0.58	0.54	0.53	1.23	0.00	0.37	0.40	0.82	0.78	0.78	1.70
Greater Connecticut, CT	x	-	100	-	0.00	0.89	0.92	2.94	2.71	2.65	6.20	0.00	1.82	1.98	4.16	3.91	3.94	8.58
Greene Co., PA	x	-	100	-	0.00	0.02	0.02	0.06	0.06	0.06	0.13	0.00	0.04	0.04	0.09	0.08	0.08	0.18
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.41	0.42	1.34	1.23	1.21	2.81	0.00	0.83	0.90	1.89	1.77	1.79	3.90

Table B2-78
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.36	0.37	1.19	1.10	1.08	2.51	0.00	0.74	0.80	1.68	1.58	1.60	3.48
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.02
Hickory, NC	-	x	-	100	0.00	0.10	0.10	0.32	0.29	0.29	0.67	0.00	0.20	0.21	0.45	0.42	0.43	0.93
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-182.47	-213.13	-252.33	-283.26	-318.55	-598.45	0.00	-299.94	-338.92	-382.19	-419.93	-456.14	-686.77
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-17.60	-20.55	-24.41	-27.38	-30.77	-57.86	0.00	-28.94	-32.70	-36.96	-40.58	-44.07	-66.47
Imperial Co., CA	x	-	100	-	0.00	0.12	0.13	0.41	0.38	0.37	0.87	0.00	0.25	0.28	0.58	0.55	0.55	1.20
Indianapolis, IN	-	x	-	100	0.00	0.84	0.87	2.76	2.54	2.49	5.82	0.00	1.71	1.86	3.90	3.67	3.70	8.05
Jamestown, NY	x	-	100	-	0.00	0.07	0.08	0.24	0.22	0.22	0.51	0.00	0.15	0.16	0.34	0.32	0.32	0.70
Jefferson Co., NY	x	-	100	-	0.00	0.07	0.07	0.24	0.22	0.22	0.50	0.00	0.15	0.16	0.34	0.32	0.32	0.70
Johnstown, PA	-	x	-	100	0.00	0.06	0.06	0.19	0.18	0.17	0.40	0.00	0.12	0.13	0.27	0.25	0.26	0.56
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.06	0.06	0.21	0.19	0.19	0.44	0.00	0.13	0.14	0.29	0.27	0.28	0.61
Knoxville, TN	x	x	100	100	0.00	0.56	0.58	1.85	1.70	1.67	3.89	0.00	1.14	1.24	2.61	2.45	2.47	5.39
Lancaster, PA	-	x	-	100	0.00	0.21	0.22	0.71	0.65	0.64	1.49	0.00	0.44	0.47	1.00	0.94	0.94	2.06
Las Vegas, NV	x	-	100	-	0.00	0.82	0.85	2.71	2.49	2.44	5.71	0.00	1.68	1.82	3.83	3.60	3.63	7.90
Libby, MT	-	x	-	100	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.02	0.02	0.02	0.03
Liberty-Clairton, PA	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.02	0.04	0.00	0.01	0.01	0.03	0.03	0.03	0.06
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-91.86	-108.16	-114.87	-133.19	-152.57	-278.00	0.00	-148.49	-168.34	-176.12	-198.22	-217.49	-308.57
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.39	0.40	1.29	1.19	1.17	2.72	0.00	0.80	0.87	1.83	1.72	1.73	3.77
Louisville, KY-IN	-	x	-	100	0.00	0.56	0.58	1.83	1.68	1.65	3.85	0.00	1.13	1.23	2.58	2.43	2.45	5.32
Macon, GA	-	x	-	100	0.00	0.10	0.11	0.34	0.32	0.31	0.72	0.00	0.21	0.23	0.48	0.45	0.46	1.00
Manitowoc Co., WI	x	-		-	0.00	0.05	0.05	0.17	0.16	0.16	0.36	0.00	0.11	0.12	0.24	0.23	0.23	0.50
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.06	0.06	0.19	0.18	0.17	0.40	0.00	0.12	0.13	0.27	0.25	0.26	0.56
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.23	0.24	0.76	0.70	0.69	1.61	0.00	0.47	0.51	1.08	1.02	1.02	2.23
Memphis, TN-AR	x	-	100	-	0.00	-13.97	-16.36	-18.78	-21.27	-24.05	-44.79	0.00	-22.86	-25.85	-28.54	-31.57	-34.39	-50.94
Milwaukee-Racine, WI	x	-	100	-	0.00	0.87	0.90	2.87	2.64	2.59	6.05	0.00	1.78	1.93	4.06	3.81	3.84	8.38
Nevada (Western Part), CA	x	-	100	-	0.00	0.05	0.05	0.17	0.16	0.16	0.36	0.00	0.11	0.12	0.24	0.23	0.23	0.50
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-18.36	-22.36	-12.32	-18.38	-23.66	-35.19	0.00	-27.48	-31.65	-20.96	-28.08	-32.84	-29.15
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.08	0.08	0.25	0.23	0.23	0.53	0.00	0.16	0.17	0.36	0.34	0.34	0.74
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-91.70	-107.40	-122.65	-139.14	-157.42	-292.80	0.00	-149.88	-169.55	-186.50	-206.53	-225.08	-332.43

Table B2-78
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	2.26	2.34	7.40	6.81	6.68	15.59	0.00	4.59	4.99	10.45	9.83	9.91	21.56
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	0.94	0.97	3.11	2.86	2.80	6.54	0.00	1.92	2.09	4.39	4.12	4.16	9.06
Poughkeepsie, NY	x	x	100	100	0.00	0.66	0.68	2.18	2.00	1.96	4.58	0.00	1.35	1.46	3.07	2.89	2.91	6.34
Providence (All RI), RI	x	-	100	-	0.00	0.46	0.47	1.50	1.38	1.36	3.16	0.00	0.93	1.01	2.12	1.99	2.01	4.38
Reading, PA	-	x	-	100	0.00	0.19	0.20	0.64	0.59	0.58	1.35	0.00	0.40	0.43	0.90	0.85	0.86	1.87
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.46	0.47	1.52	1.40	1.37	3.19	0.00	0.94	1.02	2.14	2.01	2.03	4.42
Rochester, NY	x	-	100	-	0.00	0.64	0.66	2.12	1.95	1.91	4.47	0.00	1.31	1.43	3.00	2.82	2.84	6.18
Rome, GA	-	x	-	100	0.00	0.06	0.06	0.18	0.17	0.17	0.39	0.00	0.11	0.12	0.26	0.24	0.25	0.54
Sacramento Metro, CA	x	-	50	-	0.00	1.16	1.20	3.83	3.52	3.45	8.06	0.00	2.37	2.57	5.41	5.08	5.12	11.16
San Diego, CA	x	-	100	-	0.00	1.50	1.55	4.93	4.54	4.45	10.39	0.00	3.05	3.32	6.97	6.55	6.60	14.38
San Francisco Bay Area, CA	x	-	100	-	0.00	-49.84	-58.56	-64.02	-73.57	-83.86	-154.07	0.00	-80.91	-91.65	-97.83	-109.38	-119.69	-172.60
San Joaquin Valley, CA	x	x	50	100	0.00	-6.46	-7.85	-4.47	-6.57	-8.41	-12.64	0.00	-9.69	-11.15	-7.55	-10.03	-11.69	-10.68
Sheboygan, WI	x	-	100	-	0.00	0.06	0.06	0.20	0.18	0.18	0.42	0.00	0.12	0.13	0.28	0.26	0.26	0.58
Springfield (Western MA), MA	x	-	100	-	0.00	0.47	0.48	1.54	1.41	1.39	3.24	0.00	0.95	1.03	2.17	2.04	2.06	4.48
St. Louis, MO-IL	x	x	100	100	0.00	-23.07	-27.10	-29.65	-34.07	-38.83	-71.35	0.00	-37.45	-42.42	-45.31	-50.65	-55.42	-79.95
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-1.56	-1.82	-2.10	-2.37	-2.68	-5.00	0.00	-2.55	-2.88	-3.19	-3.52	-3.84	-5.69
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.09	0.07	0.73	0.61	0.55	1.45	0.00	0.28	0.28	1.00	0.86	0.83	2.18
Washington, DC-MD-VA	x	x	100	100	0.00	2.53	2.61	8.34	7.67	7.52	17.56	0.00	5.15	5.60	11.78	11.06	11.15	24.31
Wheeling, WV-OH	-	x	-	100	0.00	0.08	0.08	0.27	0.25	0.24	0.57	0.00	0.17	0.18	0.38	0.36	0.36	0.79
York, PA	-	x	-	100	0.00	0.21	0.22	0.69	0.64	0.62	1.46	0.00	0.43	0.47	0.98	0.92	0.93	2.02

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-79
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	1.07	1.13	3.43	3.02	3.08	6.41	0.00	2.99	3.33	5.95	5.51	5.75	11.36
Allegan Co., MI	x	-	100	-	0.00	0.12	0.12	0.37	0.33	0.34	0.70	0.00	0.33	0.36	0.65	0.60	0.63	1.24
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.12	0.13	0.39	0.34	0.35	0.72	0.00	0.34	0.37	0.67	0.62	0.65	1.28
Atlanta, GA	x	x	100	100	0.00	6.85	7.23	21.92	19.26	19.66	40.92	0.00	19.13	21.24	38.01	35.17	36.70	72.56
Baltimore, MD	x	x	100	100	0.00	2.34	2.47	7.51	6.59	6.73	14.01	0.00	6.55	7.27	13.01	12.04	12.57	24.85
Baton Rouge, LA	x	-	100	-	0.00	-69.85	-80.24	-94.61	-105.30	-116.96	-218.28	0.00	-146.34	-162.09	-179.22	-194.26	-206.57	-276.33
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-141.45	-162.43	-193.09	-214.30	-237.83	-444.35	0.00	-296.91	-328.88	-365.36	-395.30	-420.27	-564.98
Birmingham, AL	-	x	-	100	0.00	0.82	0.87	2.63	2.32	2.36	4.92	0.00	2.30	2.55	4.57	4.23	4.41	8.72
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	3.55	3.75	11.37	9.98	10.19	21.21	0.00	9.92	11.01	19.71	18.23	19.03	37.62
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.52	0.55	1.65	1.45	1.48	3.09	0.00	1.45	1.61	2.86	2.65	2.77	5.46
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.84	0.89	2.69	2.36	2.41	5.02	0.00	2.35	2.61	4.67	4.32	4.50	8.91
Canton-Massillon, OH	-	x	-	100	0.00	-8.95	-10.30	-11.82	-13.28	-14.79	-27.50	0.00	-18.64	-20.65	-22.47	-24.51	-26.08	-34.31
Charleston, WV	-	x	-	100	0.00	0.22	0.23	0.69	0.61	0.62	1.29	0.00	0.60	0.67	1.20	1.11	1.16	2.29
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	1.79	1.89	5.62	4.95	5.06	10.51	0.00	4.95	5.50	9.75	9.04	9.44	18.56
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.41	0.43	1.32	1.16	1.19	2.47	0.00	1.15	1.28	2.29	2.12	2.21	4.38
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-96.79	-111.66	-121.85	-139.38	-156.09	-288.21	0.00	-199.29	-220.70	-233.41	-257.41	-274.23	-349.68
Chico, CA	x	-	100	-	0.00	0.16	0.17	0.50	0.44	0.45	0.94	0.00	0.44	0.49	0.87	0.81	0.84	1.67
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	1.50	1.59	4.79	4.21	4.30	8.94	0.00	4.18	4.65	8.30	7.68	8.02	15.83
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.13	0.13	0.40	0.36	0.36	0.75	0.00	0.35	0.39	0.70	0.65	0.68	1.34
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	1.99	2.10	6.38	5.60	5.72	11.90	0.00	5.56	6.18	11.06	10.23	10.67	21.11
Columbus, OH	x	x	100	100	0.00	1.48	1.56	4.74	4.16	4.25	8.84	0.00	4.13	4.59	8.21	7.60	7.93	15.68
Dallas-Fort Worth, TX	x	-	100	-	0.00	6.60	6.97	21.12	18.56	18.94	39.42	0.00	18.43	20.47	36.63	33.88	35.36	69.92
Dayton-Springfield, OH	-	x	-	100	0.00	0.61	0.64	1.94	1.71	1.74	3.63	0.00	1.70	1.88	3.37	3.12	3.25	6.43
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-8.98	-10.57	-7.05	-9.93	-11.73	-20.18	0.00	-16.88	-18.67	-14.78	-18.46	-19.91	-17.16
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-8.84	-10.49	-5.22	-8.55	-10.43	-17.20	0.00	-15.96	-17.65	-11.76	-15.97	-17.35	-10.68
Door Co., WI	x	-	100	-	0.00	0.02	0.03	0.08	0.07	0.07	0.15	0.00	0.07	0.08	0.14	0.13	0.13	0.26
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Evansville, IN	-	x	-	100	0.00	0.28	0.30	0.89	0.78	0.80	1.67	0.00	0.78	0.87	1.55	1.43	1.50	2.94
Greater Connecticut, CT	x	-	100	-	0.00	1.41	1.49	4.53	3.98	4.06	8.45	0.00	3.95	4.39	7.85	7.26	7.58	14.99
Greene Co., PA	x	-	100	-	0.00	0.03	0.03	0.09	0.08	0.08	0.17	0.00	0.08	0.09	0.16	0.15	0.15	0.30
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.64	0.68	2.06	1.81	1.85	3.85	0.00	1.80	2.00	3.57	3.31	3.45	6.82

Table B2-79
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.57	0.60	1.81	1.59	1.63	3.38	0.00	1.58	1.76	3.14	2.91	3.03	6.00
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.02	0.02	0.02	0.04
Hickory, NC	-	x	-	100	0.00	0.16	0.17	0.50	0.44	0.45	0.94	0.00	0.44	0.49	0.87	0.80	0.84	1.66
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-285.88	-328.60	-383.47	-428.33	-476.28	-887.61	0.00	-597.50	-661.81	-727.48	-790.30	-840.59	-1,117.56
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-27.59	-31.71	-37.17	-41.46	-46.08	-85.92	0.00	-57.73	-63.95	-70.48	-76.49	-81.34	-108.44
Imperial Co., CA	x	-	100	-	0.00	0.22	0.23	0.70	0.62	0.63	1.31	0.00	0.61	0.68	1.22	1.12	1.17	2.32
Indianapolis, IN	-	x	-	100	0.00	1.38	1.45	4.41	3.87	3.95	8.22	0.00	3.85	4.27	7.64	7.07	7.38	14.59
Jamestown, NY	x	-	100	-	0.00	0.11	0.12	0.36	0.31	0.32	0.67	0.00	0.31	0.35	0.62	0.57	0.60	1.18
Jefferson Co., NY	x	-	100	-	0.00	0.12	0.13	0.38	0.33	0.34	0.71	0.00	0.33	0.37	0.66	0.61	0.64	1.26
Johnstown, PA	-	x	-	100	0.00	0.09	0.09	0.28	0.24	0.25	0.52	0.00	0.24	0.27	0.48	0.45	0.46	0.92
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.10	0.11	0.35	0.30	0.31	0.65	0.00	0.30	0.33	0.60	0.55	0.58	1.16
Knoxville, TN	x	x	100	100	0.00	0.90	0.95	2.89	2.54	2.59	5.39	0.00	2.52	2.80	5.01	4.63	4.84	9.56
Lancaster, PA	-	x	-	100	0.00	0.34	0.36	1.08	0.95	0.97	2.01	0.00	0.94	1.04	1.87	1.73	1.80	3.56
Las Vegas, NV	x	-	100	-	0.00	1.50	1.58	4.78	4.20	4.29	8.92	0.00	4.18	4.64	8.29	7.67	8.01	15.82
Libby, MT	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.00	0.02	0.02	0.03	0.03	0.03	0.06
Liberty-Clairton, PA	-	x	-	100	0.00	0.01	0.01	0.03	0.02	0.03	0.05	0.00	0.02	0.03	0.05	0.05	0.05	0.09
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-143.27	-165.67	-172.46	-200.73	-225.92	-414.41	0.00	-291.99	-323.33	-332.71	-370.93	-395.62	-489.17
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.66	0.70	2.12	1.86	1.90	3.96	0.00	1.85	2.05	3.68	3.40	3.55	7.03
Louisville, KY-IN	-	x	-	100	0.00	0.86	0.91	2.73	2.40	2.45	5.10	0.00	2.39	2.65	4.73	4.38	4.57	9.03
Macon, GA	-	x	-	100	0.00	0.16	0.17	0.51	0.45	0.46	0.96	0.00	0.45	0.50	0.89	0.82	0.86	1.70
Manitowoc Co., WI	x	-		-	0.00	0.08	0.08	0.26	0.23	0.23	0.48	0.00	0.22	0.25	0.44	0.41	0.43	0.85
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.10	0.11	0.32	0.29	0.29	0.61	0.00	0.28	0.31	0.56	0.52	0.54	1.07
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.41	0.44	1.32	1.16	1.19	2.47	0.00	1.15	1.28	2.29	2.12	2.21	4.37
Memphis, TN-AR	x	-	100	-	0.00	-21.92	-25.23	-28.62	-32.28	-36.01	-66.84	0.00	-45.51	-50.40	-54.51	-59.59	-63.42	-82.86
Milwaukee-Racine, WI	x	-	100	-	0.00	1.35	1.43	4.33	3.81	3.89	8.09	0.00	3.78	4.20	7.52	6.95	7.26	14.35
Nevada (Western Part), CA	x	-	100	-	0.00	0.09	0.09	0.27	0.24	0.25	0.51	0.00	0.24	0.27	0.47	0.44	0.46	0.91
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-28.86	-34.17	-19.00	-29.31	-35.32	-59.20	0.00	-52.87	-58.48	-41.59	-54.66	-59.23	-41.95
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.12	0.12	0.37	0.33	0.33	0.69	0.00	0.32	0.36	0.64	0.59	0.62	1.23
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-143.62	-165.41	-186.24	-210.66	-235.13	-436.04	0.00	-297.76	-329.78	-355.12	-388.87	-413.97	-538.41

Table B2-79
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	4.01	4.24	12.78	11.24	11.47	23.87	0.00	11.18	12.42	22.16	20.52	21.41	42.27
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	1.41	1.49	4.53	3.98	4.06	8.45	0.00	3.95	4.39	7.85	7.26	7.58	14.98
Poughkeepsie, NY	x	x	100	100	0.00	1.07	1.13	3.43	3.01	3.07	6.39	0.00	2.99	3.32	5.94	5.49	5.73	11.34
Providence (All RI), RI	x	-	100	-	0.00	0.71	0.74	2.26	1.98	2.02	4.21	0.00	1.97	2.19	3.92	3.62	3.78	7.47
Reading, PA	-	x	-	100	0.00	0.32	0.33	1.01	0.89	0.90	1.88	0.00	0.88	0.98	1.75	1.62	1.69	3.34
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	0.89	0.94	2.86	2.51	2.56	5.33	0.00	2.49	2.76	4.95	4.58	4.78	9.45
Rochester, NY	x	-	100	-	0.00	1.00	1.06	3.21	2.82	2.88	6.00	0.00	2.80	3.11	5.57	5.15	5.38	10.64
Rome, GA	-	x	-	100	0.00	0.09	0.09	0.28	0.24	0.25	0.51	0.00	0.24	0.27	0.48	0.44	0.46	0.91
Sacramento Metro, CA	x	-	50	-	0.00	1.95	2.06	6.25	5.49	5.61	11.67	0.00	5.45	6.06	10.84	10.03	10.47	20.70
San Diego, CA	x	-	100	-	0.00	2.31	2.44	7.38	6.49	6.62	13.78	0.00	6.44	7.15	12.80	11.84	12.36	24.44
San Francisco Bay Area, CA	x	-	100	-	0.00	-78.15	-90.20	-97.49	-111.91	-125.45	-231.32	0.00	-160.57	-177.82	-187.01	-206.69	-220.25	-279.11
San Joaquin Valley, CA	x	x	50	100	0.00	-9.69	-11.52	-5.44	-9.18	-11.25	-18.43	0.00	-17.40	-19.24	-12.44	-17.16	-18.66	-10.70
Sheboygan, WI	x	-	100	-	0.00	0.09	0.10	0.30	0.26	0.27	0.56	0.00	0.26	0.29	0.52	0.48	0.50	1.00
Springfield (Western MA), MA	x	-	100	-	0.00	0.73	0.77	2.35	2.06	2.11	4.38	0.00	2.05	2.27	4.07	3.77	3.93	7.77
St. Louis, MO-IL	x	x	100	100	0.00	-36.17	-41.74	-45.14	-51.81	-58.07	-107.09	0.00	-74.32	-82.30	-86.59	-95.69	-101.96	-129.27
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-2.44	-2.81	-3.21	-3.61	-4.02	-7.48	0.00	-5.08	-5.63	-6.10	-6.66	-7.09	-9.30
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.14	0.12	1.10	0.85	0.82	1.84	0.00	0.64	0.71	1.83	1.55	1.60	3.82
Washington, DC-MD-VA	x	x	100	100	0.00	4.15	4.38	13.30	11.68	11.92	24.82	0.00	11.60	12.88	23.06	21.33	22.26	44.04
Wheeling, WV-OH	-	x	-	100	0.00	0.12	0.13	0.39	0.35	0.35	0.74	0.00	0.34	0.38	0.68	0.63	0.66	1.30
York, PA	-	x	-	100	0.00	0.35	0.37	1.12	0.98	1.00	2.09	0.00	0.98	1.08	1.94	1.79	1.87	3.70

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-80
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	1.38	1.48	4.44	3.72	3.87	7.04	0.00	4.85	5.45	8.99	8.22	8.70	16.00
Allegan Co., MI	x	-	100	-	0.00	0.15	0.16	0.48	0.40	0.42	0.77	0.00	0.53	0.59	0.98	0.89	0.95	1.74
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	0.18	0.19	0.57	0.47	0.49	0.90	0.00	0.62	0.70	1.15	1.05	1.11	2.04
Atlanta, GA	x	x	100	100	0.00	10.97	11.79	35.34	29.59	30.80	56.02	0.00	38.61	43.35	71.57	65.44	69.23	127.34
Baltimore, MD	x	x	100	100	0.00	2.98	3.21	9.62	8.06	8.39	15.25	0.00	10.51	11.80	19.49	17.82	18.85	34.68
Baton Rouge, LA	x	-	100	-	0.00	-98.04	-111.45	-130.00	-144.23	-159.12	-295.96	0.00	-238.69	-261.88	-285.54	-307.75	-323.81	-402.08
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-198.53	-225.61	-265.40	-293.45	-323.56	-601.68	0.00	-484.58	-531.75	-582.30	-626.38	-659.11	-822.70
Birmingham, AL	-	x	-	100	0.00	1.03	1.11	3.31	2.77	2.89	5.25	0.00	3.62	4.06	6.70	6.13	6.48	11.92
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	4.24	4.55	13.65	11.43	11.90	21.64	0.00	14.91	16.74	27.64	25.28	26.74	49.19
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	0.65	0.70	2.09	1.75	1.82	3.32	0.00	2.29	2.57	4.23	3.87	4.10	7.52
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	0.98	1.05	3.15	2.64	2.74	4.99	0.00	3.44	3.86	6.38	5.83	6.17	11.35
Canton-Massillon, OH	-	x	-	100	0.00	-12.62	-14.36	-16.38	-18.34	-20.26	-37.71	0.00	-30.52	-33.47	-36.09	-39.09	-41.12	-50.37
Charleston, WV	-	x	-	100	0.00	0.24	0.26	0.78	0.66	0.68	1.24	0.00	0.86	0.96	1.59	1.45	1.54	2.82
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	2.65	2.85	8.44	7.08	7.38	13.42	0.00	9.27	10.41	17.10	15.66	16.57	30.36
Chattanooga, AL-TN-GA	-	x	-	100	0.00	0.49	0.53	1.60	1.33	1.39	2.52	0.00	1.73	1.95	3.23	2.95	3.12	5.76
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-136.10	-155.12	-167.87	-192.06	-213.01	-396.98	0.00	-324.14	-355.03	-372.39	-408.43	-429.52	-508.28
Chico, CA	x	-	100	-	0.00	0.20	0.21	0.64	0.54	0.56	1.01	0.00	0.70	0.79	1.30	1.19	1.25	2.31
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	1.97	2.12	6.32	5.29	5.51	10.02	0.00	6.91	7.76	12.80	11.71	12.38	22.76
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	0.14	0.15	0.45	0.38	0.40	0.72	0.00	0.50	0.56	0.92	0.84	0.89	1.64
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	2.31	2.48	7.44	6.23	6.48	11.79	0.00	8.12	9.12	15.06	13.77	14.57	26.80
Columbus, OH	x	x	100	100	0.00	2.01	2.16	6.47	5.42	5.64	10.26	0.00	7.07	7.94	13.11	11.99	12.68	23.33
Dallas-Fort Worth, TX	x	-	100	-	0.00	9.96	10.71	32.09	26.87	27.97	50.86	0.00	35.05	39.36	64.98	59.41	62.86	115.62
Dayton-Springfield, OH	-	x	-	100	0.00	0.70	0.76	2.27	1.90	1.98	3.60	0.00	2.48	2.78	4.60	4.20	4.45	8.18
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-12.59	-14.56	-9.33	-13.76	-15.83	-29.90	0.00	-26.44	-28.66	-22.64	-28.54	-29.90	-22.46
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-13.16	-15.23	-9.16	-13.99	-16.18	-30.60	0.00	-27.30	-29.56	-22.53	-28.95	-30.31	-21.13
Door Co., WI	x	-	100	-	0.00	0.03	0.03	0.09	0.08	0.08	0.15	0.00	0.10	0.11	0.19	0.17	0.18	0.33
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.02
Evansville, IN	-	x	-	100	0.00	0.35	0.37	1.10	0.92	0.96	1.75	0.00	1.21	1.36	2.23	2.04	2.16	3.95
Greater Connecticut, CT	x	-	100	-	0.00	1.75	1.88	5.65	4.73	4.92	8.95	0.00	6.16	6.92	11.43	10.45	11.06	20.35
Greene Co., PA	x	-	100	-	0.00	0.03	0.03	0.10	0.08	0.09	0.16	0.00	0.11	0.12	0.20	0.18	0.19	0.35
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	0.80	0.86	2.58	2.16	2.25	4.09	0.00	2.82	3.17	5.23	4.78	5.06	9.30

Table B2-80
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	0.68	0.74	2.21	1.85	1.92	3.50	0.00	2.41	2.71	4.47	4.09	4.32	7.95
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	0.01	0.01	0.02	0.01	0.01	0.03	0.00	0.02	0.02	0.03	0.03	0.03	0.06
Hickory, NC	-	x	-	100	0.00	0.20	0.22	0.65	0.54	0.57	1.03	0.00	0.71	0.80	1.32	1.21	1.27	2.35
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-401.30	-456.35	-526.87	-586.95	-648.02	-1,205.64	0.00	-974.01	-1,068.37	-1,158.76	-1,251.84	-1,317.08	-1,624.97
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-38.80	-44.11	-51.28	-56.97	-62.86	-116.93	0.00	-94.36	-103.52	-112.67	-121.53	-127.87	-158.44
Imperial Co., CA	x	-	100	-	0.00	0.33	0.36	1.07	0.90	0.93	1.70	0.00	1.17	1.31	2.17	1.98	2.10	3.86
Indianapolis, IN	-	x	-	100	0.00	1.87	2.01	6.04	5.06	5.26	9.57	0.00	6.60	7.41	12.23	11.18	11.83	21.76
Jamestown, NY	x	-	100	-	0.00	0.13	0.14	0.42	0.35	0.36	0.66	0.00	0.45	0.51	0.84	0.77	0.81	1.50
Jefferson Co., NY	x	-	100	-	0.00	0.16	0.17	0.51	0.43	0.45	0.81	0.00	0.56	0.63	1.04	0.95	1.00	1.84
Johnstown, PA	-	x	-	100	0.00	0.10	0.10	0.31	0.26	0.27	0.49	0.00	0.34	0.38	0.62	0.57	0.60	1.11
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	0.14	0.15	0.51	0.42	0.44	0.79	0.00	0.54	0.60	1.04	0.93	0.99	1.87
Knoxville, TN	x	x	100	100	0.00	1.15	1.24	3.72	3.11	3.24	5.90	0.00	4.06	4.56	7.53	6.89	7.29	13.40
Lancaster, PA	-	x	-	100	0.00	0.41	0.44	1.32	1.10	1.15	2.09	0.00	1.44	1.62	2.67	2.44	2.58	4.75
Las Vegas, NV	x	-	100	-	0.00	2.44	2.62	7.83	6.57	6.84	12.43	0.00	8.57	9.62	15.87	14.52	15.36	28.22
Libby, MT	-	x	-	100	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.00	0.02	0.03	0.04	0.04	0.04	0.08
Liberty-Clairton, PA	-	x	-	100	0.00	0.01	0.01	0.03	0.02	0.02	0.04	0.00	0.03	0.03	0.06	0.05	0.06	0.10
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-201.05	-229.55	-235.44	-275.60	-306.82	-572.60	0.00	-471.64	-515.98	-526.20	-584.63	-614.58	-701.16
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	0.93	0.99	3.02	2.52	2.62	4.77	0.00	3.28	3.68	6.11	5.58	5.90	10.90
Louisville, KY-IN	-	x	-	100	0.00	1.00	1.08	3.21	2.70	2.81	5.10	0.00	3.52	3.95	6.51	5.96	6.30	11.57
Macon, GA	-	x	-	100	0.00	0.19	0.20	0.61	0.51	0.53	0.97	0.00	0.67	0.75	1.23	1.13	1.19	2.19
Manitowoc Co., WI	x	-		-	0.00	0.09	0.10	0.30	0.25	0.26	0.47	0.00	0.33	0.37	0.61	0.55	0.59	1.08
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	0.15	0.16	0.49	0.41	0.43	0.78	0.00	0.54	0.60	1.00	0.91	0.96	1.77
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	0.65	0.70	2.09	1.75	1.82	3.31	0.00	2.28	2.57	4.24	3.87	4.10	7.54
Memphis, TN-AR	x	-	100	-	0.00	-30.92	-35.19	-39.76	-44.68	-49.41	-91.97	0.00	-74.57	-81.75	-87.69	-95.21	-100.15	-121.90
Milwaukee-Racine, WI	x	-	100	-	0.00	1.62	1.74	5.21	4.36	4.54	8.26	0.00	5.69	6.39	10.55	9.65	10.20	18.77
Nevada (Western Part), CA	x	-	100	-	0.00	0.11	0.12	0.37	0.31	0.32	0.58	0.00	0.40	0.45	0.74	0.68	0.72	1.32
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-42.82	-49.47	-32.20	-47.08	-54.13	-102.19	0.00	-90.18	-97.77	-77.88	-97.76	-102.42	-78.27
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	0.13	0.14	0.42	0.35	0.37	0.66	0.00	0.46	0.51	0.85	0.78	0.82	1.51
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-202.23	-230.23	-257.44	-290.56	-321.52	-598.68	0.00	-486.22	-532.94	-568.57	-618.81	-650.92	-786.94

Table B2-80
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

PM 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	6.26	6.74	20.07	16.83	17.52	31.87	0.00	21.99	24.68	40.65	37.20	39.36	72.27
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	1.58	1.69	5.07	4.25	4.42	8.04	0.00	5.54	6.22	10.27	9.39	9.94	18.28
Poughkeepsie, NY	x	x	100	100	0.00	1.39	1.49	4.47	3.74	3.90	7.09	0.00	4.88	5.48	9.05	8.28	8.76	16.11
Providence (All RI), RI	x	-	100	-	0.00	0.83	0.90	2.69	2.25	2.34	4.26	0.00	2.93	3.29	5.44	4.97	5.26	9.68
Reading, PA	-	x	-	100	0.00	0.41	0.44	1.32	1.11	1.15	2.09	0.00	1.44	1.62	2.67	2.44	2.59	4.76
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	1.65	1.77	5.33	4.46	4.64	8.43	0.00	5.81	6.52	10.78	9.85	10.43	19.20
Rochester, NY	x	-	100	-	0.00	1.21	1.30	3.89	3.25	3.39	6.16	0.00	4.25	4.77	7.87	7.20	7.61	14.01
Rome, GA	-	x	-	100	0.00	0.10	0.11	0.33	0.27	0.28	0.52	0.00	0.36	0.40	0.66	0.60	0.64	1.17
Sacramento Metro, CA	x	-	50	-	0.00	2.76	2.97	8.90	7.45	7.75	14.10	0.00	9.72	10.91	18.02	16.48	17.43	32.07
San Diego, CA	x	-	100	-	0.00	2.70	2.91	8.71	7.30	7.59	13.81	0.00	9.52	10.69	17.64	16.13	17.07	31.39
San Francisco Bay Area, CA	x	-	100	-	0.00	-110.69	-126.16	-136.59	-156.25	-173.28	-322.93	0.00	-263.67	-288.79	-302.97	-332.27	-349.43	-413.60
San Joaquin Valley, CA	x	x	50	100	0.00	-13.17	-15.36	-5.60	-11.70	-13.96	-26.69	0.00	-25.27	-27.17	-15.76	-23.65	-24.67	-7.03
Sheboygan, WI	x	-	100	-	0.00	0.11	0.12	0.37	0.31	0.32	0.58	0.00	0.40	0.45	0.75	0.68	0.72	1.33
Springfield (Western MA), MA	x	-	100	-	0.00	0.90	0.96	2.89	2.42	2.52	4.57	0.00	3.15	3.54	5.84	5.34	5.65	10.40
St. Louis, MO-IL	x	x	100	100	0.00	-51.18	-58.34	-63.14	-72.23	-80.11	-149.30	0.00	-121.90	-133.52	-140.05	-153.60	-161.54	-191.16
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-3.45	-3.93	-4.47	-5.01	-5.54	-10.31	0.00	-8.35	-9.15	-9.86	-10.68	-11.24	-13.74
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	0.10	0.07	1.24	0.86	0.85	1.51	0.00	0.87	1.01	2.40	1.96	2.08	4.80
Washington, DC-MD-VA	x	x	100	100	0.00	5.72	6.15	18.47	15.46	16.09	29.26	0.00	20.16	22.64	37.40	34.19	36.17	66.57
Wheeling, WV-OH	-	x	-	100	0.00	0.14	0.15	0.44	0.37	0.39	0.70	0.00	0.48	0.54	0.90	0.82	0.87	1.60
York, PA	-	x	-	100	0.00	0.48	0.51	1.53	1.28	1.34	2.43	0.00	1.68	1.88	3.11	2.84	3.00	5.53

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-81
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-2.00	-2.48	-3.67	-4.27	-5.29	-13.85	0.00	-2.00	-2.49	-3.67	-4.27	-5.29	-13.85
Allegan Co., MI	x	-	100	-	0.00	-0.22	-0.27	-0.40	-0.47	-0.58	-1.51	0.00	-0.22	-0.27	-0.40	-0.47	-0.58	-1.51
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.20	-0.25	-0.36	-0.42	-0.53	-1.38	0.00	-0.20	-0.25	-0.37	-0.42	-0.53	-1.38
Atlanta, GA	x	x	100	100	0.00	-10.61	-13.20	-19.50	-22.69	-28.12	-73.62	0.00	-10.64	-13.22	-19.53	-22.71	-28.15	-73.63
Baltimore, MD	x	x	100	100	0.00	-4.42	-5.49	-8.12	-9.44	-11.70	-30.62	0.00	-4.43	-5.51	-8.13	-9.45	-11.71	-30.63
Baton Rouge, LA	x	-	100	-	0.00	-59.93	-75.50	-96.16	-109.83	-127.58	-243.00	0.00	-60.10	-75.68	-96.35	-110.03	-127.78	-243.13
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-119.23	-150.23	-190.99	-218.08	-253.07	-479.34	0.00	-119.57	-150.59	-191.36	-218.48	-253.48	-479.61
Birmingham, AL	-	x	-	100	0.00	-1.61	-2.00	-2.96	-3.44	-4.27	-11.18	0.00	-1.61	-2.01	-2.96	-3.45	-4.27	-11.18
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-7.18	-8.93	-13.20	-15.35	-19.03	-49.81	0.00	-7.20	-8.95	-13.22	-15.37	-19.05	-49.82
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-0.95	-1.18	-1.75	-2.03	-2.52	-6.64	0.00	-0.95	-1.18	-1.75	-2.04	-2.53	-6.65
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-1.73	-2.15	-3.17	-3.69	-4.58	-11.98	0.00	-1.73	-2.15	-3.18	-3.70	-4.58	-11.98
Canton-Massillon, OH	-	x	-	100	0.00	-8.18	-10.30	-13.22	-15.11	-17.61	-34.22	0.00	-8.21	-10.33	-13.24	-15.13	-17.64	-34.23
Charleston, WV	-	x	-	100	0.00	-0.46	-0.57	-0.85	-0.99	-1.22	-3.21	0.00	-0.46	-0.58	-0.85	-0.99	-1.23	-3.21
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-2.63	-3.27	-4.88	-5.68	-7.06	-18.73	0.00	-2.64	-3.28	-4.88	-5.69	-7.07	-18.73
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-0.82	-1.02	-1.51	-1.75	-2.17	-5.70	0.00	-0.82	-1.02	-1.51	-1.75	-2.17	-5.70
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-96.73	-121.70	-157.40	-180.14	-210.81	-419.35	0.00	-96.99	-121.99	-157.70	-180.45	-211.13	-419.56
Chico, CA	x	-	100	-	0.00	-0.30	-0.37	-0.55	-0.64	-0.79	-2.07	0.00	-0.30	-0.37	-0.55	-0.64	-0.79	-2.07
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-2.84	-3.53	-5.22	-6.07	-7.53	-19.74	0.00	-2.84	-3.54	-5.23	-6.08	-7.54	-19.75
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.27	-0.34	-0.50	-0.58	-0.72	-1.88	0.00	-0.27	-0.34	-0.50	-0.58	-0.72	-1.88
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-4.12	-5.12	-7.57	-8.81	-10.91	-28.57	0.00	-4.13	-5.13	-7.58	-8.82	-10.93	-28.58
Columbus, OH	x	x	100	100	0.00	-2.66	-3.31	-4.89	-5.69	-7.05	-18.46	0.00	-2.67	-3.32	-4.90	-5.70	-7.06	-18.47
Dallas-Fort Worth, TX	x	-	100	-	0.00	-10.79	-13.41	-19.82	-23.06	-28.58	-74.81	0.00	-10.81	-13.44	-19.85	-23.08	-28.61	-74.83
Dayton-Springfield, OH	-	x	-	100	0.00	-1.25	-1.55	-2.29	-2.67	-3.31	-8.66	0.00	-1.25	-1.56	-2.30	-2.67	-3.31	-8.66
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-14.90	-18.69	-25.03	-28.78	-34.23	-74.31	0.00	-14.94	-18.74	-25.07	-28.82	-34.28	-74.34
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-18.06	-22.63	-30.69	-35.33	-42.26	-94.36	0.00	-18.11	-22.68	-30.74	-35.39	-42.32	-94.40
Door Co., WI	x	-	100	-	0.00	-0.05	-0.06	-0.09	-0.11	-0.13	-0.35	0.00	-0.05	-0.06	-0.09	-0.11	-0.13	-0.35
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01
Evansville, IN	-	x	-	100	0.00	-0.51	-0.64	-0.95	-1.10	-1.37	-3.62	0.00	-0.51	-0.64	-0.95	-1.10	-1.37	-3.62
Greater Connecticut, CT	x	-	100	-	0.00	-2.74	-3.41	-5.03	-5.85	-7.25	-18.97	0.00	-2.75	-3.41	-5.04	-5.86	-7.26	-18.98
Greene Co., PA	x	-	100	-	0.00	-0.06	-0.08	-0.12	-0.13	-0.17	-0.43	0.00	-0.06	-0.08	-0.12	-0.13	-0.17	-0.44
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-1.24	-1.54	-2.27	-2.64	-3.27	-8.57	0.00	-1.24	-1.54	-2.27	-2.64	-3.28	-8.57

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Emission Changes a/ by Nonattainment Area

SOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-1.12	-1.39	-2.06	-2.39	-2.96	-7.76	0.00	-1.12	-1.39	-2.06	-2.39	-2.97	-7.76
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.05	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.05
Hickory, NC	-	x	-	100	0.00	-0.29	-0.36	-0.53	-0.62	-0.77	-2.01	0.00	-0.29	-0.36	-0.53	-0.62	-0.77	-2.01
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-250.71	-315.78	-403.16	-460.62	-535.65	-1,027.30	0.00	-251.42	-316.54	-403.95	-461.44	-536.49	-1,027.87
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-23.98	-30.20	-38.54	-44.03	-51.18	-98.00	0.00	-24.04	-30.27	-38.61	-44.10	-51.26	-98.06
Imperial Co., CA	x	-	100	-	0.00	-0.34	-0.43	-0.63	-0.74	-0.91	-2.39	0.00	-0.35	-0.43	-0.63	-0.74	-0.91	-2.39
Indianapolis, IN	-	x	-	100	0.00	-2.49	-3.09	-4.57	-5.31	-6.58	-17.24	0.00	-2.49	-3.10	-4.57	-5.32	-6.59	-17.24
Jamestown, NY	x	-	100	-	0.00	-0.23	-0.29	-0.42	-0.49	-0.61	-1.59	0.00	-0.23	-0.29	-0.42	-0.49	-0.61	-1.59
Jefferson Co., NY	x	-	100	-	0.00	-0.21	-0.27	-0.39	-0.46	-0.57	-1.48	0.00	-0.21	-0.27	-0.39	-0.46	-0.57	-1.48
Johnstown, PA	-	x	-	100	0.00	-0.19	-0.23	-0.35	-0.40	-0.50	-1.31	0.00	-0.19	-0.24	-0.35	-0.40	-0.50	-1.31
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.19	-0.24	-0.35	-0.40	-0.50	-1.29	0.00	-0.19	-0.24	-0.35	-0.40	-0.50	-1.29
Knoxville, TN	x	x	100	100	0.00	-1.69	-2.10	-3.10	-3.61	-4.47	-11.71	0.00	-1.69	-2.10	-3.10	-3.61	-4.47	-11.71
Lancaster, PA	-	x	-	100	0.00	-0.66	-0.82	-1.21	-1.41	-1.75	-4.58	0.00	-0.66	-0.82	-1.21	-1.41	-1.75	-4.58
Las Vegas, NV	x	-	100	-	0.00	-2.18	-2.71	-4.01	-4.67	-5.78	-15.15	0.00	-2.19	-2.72	-4.02	-4.67	-5.79	-15.15
Libby, MT	-	x	-	100	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.08	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.08
Liberty-Clairton, PA	-	x	-	100	0.00	-0.02	-0.03	-0.04	-0.05	-0.06	-0.15	0.00	-0.02	-0.03	-0.04	-0.05	-0.06	-0.15
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-153.54	-193.09	-251.15	-287.66	-337.56	-681.85	0.00	-153.96	-193.54	-251.62	-288.15	-338.06	-682.19
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-1.13	-1.41	-2.08	-2.42	-2.99	-7.83	0.00	-1.13	-1.41	-2.08	-2.42	-3.00	-7.84
Louisville, KY-IN	-	x	-	100	0.00	-1.71	-2.13	-3.15	-3.66	-4.54	-11.93	0.00	-1.71	-2.13	-3.15	-3.67	-4.55	-11.93
Macon, GA	-	x	-	100	0.00	-0.32	-0.40	-0.59	-0.68	-0.84	-2.22	0.00	-0.32	-0.40	-0.59	-0.68	-0.85	-2.22
Manitowoc Co., WI	x	-		-	0.00	-0.17	-0.21	-0.31	-0.36	-0.44	-1.15	0.00	-0.17	-0.21	-0.31	-0.36	-0.44	-1.15
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.16	-0.20	-0.30	-0.35	-0.43	-1.12	0.00	-0.16	-0.20	-0.30	-0.35	-0.43	-1.12
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-0.63	-0.79	-1.16	-1.35	-1.68	-4.39	0.00	-0.63	-0.79	-1.16	-1.35	-1.68	-4.39
Memphis, TN-AR	x	-	100	-	0.00	-20.50	-25.81	-33.18	-37.94	-44.27	-86.60	0.00	-20.56	-25.87	-33.24	-38.01	-44.34	-86.64
Milwaukee-Racine, WI	x	-	100	-	0.00	-2.72	-3.39	-5.00	-5.82	-7.21	-18.87	0.00	-2.73	-3.39	-5.01	-5.82	-7.22	-18.88
Nevada (Western Part), CA	x	-	100	-	0.00	-0.15	-0.19	-0.28	-0.33	-0.41	-1.07	0.00	-0.15	-0.19	-0.28	-0.33	-0.41	-1.07
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-55.92	-70.09	-94.80	-109.12	-130.38	-289.54	0.00	-56.06	-70.24	-94.96	-109.29	-130.55	-289.66
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.24	-0.30	-0.45	-0.52	-0.65	-1.69	0.00	-0.24	-0.30	-0.45	-0.52	-0.65	-1.69
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-135.60	-170.68	-219.56	-251.10	-293.09	-574.34	0.00	-135.97	-171.09	-219.98	-251.55	-293.54	-574.65

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SOx 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-6.00	-7.46	-11.05	-12.86	-15.94	-41.85	0.00	-6.02	-7.48	-11.06	-12.87	-15.96	-41.86
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-3.04	-3.78	-5.58	-6.49	-8.05	-21.07	0.00	-3.04	-3.78	-5.59	-6.50	-8.05	-21.08
Poughkeepsie, NY	x	x	100	100	0.00	-1.97	-2.45	-3.62	-4.21	-5.22	-13.67	0.00	-1.98	-2.46	-3.63	-4.22	-5.23	-13.67
Providence (All RI), RI	x	-	100	-	0.00	-1.43	-1.77	-2.62	-3.05	-3.78	-9.89	0.00	-1.43	-1.78	-2.62	-3.05	-3.78	-9.89
Reading, PA	-	x	-	100	0.00	-0.58	-0.72	-1.06	-1.24	-1.53	-4.02	0.00	-0.58	-0.72	-1.07	-1.24	-1.54	-4.02
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-1.15	-1.43	-2.12	-2.46	-3.05	-7.98	0.00	-1.16	-1.44	-2.12	-2.47	-3.05	-7.99
Rochester, NY	x	-	100	-	0.00	-2.00	-2.48	-3.67	-4.27	-5.29	-13.85	0.00	-2.00	-2.49	-3.67	-4.27	-5.30	-13.85
Rome, GA	-	x	-	100	0.00	-0.17	-0.22	-0.32	-0.37	-0.46	-1.21	0.00	-0.18	-0.22	-0.32	-0.37	-0.46	-1.21
Sacramento Metro, CA	x	-	50	-	0.00	-3.35	-4.17	-6.16	-7.17	-8.88	-23.26	0.00	-3.36	-4.18	-6.17	-7.18	-8.89	-23.26
San Diego, CA	x	-	100	-	0.00	-4.70	-5.84	-8.63	-10.04	-12.44	-32.57	0.00	-4.71	-5.85	-8.64	-10.05	-12.45	-32.58
San Francisco Bay Area, CA	x	-	100	-	0.00	-79.81	-100.40	-130.18	-149.04	-174.63	-349.80	0.00	-80.03	-100.63	-130.43	-149.30	-174.89	-349.98
San Joaquin Valley, CA	x	x	50	100	0.00	-18.53	-23.23	-31.27	-35.98	-42.90	-94.25	0.00	-18.58	-23.29	-31.33	-36.04	-42.95	-94.29
Sheboygan, WI	x	-	100	-	0.00	-0.19	-0.23	-0.34	-0.40	-0.49	-1.29	0.00	-0.19	-0.23	-0.34	-0.40	-0.49	-1.29
Springfield (Western MA), MA	x	-	100	-	0.00	-1.43	-1.78	-2.63	-3.06	-3.80	-9.94	0.00	-1.44	-1.79	-2.64	-3.07	-3.80	-9.94
St. Louis, MO-IL	x	x	100	100	0.00	-37.01	-46.56	-60.36	-69.10	-80.96	-162.11	0.00	-37.11	-46.67	-60.47	-69.22	-81.09	-162.19
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-2.27	-2.86	-3.68	-4.21	-4.91	-9.59	0.00	-2.28	-2.87	-3.69	-4.21	-4.92	-9.60
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-1.28	-1.60	-2.28	-2.64	-3.23	-8.01	0.00	-1.28	-1.60	-2.29	-2.65	-3.24	-8.01
Washington, DC-MD-VA	x	x	100	100	0.00	-7.57	-9.42	-13.90	-16.18	-20.04	-52.44	0.00	-7.59	-9.43	-13.92	-16.19	-20.06	-52.45
Wheeling, WV-OH	-	x	-	100	0.00	-0.26	-0.33	-0.48	-0.56	-0.70	-1.82	0.00	-0.26	-0.33	-0.48	-0.56	-0.70	-1.82
York, PA	-	x	-	100	0.00	-0.61	-0.76	-1.12	-1.31	-1.62	-4.24	0.00	-0.61	-0.76	-1.13	-1.31	-1.62	-4.25

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-82
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-6.43	-7.06	-9.74	-11.36	-13.54	-35.31	0.00	-9.21	-9.99	-12.91	-14.82	-17.16	-36.86
Allegan Co., MI	x	-	100	-	0.00	-0.70	-0.77	-1.06	-1.24	-1.48	-3.86	0.00	-1.01	-1.09	-1.41	-1.62	-1.88	-4.03
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-0.68	-0.75	-1.03	-1.20	-1.43	-3.74	0.00	-0.98	-1.06	-1.37	-1.57	-1.82	-3.90
Atlanta, GA	x	x	100	100	0.00	-37.24	-40.90	-56.43	-65.80	-78.47	-204.64	0.00	-53.35	-57.89	-74.82	-85.84	-99.41	-213.60
Baltimore, MD	x	x	100	100	0.00	-14.15	-15.54	-21.44	-25.00	-29.81	-77.70	0.00	-20.28	-22.01	-28.44	-32.62	-37.77	-81.12
Baton Rouge, LA	x	-	100	-	0.00	-187.23	-219.36	-262.66	-292.66	-326.16	-595.62	0.00	-312.02	-353.13	-401.33	-438.63	-473.14	-695.79
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-372.26	-436.49	-521.68	-580.91	-646.75	-1,173.28	0.00	-621.45	-703.66	-798.56	-872.26	-940.03	-1,373.84
Birmingham, AL	-	x	-	100	0.00	-5.04	-5.53	-7.63	-8.90	-10.61	-27.69	0.00	-7.21	-7.82	-10.12	-11.61	-13.44	-28.90
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-22.16	-24.34	-33.58	-39.16	-46.69	-121.74	0.00	-31.76	-34.46	-44.53	-51.09	-59.16	-127.08
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-3.03	-3.32	-4.60	-5.37	-6.41	-16.81	0.00	-4.33	-4.69	-6.08	-6.99	-8.10	-17.52
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-5.30	-5.82	-8.03	-9.36	-11.16	-29.10	0.00	-7.59	-8.24	-10.64	-12.21	-14.14	-30.37
Canton-Massillon, OH	-	x	-	100	0.00	-25.53	-29.83	-35.94	-40.13	-44.87	-83.71	0.00	-42.29	-47.79	-54.58	-59.77	-64.67	-97.05
Charleston, WV	-	x	-	100	0.00	-1.39	-1.53	-2.11	-2.45	-2.93	-7.63	0.00	-1.99	-2.16	-2.79	-3.20	-3.71	-7.97
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-9.19	-10.07	-13.98	-16.34	-19.54	-51.57	0.00	-13.07	-14.14	-18.41	-21.18	-24.61	-53.65
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-2.56	-2.81	-3.88	-4.53	-5.40	-14.09	0.00	-3.67	-3.98	-5.15	-5.91	-6.84	-14.71
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-302.62	-352.35	-427.90	-479.14	-538.13	-1,032.15	0.00	-497.28	-560.80	-644.62	-707.81	-769.00	-1,185.22
Chico, CA	x	-	100	-	0.00	-0.95	-1.05	-1.44	-1.68	-2.01	-5.24	0.00	-1.37	-1.48	-1.92	-2.20	-2.54	-5.47
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-8.94	-9.82	-13.56	-15.82	-18.87	-49.29	0.00	-12.80	-13.88	-17.96	-20.61	-23.88	-51.43
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-0.81	-0.89	-1.23	-1.44	-1.71	-4.46	0.00	-1.16	-1.26	-1.63	-1.87	-2.17	-4.66
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-12.59	-13.82	-19.07	-22.24	-26.52	-69.13	0.00	-18.03	-19.57	-25.29	-29.01	-33.59	-72.17
Columbus, OH	x	x	100	100	0.00	-8.69	-9.55	-13.18	-15.36	-18.32	-47.78	0.00	-12.46	-13.52	-17.47	-20.04	-23.21	-49.87
Dallas-Fort Worth, TX	x	-	100	-	0.00	-36.92	-40.55	-55.95	-65.24	-77.80	-202.87	0.00	-52.90	-57.40	-74.19	-85.12	-98.56	-211.76
Dayton-Springfield, OH	-	x	-	100	0.00	-3.83	-4.20	-5.80	-6.76	-8.06	-21.02	0.00	-5.48	-5.95	-7.69	-8.82	-10.21	-21.94
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-47.48	-54.45	-68.40	-77.47	-88.55	-188.04	0.00	-75.38	-84.24	-99.62	-110.62	-122.25	-208.73
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-56.25	-64.23	-81.46	-92.55	-106.28	-231.54	0.00	-88.41	-98.54	-117.50	-130.91	-145.37	-254.94
Door Co., WI	x	-	100	-	0.00	-0.16	-0.17	-0.24	-0.27	-0.33	-0.85	0.00	-0.22	-0.24	-0.31	-0.36	-0.41	-0.89
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.04	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.04
Evansville, IN	-	x	-	100	0.00	-1.62	-1.77	-2.46	-2.87	-3.43	-9.04	0.00	-2.30	-2.49	-3.24	-3.72	-4.32	-9.41
Greater Connecticut, CT	x	-	100	-	0.00	-8.67	-9.52	-13.13	-15.30	-18.25	-47.55	0.00	-12.42	-13.48	-17.41	-19.97	-23.13	-49.65
Greene Co., PA	x	-	100	-	0.00	-0.19	-0.20	-0.28	-0.33	-0.39	-1.02	0.00	-0.27	-0.29	-0.37	-0.43	-0.49	-1.06
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-3.92	-4.30	-5.94	-6.92	-8.26	-21.53	0.00	-5.61	-6.09	-7.87	-9.03	-10.46	-22.47

Table B2-82
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Emission Changes a/ by Nonattainment Area

SOx 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-3.50	-3.84	-5.30	-6.18	-7.37	-19.22	0.00	-5.01	-5.44	-7.03	-8.06	-9.34	-20.06
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.02	-0.03	-0.04	-0.04	-0.05	-0.13	0.00	-0.03	-0.04	-0.05	-0.05	-0.06	-0.14
Hickory, NC	-	x	-	100	0.00	-0.94	-1.03	-1.42	-1.66	-1.98	-5.15	0.00	-1.34	-1.46	-1.89	-2.16	-2.51	-5.38
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-783.60	-917.20	-1,100.61	-1,227.28	-1,369.41	-2,520.35	0.00	-1,303.05	-1,473.96	-1,678.02	-1,835.29	-1,981.88	-2,936.09
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-74.84	-87.62	-105.07	-117.13	-130.65	-239.84	0.00	-124.53	-140.89	-160.31	-175.29	-189.22	-279.65
Imperial Co., CA	x	-	100	-	0.00	-1.21	-1.33	-1.83	-2.13	-2.54	-6.63	0.00	-1.73	-1.88	-2.42	-2.78	-3.22	-6.92
Indianapolis, IN	-	x	-	100	0.00	-8.10	-8.89	-12.27	-14.31	-17.07	-44.50	0.00	-11.60	-12.59	-16.27	-18.67	-21.62	-46.45
Jamestown, NY	x	-	100	-	0.00	-0.70	-0.77	-1.07	-1.24	-1.48	-3.87	0.00	-1.01	-1.09	-1.41	-1.62	-1.88	-4.03
Jefferson Co., NY	x	-	100	-	0.00	-0.70	-0.77	-1.06	-1.24	-1.48	-3.85	0.00	-1.00	-1.09	-1.41	-1.62	-1.87	-4.02
Johnstown, PA	-	x	-	100	0.00	-0.56	-0.62	-0.85	-1.00	-1.19	-3.09	0.00	-0.81	-0.88	-1.13	-1.30	-1.51	-3.23
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-0.68	-0.75	-1.02	-1.19	-1.41	-3.61	0.00	-0.98	-1.07	-1.37	-1.57	-1.80	-3.79
Knoxville, TN	x	x	100	100	0.00	-5.42	-5.95	-8.21	-9.57	-11.41	-29.76	0.00	-7.76	-8.42	-10.88	-12.48	-14.46	-31.07
Lancaster, PA	-	x	-	100	0.00	-2.07	-2.27	-3.14	-3.66	-4.36	-11.38	0.00	-2.97	-3.22	-4.16	-4.77	-5.53	-11.87
Las Vegas, NV	x	-	100	-	0.00	-7.91	-8.68	-11.99	-13.98	-16.67	-43.51	0.00	-11.32	-12.29	-15.89	-18.23	-21.11	-45.40
Libby, MT	-	x	-	100	0.00	-0.03	-0.04	-0.05	-0.06	-0.07	-0.19	0.00	-0.05	-0.05	-0.07	-0.08	-0.09	-0.20
Liberty-Clairton, PA	-	x	-	100	0.00	-0.06	-0.07	-0.09	-0.11	-0.13	-0.34	0.00	-0.09	-0.10	-0.13	-0.14	-0.17	-0.36
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-483.22	-561.17	-685.51	-769.15	-866.55	-1,694.18	0.00	-789.39	-888.88	-1,026.65	-1,129.48	-1,230.76	-1,932.75
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-3.83	-4.21	-5.80	-6.76	-8.06	-20.98	0.00	-5.49	-5.96	-7.70	-8.83	-10.22	-21.91
Louisville, KY-IN	-	x	-	100	0.00	-5.26	-5.77	-7.97	-9.30	-11.10	-29.05	0.00	-7.51	-8.15	-10.55	-12.11	-14.04	-30.29
Macon, GA	-	x	-	100	0.00	-0.98	-1.07	-1.49	-1.73	-2.07	-5.42	0.00	-1.40	-1.52	-1.97	-2.26	-2.62	-5.65
Manitowoc Co., WI	x	-		-	0.00	-0.51	-0.56	-0.77	-0.90	-1.07	-2.79	0.00	-0.73	-0.79	-1.02	-1.17	-1.36	-2.92
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.56	-0.62	-0.85	-0.99	-1.19	-3.09	0.00	-0.81	-0.88	-1.13	-1.30	-1.50	-3.23
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-2.24	-2.46	-3.40	-3.96	-4.73	-12.32	0.00	-3.21	-3.49	-4.51	-5.17	-5.99	-12.86
Memphis, TN-AR	x	-	100	-	0.00	-63.96	-74.67	-90.14	-100.72	-112.76	-211.95	0.00	-105.73	-119.41	-136.60	-149.70	-162.15	-245.09
Milwaukee-Racine, WI	x	-	100	-	0.00	-8.44	-9.27	-12.78	-14.90	-17.77	-46.33	0.00	-12.09	-13.12	-16.95	-19.45	-22.52	-48.36
Nevada (Western Part), CA	x	-	100	-	0.00	-0.50	-0.55	-0.76	-0.89	-1.06	-2.77	0.00	-0.72	-0.78	-1.01	-1.16	-1.35	-2.89
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-174.23	-199.17	-252.03	-286.13	-328.22	-710.79	0.00	-274.53	-306.18	-364.37	-405.63	-449.92	-784.09
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-0.74	-0.81	-1.11	-1.30	-1.55	-4.05	0.00	-1.05	-1.14	-1.48	-1.69	-1.96	-4.22
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-424.17	-494.97	-598.09	-668.55	-748.82	-1,412.12	0.00	-700.52	-791.01	-905.55	-992.68	-1,075.75	-1,631.08

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Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-21.34	-23.42	-32.37	-37.76	-45.07	-117.86	0.00	-30.52	-33.10	-42.85	-49.19	-57.01	-122.92
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-9.09	-9.99	-13.78	-16.07	-19.16	-49.99	0.00	-13.03	-14.13	-18.27	-20.96	-24.27	-52.17
Poughkeepsie, NY	x	x	100	100	0.00	-6.38	-7.01	-9.67	-11.27	-13.44	-35.06	0.00	-9.14	-9.92	-12.82	-14.71	-17.03	-36.59
Providence (All RI), RI	x	-	100	-	0.00	-4.41	-4.84	-6.68	-7.79	-9.29	-24.22	0.00	-6.32	-6.85	-8.86	-10.16	-11.77	-25.28
Reading, PA	-	x	-	100	0.00	-1.88	-2.06	-2.85	-3.32	-3.96	-10.32	0.00	-2.69	-2.92	-3.77	-4.33	-5.01	-10.77
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-4.47	-4.91	-6.78	-7.90	-9.42	-24.53	0.00	-6.41	-6.96	-8.99	-10.31	-11.94	-25.61
Rochester, NY	x	-	100	-	0.00	-6.22	-6.83	-9.43	-10.99	-13.11	-34.18	0.00	-8.91	-9.67	-12.50	-14.34	-16.60	-35.67
Rome, GA	-	x	-	100	0.00	-0.54	-0.59	-0.82	-0.95	-1.13	-2.96	0.00	-0.77	-0.84	-1.08	-1.24	-1.44	-3.09
Sacramento Metro, CA	x	-	50	-	0.00	-11.22	-12.33	-17.01	-19.83	-23.65	-61.67	0.00	-16.08	-17.45	-22.55	-25.87	-29.96	-64.38
San Diego, CA	x	-	100	-	0.00	-14.46	-15.88	-21.91	-25.55	-30.47	-79.46	0.00	-20.72	-22.48	-29.06	-33.34	-38.60	-82.94
San Francisco Bay Area, CA	x	-	100	-	0.00	-249.19	-289.89	-352.75	-395.26	-444.39	-857.95	0.00	-408.68	-460.65	-530.35	-582.72	-633.73	-982.98
San Joaquin Valley, CA	x	x	50	100	0.00	-60.20	-68.84	-87.05	-98.80	-113.30	-244.91	0.00	-94.92	-105.88	-125.93	-140.16	-155.41	-270.32
Sheboygan, WI	x	-	100	-	0.00	-0.58	-0.64	-0.88	-1.03	-1.23	-3.20	0.00	-0.84	-0.91	-1.17	-1.34	-1.56	-3.34
Springfield (Western MA), MA	x	-	100	-	0.00	-4.50	-4.95	-6.83	-7.96	-9.49	-24.75	0.00	-6.45	-7.00	-9.05	-10.38	-12.02	-25.83
St. Louis, MO-IL	x	x	100	100	0.00	-115.51	-134.38	-163.50	-183.19	-205.94	-397.38	0.00	-189.47	-213.57	-245.85	-270.12	-293.74	-455.37
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-7.07	-8.26	-9.96	-11.13	-12.46	-23.37	0.00	-11.70	-13.22	-15.11	-16.56	-17.93	-27.04
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-3.98	-4.45	-5.93	-6.85	-8.05	-19.72	0.00	-5.93	-6.51	-8.13	-9.22	-10.50	-20.96
Washington, DC-MD-VA	x	x	100	100	0.00	-24.56	-26.98	-37.20	-43.37	-51.72	-134.74	0.00	-35.20	-38.20	-49.35	-56.61	-65.54	-140.68
Wheeling, WV-OH	-	x	-	100	0.00	-0.79	-0.87	-1.20	-1.40	-1.67	-4.34	0.00	-1.13	-1.23	-1.59	-1.82	-2.11	-4.53
York, PA	-	x	-	100	0.00	-2.03	-2.23	-3.08	-3.59	-4.28	-11.16	0.00	-2.91	-3.16	-4.08	-4.68	-5.42	-11.65

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-83
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-10.03	-10.73	-14.61	-17.02	-20.10	-52.25	0.00	-17.30	-18.38	-22.91	-26.08	-29.58	-56.07
Allegan Co., MI	x	-	100	-	0.00	-1.10	-1.17	-1.60	-1.86	-2.20	-5.71	0.00	-1.89	-2.01	-2.50	-2.85	-3.23	-6.13
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-1.13	-1.21	-1.65	-1.92	-2.27	-5.89	0.00	-1.95	-2.07	-2.58	-2.94	-3.34	-6.32
Atlanta, GA	x	x	100	100	0.00	-64.01	-68.52	-93.28	-108.64	-128.33	-333.57	0.00	-110.41	-117.33	-146.25	-166.48	-188.85	-357.98
Baltimore, MD	x	x	100	100	0.00	-21.97	-23.52	-32.01	-37.28	-44.04	-114.41	0.00	-37.92	-40.30	-50.22	-57.15	-64.82	-122.81
Baton Rouge, LA	x	-	100	-	0.00	-293.46	-338.60	-399.89	-442.66	-488.38	-880.98	0.00	-624.92	-693.46	-767.87	-829.93	-878.31	-1,143.31
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-583.25	-673.61	-794.07	-878.37	-968.08	-1,734.16	0.00	-1,245.10	-1,382.29	-1,528.68	-1,651.22	-1,745.98	-2,259.45
Birmingham, AL	-	x	-	100	0.00	-7.67	-8.21	-11.18	-13.02	-15.39	-40.02	0.00	-13.23	-14.06	-17.53	-19.95	-22.63	-42.93
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-33.23	-35.57	-48.42	-56.39	-66.60	-173.09	0.00	-57.33	-60.92	-75.93	-86.43	-98.03	-185.78
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-4.69	-5.01	-6.84	-7.98	-9.43	-24.65	0.00	-8.05	-8.54	-10.68	-12.17	-13.83	-26.39
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-7.87	-8.42	-11.46	-13.35	-15.77	-40.98	0.00	-13.57	-14.43	-17.98	-20.46	-23.21	-43.99
Canton-Massillon, OH	-	x	-	100	0.00	-39.89	-45.90	-54.51	-60.47	-66.92	-123.23	0.00	-84.32	-93.44	-103.86	-112.46	-119.33	-158.08
Charleston, WV	-	x	-	100	0.00	-2.02	-2.17	-2.95	-3.44	-4.06	-10.55	0.00	-3.49	-3.71	-4.63	-5.27	-5.97	-11.32
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-15.56	-16.61	-22.74	-26.53	-31.41	-82.47	0.00	-26.59	-28.20	-35.35	-40.33	-45.89	-88.09
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-3.89	-4.17	-5.67	-6.61	-7.80	-20.24	0.00	-6.73	-7.15	-8.91	-10.13	-11.49	-21.74
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-473.68	-542.65	-649.91	-723.36	-804.26	-1,525.42	0.00	-989.77	-1,094.54	-1,223.93	-1,328.99	-1,415.72	-1,924.87
Chico, CA	x	-	100	-	0.00	-1.47	-1.58	-2.15	-2.50	-2.96	-7.68	0.00	-2.54	-2.70	-3.37	-3.83	-4.35	-8.24
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-13.84	-14.81	-20.18	-23.51	-27.78	-72.35	0.00	-23.84	-25.32	-31.60	-35.98	-40.83	-77.58
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-1.18	-1.27	-1.72	-2.01	-2.37	-6.16	0.00	-2.04	-2.17	-2.70	-3.07	-3.49	-6.61
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-18.64	-19.95	-27.16	-31.63	-37.36	-97.08	0.00	-32.15	-34.17	-42.59	-48.47	-54.98	-104.20
Columbus, OH	x	x	100	100	0.00	-13.83	-14.81	-20.15	-23.47	-27.73	-72.07	0.00	-23.86	-25.35	-31.60	-35.97	-40.80	-77.35
Dallas-Fort Worth, TX	x	-	100	-	0.00	-61.70	-66.06	-89.92	-104.72	-123.70	-321.51	0.00	-106.44	-113.11	-140.99	-160.48	-182.04	-345.05
Dayton-Springfield, OH	-	x	-	100	0.00	-5.68	-6.08	-8.27	-9.64	-11.38	-29.58	0.00	-9.79	-10.41	-12.97	-14.77	-16.75	-31.75
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-75.19	-84.60	-104.91	-118.30	-133.94	-282.84	0.00	-149.66	-163.98	-188.17	-206.77	-223.94	-336.81
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-86.70	-97.19	-121.38	-137.24	-155.94	-335.82	0.00	-170.80	-186.76	-215.53	-237.44	-258.04	-395.80
Door Co., WI	x	-	100	-	0.00	-0.23	-0.25	-0.34	-0.39	-0.46	-1.20	0.00	-0.40	-0.42	-0.53	-0.60	-0.68	-1.29
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.05	0.00	-0.02	-0.02	-0.02	-0.03	-0.03	-0.05
Evansville, IN	-	x	-	100	0.00	-2.47	-2.64	-3.61	-4.21	-4.98	-13.08	0.00	-4.22	-4.48	-5.61	-6.40	-7.28	-13.97
Greater Connecticut, CT	x	-	100	-	0.00	-13.28	-14.22	-19.35	-22.53	-26.61	-69.12	0.00	-22.92	-24.36	-30.36	-34.55	-39.18	-74.20
Greene Co., PA	x	-	100	-	0.00	-0.26	-0.28	-0.39	-0.45	-0.53	-1.38	0.00	-0.46	-0.49	-0.60	-0.69	-0.78	-1.48
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-6.02	-6.44	-8.77	-10.22	-12.07	-31.36	0.00	-10.38	-11.03	-13.75	-15.65	-17.76	-33.66

Table B2-83
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-5.30	-5.67	-7.72	-8.99	-10.62	-27.59	0.00	-9.14	-9.71	-12.10	-13.77	-15.63	-29.61
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.04	-0.04	-0.05	-0.06	-0.07	-0.19	0.00	-0.06	-0.06	-0.08	-0.09	-0.11	-0.20
Hickory, NC	-	x	-	100	0.00	-1.47	-1.57	-2.14	-2.49	-2.94	-7.64	0.00	-2.53	-2.69	-3.36	-3.82	-4.33	-8.21
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-1,228.28	-1,415.66	-1,675.55	-1,856.35	-2,050.57	-3,728.94	0.00	-2,608.01	-2,892.55	-3,207.73	-3,469.44	-3,675.41	-4,817.30
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-117.13	-135.07	-159.72	-176.88	-195.29	-353.90	0.00	-249.03	-276.26	-306.16	-331.04	-350.54	-458.09
Imperial Co., CA	x	-	100	-	0.00	-2.05	-2.19	-2.98	-3.47	-4.10	-10.67	0.00	-3.53	-3.75	-4.68	-5.33	-6.04	-11.45
Indianapolis, IN	-	x	-	100	0.00	-12.87	-13.78	-18.76	-21.85	-25.80	-67.07	0.00	-22.20	-23.60	-29.41	-33.48	-37.98	-71.98
Jamestown, NY	x	-	100	-	0.00	-1.04	-1.12	-1.52	-1.77	-2.09	-5.43	0.00	-1.80	-1.91	-2.38	-2.71	-3.08	-5.83
Jefferson Co., NY	x	-	100	-	0.00	-1.11	-1.19	-1.62	-1.89	-2.23	-5.81	0.00	-1.92	-2.04	-2.55	-2.90	-3.29	-6.23
Johnstown, PA	-	x	-	100	0.00	-0.82	-0.87	-1.19	-1.38	-1.63	-4.24	0.00	-1.41	-1.50	-1.86	-2.12	-2.41	-4.56
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-1.18	-1.27	-1.71	-1.98	-2.32	-5.88	0.00	-2.08	-2.22	-2.73	-3.09	-3.48	-6.39
Knoxville, TN	x	x	100	100	0.00	-8.43	-9.02	-12.28	-14.30	-16.89	-43.92	0.00	-14.53	-15.44	-19.25	-21.91	-24.86	-47.13
Lancaster, PA	-	x	-	100	0.00	-3.15	-3.37	-4.58	-5.34	-6.31	-16.39	0.00	-5.43	-5.77	-7.19	-8.18	-9.28	-17.59
Las Vegas, NV	x	-	100	-	0.00	-13.88	-14.85	-20.23	-23.57	-27.84	-72.45	0.00	-23.92	-25.41	-31.69	-36.08	-40.95	-77.72
Libby, MT	-	x	-	100	0.00	-0.05	-0.06	-0.08	-0.09	-0.10	-0.27	0.00	-0.09	-0.10	-0.12	-0.14	-0.15	-0.29
Liberty-Clairton, PA	-	x	-	100	0.00	-0.09	-0.09	-0.13	-0.15	-0.17	-0.45	0.00	-0.15	-0.16	-0.20	-0.23	-0.26	-0.48
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-760.22	-868.07	-1,046.29	-1,167.39	-1,302.41	-2,523.62	0.00	-1,574.69	-1,738.56	-1,952.99	-2,125.17	-2,270.67	-3,147.21
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-6.30	-6.75	-9.17	-10.68	-12.60	-32.66	0.00	-10.90	-11.59	-14.42	-16.40	-18.59	-35.10
Louisville, KY-IN	-	x	-	100	0.00	-7.82	-8.37	-11.41	-13.30	-15.72	-41.01	0.00	-13.45	-14.29	-17.84	-20.33	-23.08	-43.94
Macon, GA	-	x	-	100	0.00	-1.46	-1.56	-2.13	-2.49	-2.94	-7.68	0.00	-2.51	-2.67	-3.33	-3.80	-4.31	-8.22
Manitowoc Co., WI	x	-		-	0.00	-0.76	-0.81	-1.10	-1.28	-1.51	-3.93	0.00	-1.30	-1.39	-1.73	-1.96	-2.23	-4.22
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-0.95	-1.02	-1.38	-1.61	-1.90	-4.95	0.00	-1.64	-1.74	-2.17	-2.47	-2.80	-5.31
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-3.86	-4.13	-5.62	-6.55	-7.74	-20.11	0.00	-6.66	-7.08	-8.82	-10.04	-11.39	-21.59
Memphis, TN-AR	x	-	100	-	0.00	-99.89	-114.81	-136.63	-151.70	-168.08	-311.80	0.00	-210.53	-233.19	-259.59	-281.28	-298.74	-398.33
Milwaukee-Racine, WI	x	-	100	-	0.00	-12.68	-13.57	-18.47	-21.51	-25.41	-66.02	0.00	-21.87	-23.24	-28.97	-32.97	-37.40	-70.87
Nevada (Western Part), CA	x	-	100	-	0.00	-0.80	-0.86	-1.17	-1.36	-1.61	-4.17	0.00	-1.38	-1.47	-1.83	-2.09	-2.37	-4.48
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-268.73	-301.60	-375.82	-424.57	-481.87	-1,031.42	0.00	-531.12	-581.13	-669.44	-736.89	-799.97	-1,219.53
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-1.07	-1.15	-1.57	-1.82	-2.15	-5.61	0.00	-1.85	-1.97	-2.45	-2.79	-3.17	-6.01
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-664.20	-762.88	-909.06	-1,009.82	-1,119.66	-2,086.56	0.00	-1,397.45	-1,547.34	-1,724.07	-1,868.91	-1,986.14	-2,658.83

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SOx 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-36.73	-39.29	-53.57	-62.43	-73.79	-192.36	0.00	-63.19	-67.11	-83.79	-95.44	-108.36	-206.16
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-13.20	-14.13	-19.24	-22.40	-26.47	-68.81	0.00	-22.76	-24.19	-30.16	-34.33	-38.94	-73.84
Poughkeepsie, NY	x	x	100	100	0.00	-10.01	-10.71	-14.58	-16.98	-20.06	-52.14	0.00	-17.26	-18.34	-22.87	-26.03	-29.52	-55.95
Providence (All RI), RI	x	-	100	-	0.00	-6.60	-7.07	-9.62	-11.20	-13.23	-34.38	0.00	-11.39	-12.10	-15.08	-17.17	-19.47	-36.90
Reading, PA	-	x	-	100	0.00	-2.95	-3.16	-4.30	-5.00	-5.91	-15.36	0.00	-5.09	-5.40	-6.74	-7.67	-8.70	-16.49
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-8.41	-9.00	-12.25	-14.26	-16.84	-43.69	0.00	-14.52	-15.44	-19.23	-21.88	-24.80	-46.93
Rochester, NY	x	-	100	-	0.00	-9.39	-10.05	-13.68	-15.93	-18.82	-48.91	0.00	-16.19	-17.21	-21.45	-24.42	-27.70	-52.49
Rome, GA	-	x	-	100	0.00	-0.80	-0.86	-1.17	-1.36	-1.61	-4.19	0.00	-1.39	-1.47	-1.84	-2.09	-2.37	-4.50
Sacramento Metro, CA	x	-	50	-	0.00	-18.28	-19.57	-26.63	-31.02	-36.64	-95.22	0.00	-31.54	-33.51	-41.77	-47.54	-53.93	-102.20
San Diego, CA	x	-	100	-	0.00	-21.57	-23.09	-31.43	-36.61	-43.24	-112.38	0.00	-37.20	-39.54	-49.28	-56.10	-63.63	-120.61
San Francisco Bay Area, CA	x	-	100	-	0.00	-388.80	-445.09	-533.83	-594.49	-661.49	-1,260.75	0.00	-810.83	-896.34	-1,003.32	-1,089.97	-1,161.88	-1,586.62
San Joaquin Valley, CA	x	x	50	100	0.00	-97.03	-108.71	-135.90	-153.71	-174.73	-377.26	0.00	-190.88	-208.66	-240.98	-265.57	-288.75	-444.06
Sheboygan, WI	x	-	100	-	0.00	-0.88	-0.95	-1.29	-1.50	-1.77	-4.60	0.00	-1.53	-1.62	-2.02	-2.30	-2.61	-4.94
Springfield (Western MA), MA	x	-	100	-	0.00	-6.86	-7.34	-9.99	-11.64	-13.75	-35.73	0.00	-11.83	-12.57	-15.67	-17.83	-20.23	-38.34
St. Louis, MO-IL	x	x	100	100	0.00	-180.21	-206.31	-247.41	-275.51	-306.53	-583.95	0.00	-375.89	-415.54	-465.09	-505.23	-538.53	-735.08
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-11.02	-12.67	-15.07	-16.72	-18.52	-34.23	0.00	-23.26	-25.76	-28.66	-31.05	-32.96	-43.81
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-6.06	-6.61	-8.69	-10.01	-11.65	-28.32	0.00	-11.05	-11.89	-14.33	-16.09	-17.94	-31.39
Washington, DC-MD-VA	x	x	100	100	0.00	-39.03	-41.79	-56.86	-66.22	-78.20	-203.08	0.00	-67.38	-71.62	-89.23	-101.54	-115.16	-218.04
Wheeling, WV-OH	-	x	-	100	0.00	-1.15	-1.23	-1.68	-1.95	-2.31	-6.00	0.00	-1.99	-2.11	-2.63	-2.99	-3.40	-6.44
York, PA	-	x	-	100	0.00	-3.27	-3.50	-4.76	-5.55	-6.55	-17.02	0.00	-5.64	-5.99	-7.47	-8.50	-9.64	-18.27

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-84
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

SOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-13.65	-14.39	-19.27	-22.48	-26.46	-68.77	0.00	-26.51	-27.90	-33.96	-38.52	-43.25	-75.40
Allegan Co., MI	x	-	100	-	0.00	-1.49	-1.57	-2.10	-2.45	-2.88	-7.48	0.00	-2.88	-3.04	-3.69	-4.19	-4.71	-8.20
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-1.74	-1.84	-2.46	-2.87	-3.38	-8.79	0.00	-3.39	-3.57	-4.34	-4.92	-5.53	-9.63
Atlanta, GA	x	x	100	100	0.00	-108.63	-114.44	-153.34	-178.85	-210.50	-547.16	0.00	-210.90	-221.91	-270.13	-306.42	-344.07	-599.88
Baltimore, MD	x	x	100	100	0.00	-29.66	-31.25	-41.86	-48.82	-57.45	-149.27	0.00	-57.61	-60.62	-73.77	-83.68	-93.94	-163.70
Baton Rouge, LA	x	-	100	-	0.00	-411.65	-470.18	-549.57	-605.92	-664.11	-1,190.65	0.00	-1,021.40	-1,122.66	-1,226.30	-1,318.07	-1,381.08	-1,670.77
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-817.61	-934.85	-1,090.69	-1,201.52	-1,315.39	-2,340.78	0.00	-2,034.74	-2,237.48	-2,441.16	-2,622.20	-2,745.18	-3,302.03
Birmingham, AL	-	x	-	100	0.00	-10.14	-10.68	-14.32	-16.70	-19.66	-51.14	0.00	-19.68	-20.71	-25.21	-28.61	-32.13	-56.05
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-42.01	-44.26	-59.30	-69.16	-81.39	-211.52	0.00	-81.58	-85.84	-104.48	-118.51	-133.06	-231.93
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-6.26	-6.59	-8.85	-10.33	-12.17	-31.79	0.00	-12.10	-12.71	-15.52	-17.62	-19.81	-34.75
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-9.69	-10.21	-13.68	-15.95	-18.78	-48.80	0.00	-18.82	-19.80	-24.10	-27.34	-30.70	-53.51
Canton-Massillon, OH	-	x	-	100	0.00	-55.58	-63.32	-74.34	-82.13	-90.26	-164.67	0.00	-136.93	-150.34	-164.68	-177.27	-186.13	-228.26
Charleston, WV	-	x	-	100	0.00	-2.41	-2.54	-3.40	-3.97	-4.67	-12.14	0.00	-4.68	-4.92	-5.99	-6.80	-7.63	-13.31
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-25.10	-26.38	-35.47	-41.43	-48.83	-127.73	0.00	-48.39	-50.84	-62.10	-70.56	-79.37	-139.49
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-5.05	-5.33	-7.12	-8.30	-9.76	-25.22	0.00	-9.87	-10.40	-12.62	-14.30	-16.03	-27.75
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-663.02	-751.45	-890.20	-987.41	-1,091.00	-2,058.87	0.00	-1,609.58	-1,763.16	-1,942.72	-2,097.86	-2,212.08	-2,787.35
Chico, CA	x	-	100	-	0.00	-1.97	-2.07	-2.78	-3.24	-3.81	-9.91	0.00	-3.82	-4.02	-4.89	-5.55	-6.23	-10.87
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-19.24	-20.26	-27.17	-31.70	-37.33	-97.20	0.00	-37.29	-39.22	-47.79	-54.23	-60.92	-106.45
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-1.40	-1.47	-1.97	-2.30	-2.71	-7.03	0.00	-2.71	-2.85	-3.47	-3.94	-4.43	-7.71
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-22.88	-24.11	-32.30	-37.67	-44.34	-115.23	0.00	-44.43	-46.76	-56.91	-64.55	-72.48	-126.34
Columbus, OH	x	x	100	100	0.00	-19.90	-20.97	-28.10	-32.77	-38.57	-100.25	0.00	-38.64	-40.66	-49.50	-56.15	-63.04	-109.91
Dallas-Fort Worth, TX	x	-	100	-	0.00	-98.66	-103.94	-139.26	-162.43	-191.17	-496.90	0.00	-191.56	-201.56	-245.35	-278.31	-312.49	-544.80
Dayton-Springfield, OH	-	x	-	100	0.00	-6.98	-7.35	-9.85	-11.49	-13.53	-35.16	0.00	-13.55	-14.26	-17.36	-19.69	-22.11	-38.55
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-107.69	-119.58	-146.71	-165.23	-186.22	-394.05	0.00	-246.41	-267.33	-301.84	-330.13	-354.06	-493.42
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-117.00	-129.79	-159.52	-179.78	-202.82	-431.37	0.00	-266.91	-289.43	-327.21	-358.11	-384.41	-538.31
Door Co., WI	x	-	100	-	0.00	-0.28	-0.30	-0.40	-0.46	-0.55	-1.42	0.00	-0.55	-0.58	-0.70	-0.80	-0.89	-1.56
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.06	0.00	-0.02	-0.02	-0.03	-0.03	-0.04	-0.07
Evansville, IN	-	x	-	100	0.00	-3.22	-3.39	-4.56	-5.33	-6.28	-16.48	0.00	-6.20	-6.51	-7.96	-9.05	-10.19	-17.97
Greater Connecticut, CT	x	-	100	-	0.00	-17.42	-18.36	-24.59	-28.68	-33.75	-87.66	0.00	-33.86	-35.63	-43.36	-49.17	-55.20	-96.15
Greene Co., PA	x	-	100	-	0.00	-0.30	-0.32	-0.43	-0.50	-0.59	-1.52	0.00	-0.59	-0.62	-0.75	-0.85	-0.96	-1.67
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-7.93	-8.36	-11.20	-13.06	-15.37	-39.96	0.00	-15.41	-16.21	-19.73	-22.38	-25.13	-43.81

Table B2-84
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Emission Changes a/ by Nonattainment Area

SOx 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-6.79	-7.15	-9.58	-11.17	-13.15	-34.18	0.00	-13.18	-13.87	-16.88	-19.14	-21.50	-37.47
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.05	-0.05	-0.07	-0.08	-0.09	-0.24	0.00	-0.09	-0.09	-0.11	-0.13	-0.14	-0.26
Hickory, NC	-	x	-	100	0.00	-2.01	-2.11	-2.83	-3.30	-3.89	-10.10	0.00	-3.90	-4.10	-4.99	-5.66	-6.35	-11.07
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-1,724.06	-1,966.75	-2,303.79	-2,542.50	-2,790.29	-5,045.49	0.00	-4,262.97	-4,683.09	-5,122.40	-5,509.83	-5,779.04	-7,037.64
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-163.84	-187.06	-218.81	-241.32	-264.62	-475.82	0.00	-406.05	-446.22	-487.64	-524.27	-549.52	-666.30
Imperial Co., CA	x	-	100	-	0.00	-3.29	-3.47	-4.65	-5.42	-6.38	-16.58	0.00	-6.39	-6.72	-8.18	-9.28	-10.42	-18.17
Indianapolis, IN	-	x	-	100	0.00	-18.56	-19.56	-26.20	-30.56	-35.97	-93.50	0.00	-36.04	-37.93	-46.17	-52.37	-58.80	-102.51
Jamestown, NY	x	-	100	-	0.00	-1.28	-1.35	-1.81	-2.11	-2.48	-6.44	0.00	-2.48	-2.61	-3.18	-3.61	-4.05	-7.06
Jefferson Co., NY	x	-	100	-	0.00	-1.57	-1.66	-2.22	-2.59	-3.05	-7.92	0.00	-3.06	-3.22	-3.91	-4.44	-4.98	-8.69
Johnstown, PA	-	x	-	100	0.00	-0.95	-1.00	-1.34	-1.57	-1.84	-4.79	0.00	-1.85	-1.95	-2.37	-2.69	-3.02	-5.25
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-1.99	-2.12	-2.78	-3.22	-3.75	-9.36	0.00	-4.02	-4.26	-5.09	-5.72	-6.35	-10.53
Knoxville, TN	x	x	100	100	0.00	-11.42	-12.03	-16.13	-18.81	-22.14	-57.55	0.00	-22.18	-23.33	-28.40	-32.22	-36.18	-63.09
Lancaster, PA	-	x	-	100	0.00	-4.05	-4.27	-5.72	-6.67	-7.85	-20.41	0.00	-7.87	-8.28	-10.08	-11.43	-12.84	-22.38
Las Vegas, NV	x	-	100	-	0.00	-23.87	-25.13	-33.70	-39.33	-46.30	-120.57	0.00	-46.26	-48.65	-59.28	-67.27	-75.57	-132.04
Libby, MT	-	x	-	100	0.00	-0.07	-0.07	-0.10	-0.11	-0.13	-0.34	0.00	-0.13	-0.14	-0.17	-0.19	-0.21	-0.37
Liberty-Clairton, PA	-	x	-	100	0.00	-0.10	-0.10	-0.13	-0.16	-0.18	-0.47	0.00	-0.19	-0.20	-0.24	-0.27	-0.31	-0.52
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-1,075.62	-1,214.13	-1,448.45	-1,611.65	-1,788.08	-3,460.09	0.00	-2,581.04	-2,822.10	-3,124.15	-3,382.05	-3,578.17	-4,603.81
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-9.61	-10.14	-13.54	-15.77	-18.54	-47.88	0.00	-18.78	-19.78	-24.00	-27.18	-30.47	-52.70
Louisville, KY-IN	-	x	-	100	0.00	-9.70	-10.21	-13.70	-16.00	-18.84	-49.15	0.00	-18.76	-19.73	-24.06	-27.32	-30.70	-53.77
Macon, GA	-	x	-	100	0.00	-1.82	-1.91	-2.57	-3.00	-3.53	-9.23	0.00	-3.51	-3.69	-4.50	-5.11	-5.75	-10.09
Manitowoc Co., WI	x	-		-	0.00	-0.93	-0.98	-1.31	-1.52	-1.79	-4.65	0.00	-1.80	-1.90	-2.31	-2.61	-2.93	-5.11
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-1.51	-1.59	-2.14	-2.49	-2.93	-7.62	0.00	-2.94	-3.09	-3.76	-4.27	-4.79	-8.35
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-6.43	-6.77	-9.08	-10.59	-12.46	-32.39	0.00	-12.48	-13.14	-15.99	-18.14	-20.37	-35.51
Memphis, TN-AR	x	-	100	-	0.00	-139.01	-158.20	-186.08	-205.74	-226.36	-415.92	0.00	-341.43	-374.69	-410.93	-442.64	-465.17	-573.66
Milwaukee-Racine, WI	x	-	100	-	0.00	-16.04	-16.90	-22.63	-26.40	-31.07	-80.74	0.00	-31.14	-32.77	-39.89	-45.24	-50.80	-88.53
Nevada (Western Part), CA	x	-	100	-	0.00	-1.13	-1.19	-1.59	-1.86	-2.19	-5.68	0.00	-2.19	-2.31	-2.81	-3.19	-3.58	-6.23
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-362.67	-402.86	-494.01	-556.24	-626.76	-1,324.34	0.00	-830.59	-901.23	-1,017.20	-1,112.33	-1,192.68	-1,659.91
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-1.28	-1.35	-1.81	-2.11	-2.48	-6.46	0.00	-2.48	-2.61	-3.18	-3.61	-4.05	-7.07
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-928.88	-1,055.99	-1,244.38	-1,377.02	-1,516.70	-2,806.69	0.00	-2,274.56	-2,494.96	-2,739.56	-2,952.87	-3,105.88	-3,851.97

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					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-60.75	-63.94	-85.80	-100.14	-117.94	-307.48	0.00	-117.57	-123.63	-150.72	-171.10	-192.28	-336.49
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-15.57	-16.41	-21.98	-25.64	-30.18	-78.48	0.00	-30.23	-31.81	-38.72	-43.93	-49.33	-86.03
Poughkeepsie, NY	x	x	100	100	0.00	-13.75	-14.48	-19.41	-22.63	-26.64	-69.24	0.00	-26.69	-28.09	-34.19	-38.78	-43.55	-75.91
Providence (All RI), RI	x	-	100	-	0.00	-8.26	-8.71	-11.67	-13.61	-16.01	-41.62	0.00	-16.05	-16.89	-20.55	-23.31	-26.18	-45.63
Reading, PA	-	x	-	100	0.00	-4.06	-4.28	-5.73	-6.68	-7.86	-20.44	0.00	-7.88	-8.29	-10.09	-11.45	-12.85	-22.41
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-16.58	-17.48	-23.39	-27.27	-32.08	-83.19	0.00	-32.27	-33.98	-41.31	-46.83	-52.54	-91.34
Rochester, NY	x	-	100	-	0.00	-11.95	-12.59	-16.87	-19.68	-23.16	-60.20	0.00	-23.21	-24.42	-29.73	-33.72	-37.86	-66.00
Rome, GA	-	x	-	100	0.00	-1.00	-1.05	-1.41	-1.65	-1.94	-5.04	0.00	-1.94	-2.05	-2.49	-2.82	-3.17	-5.53
Sacramento Metro, CA	x	-	50	-	0.00	-27.43	-28.91	-38.72	-45.16	-53.14	-138.05	0.00	-53.29	-56.08	-68.24	-77.40	-86.90	-151.40
San Diego, CA	x	-	100	-	0.00	-26.78	-28.22	-37.81	-44.10	-51.90	-134.90	0.00	-52.00	-54.72	-66.61	-75.55	-84.84	-147.90
San Francisco Bay Area, CA	x	-	100	-	0.00	-539.52	-611.51	-724.36	-803.44	-887.69	-1,674.75	0.00	-1,309.94	-1,434.95	-1,581.01	-1,707.22	-1,800.11	-2,267.74
San Joaquin Valley, CA	x	x	50	100	0.00	-143.29	-158.16	-196.04	-221.72	-251.27	-547.36	0.00	-322.07	-348.36	-396.34	-435.17	-469.10	-672.27
Sheboygan, WI	x	-	100	-	0.00	-1.14	-1.20	-1.61	-1.87	-2.21	-5.73	0.00	-2.21	-2.33	-2.83	-3.21	-3.61	-6.28
Springfield (Western MA), MA	x	-	100	-	0.00	-8.87	-9.35	-12.52	-14.61	-17.19	-44.69	0.00	-17.23	-18.13	-22.06	-25.03	-28.10	-48.99
St. Louis, MO-IL	x	x	100	100	0.00	-250.24	-283.63	-335.98	-372.66	-411.74	-776.85	0.00	-607.56	-665.54	-733.29	-791.83	-834.92	-1,051.88
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-15.28	-17.40	-20.44	-22.58	-24.82	-45.36	0.00	-37.61	-41.29	-45.24	-48.70	-51.15	-62.80
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-7.87	-8.48	-10.95	-12.60	-14.59	-35.23	0.00	-16.40	-17.49	-20.59	-22.99	-25.32	-40.46
Washington, DC-MD-VA	x	x	100	100	0.00	-57.06	-60.13	-80.52	-93.91	-110.50	-286.95	0.00	-110.89	-116.70	-141.99	-161.03	-180.76	-314.78
Wheeling, WV-OH	-	x	-	100	0.00	-1.36	-1.44	-1.93	-2.25	-2.64	-6.87	0.00	-2.65	-2.79	-3.39	-3.85	-4.32	-7.53
York, PA	-	x	-	100	0.00	-4.72	-4.97	-6.66	-7.77	-9.14	-23.75	0.00	-9.16	-9.64	-11.73	-13.31	-14.94	-26.04

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-85
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-32.66	-39.53	-64.83	-75.19	-93.80	-265.80	0.00	-32.72	-39.59	-64.89	-75.26	-93.87	-265.84
Allegan Co., MI	x	-	100	-	0.00	-3.57	-4.32	-7.09	-8.23	-10.26	-29.07	0.00	-3.58	-4.33	-7.10	-8.23	-10.27	-29.08
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-3.25	-3.93	-6.45	-7.48	-9.33	-26.44	0.00	-3.25	-3.94	-6.46	-7.49	-9.34	-26.44
Atlanta, GA	x	x	100	100	0.00	-173.59	-210.12	-344.60	-399.72	-498.62	-1,413.03	0.00	-173.91	-210.46	-344.95	-400.08	-499.00	-1,413.25
Baltimore, MD	x	x	100	100	0.00	-72.29	-87.50	-143.47	-166.42	-207.58	-588.12	0.00	-72.42	-87.65	-143.62	-166.57	-207.74	-588.21
Baton Rouge, LA	x	-	100	-	0.00	-34.60	-42.04	-64.70	-74.77	-92.37	-245.09	0.00	-34.67	-42.12	-64.77	-74.85	-92.46	-245.14
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-46.28	-56.34	-83.83	-96.69	-118.81	-303.10	0.00	-46.37	-56.45	-83.94	-96.80	-118.92	-303.16
Birmingham, AL	-	x	-	100	0.00	-26.33	-31.87	-52.28	-60.65	-75.65	-214.45	0.00	-26.38	-31.92	-52.34	-60.70	-75.71	-214.48
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-117.52	-142.25	-233.26	-270.56	-337.50	-956.30	0.00	-117.73	-142.48	-233.49	-270.81	-337.76	-956.45
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-15.47	-18.72	-30.80	-35.74	-44.60	-126.77	0.00	-15.50	-18.75	-30.83	-35.77	-44.63	-126.79
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-28.26	-34.20	-56.09	-65.06	-81.15	-229.94	0.00	-28.31	-34.26	-56.14	-65.12	-81.21	-229.98
Canton-Massillon, OH	-	x	-	100	0.00	-10.37	-12.58	-20.07	-23.25	-28.88	-79.66	0.00	-10.39	-12.60	-20.09	-23.27	-28.90	-79.67
Charleston, WV	-	x	-	100	0.00	-7.56	-9.15	-15.01	-17.41	-21.72	-61.54	0.00	-7.57	-9.17	-15.02	-17.43	-21.73	-61.55
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-42.77	-51.74	-85.55	-99.27	-123.98	-354.06	0.00	-42.84	-51.82	-85.63	-99.36	-124.08	-354.12
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-13.37	-16.18	-26.58	-30.83	-38.47	-109.14	0.00	-13.40	-16.21	-26.60	-30.86	-38.49	-109.16
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-202.13	-244.88	-395.98	-458.95	-571.32	-1,596.96	0.00	-202.51	-245.29	-396.39	-459.38	-571.77	-1,597.22
Chico, CA	x	-	100	-	0.00	-4.88	-5.91	-9.69	-11.24	-14.03	-39.74	0.00	-4.89	-5.92	-9.70	-11.25	-14.04	-39.75
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-46.38	-56.14	-92.16	-106.90	-133.37	-378.30	0.00	-46.47	-56.23	-92.25	-107.00	-133.47	-378.36
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-4.42	-5.36	-8.78	-10.19	-12.71	-36.01	0.00	-4.43	-5.36	-8.79	-10.20	-12.72	-36.01
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-67.40	-81.59	-133.79	-155.19	-193.58	-548.52	0.00	-67.53	-81.72	-133.93	-155.33	-193.73	-548.61
Columbus, OH	x	x	100	100	0.00	-43.54	-52.70	-86.43	-100.25	-125.05	-354.38	0.00	-43.62	-52.79	-86.51	-100.34	-125.15	-354.43
Dallas-Fort Worth, TX	x	-	100	-	0.00	-176.45	-213.58	-350.26	-406.28	-506.80	-1,436.13	0.00	-176.77	-213.93	-350.61	-406.65	-507.18	-1,436.36
Dayton-Springfield, OH	-	x	-	100	0.00	-20.43	-24.73	-40.55	-47.04	-58.68	-166.28	0.00	-20.47	-24.77	-40.60	-47.08	-58.72	-166.31
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-84.70	-102.56	-167.47	-194.22	-242.12	-683.31	0.00	-84.86	-102.72	-167.65	-194.39	-242.30	-683.42
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-126.23	-152.83	-249.86	-289.77	-361.31	-1,020.83	0.00	-126.47	-153.08	-250.12	-290.04	-361.58	-1,021.00
Door Co., WI	x	-	100	-	0.00	-0.83	-1.00	-1.65	-1.91	-2.38	-6.75	0.00	-0.83	-1.01	-1.65	-1.91	-2.38	-6.75
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.03	-0.04	-0.07	-0.08	-0.10	-0.28	0.00	-0.03	-0.04	-0.07	-0.08	-0.10	-0.28
Evansville, IN	-	x	-	100	0.00	-8.33	-10.08	-16.64	-19.30	-24.10	-68.69	0.00	-8.35	-10.10	-16.65	-19.32	-24.12	-68.70
Greater Connecticut, CT	x	-	100	-	0.00	-44.81	-54.25	-88.93	-103.15	-128.66	-364.46	0.00	-44.90	-54.34	-89.02	-103.24	-128.76	-364.52
Greene Co., PA	x	-	100	-	0.00	-1.03	-1.24	-2.04	-2.36	-2.95	-8.35	0.00	-1.03	-1.24	-2.04	-2.36	-2.95	-8.35
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-20.20	-24.45	-40.10	-46.52	-58.03	-164.44	0.00	-20.24	-24.49	-40.15	-46.56	-58.07	-164.46

Table B2-85
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-18.31	-22.16	-36.34	-42.15	-52.58	-148.99	0.00	-18.34	-22.19	-36.37	-42.19	-52.62	-149.01
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.12	-0.15	-0.25	-0.29	-0.36	-1.01	0.00	-0.12	-0.15	-0.25	-0.29	-0.36	-1.01
Hickory, NC	-	x	-	100	0.00	-4.75	-5.75	-9.43	-10.94	-13.65	-38.68	0.00	-4.76	-5.76	-9.44	-10.95	-13.66	-38.68
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-203.42	-246.90	-387.38	-448.21	-555.41	-1,505.19	0.00	-203.81	-247.32	-387.80	-448.65	-555.87	-1,505.46
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-16.45	-19.96	-31.45	-36.40	-45.14	-122.89	0.00	-16.48	-19.99	-31.49	-36.44	-45.17	-122.91
Imperial Co., CA	x	-	100	-	0.00	-5.63	-6.82	-11.18	-12.97	-16.18	-45.85	0.00	-5.64	-6.83	-11.19	-12.98	-16.19	-45.86
Indianapolis, IN	-	x	-	100	0.00	-40.65	-49.21	-80.70	-93.61	-116.77	-330.89	0.00	-40.73	-49.29	-80.78	-93.69	-116.86	-330.94
Jamestown, NY	x	-	100	-	0.00	-3.76	-4.55	-7.47	-8.66	-10.80	-30.61	0.00	-3.77	-4.56	-7.47	-8.67	-10.81	-30.61
Jefferson Co., NY	x	-	100	-	0.00	-3.49	-4.23	-6.94	-8.05	-10.04	-28.44	0.00	-3.50	-4.24	-6.94	-8.05	-10.04	-28.44
Johnstown, PA	-	x	-	100	0.00	-3.09	-3.74	-6.13	-7.11	-8.87	-25.14	0.00	-3.10	-3.75	-6.14	-7.12	-8.88	-25.14
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-3.12	-3.77	-6.15	-7.13	-8.89	-25.03	0.00	-3.12	-3.78	-6.15	-7.14	-8.89	-25.03
Knoxville, TN	x	x	100	100	0.00	-27.59	-33.40	-54.78	-63.54	-79.27	-224.65	0.00	-27.64	-33.46	-54.84	-63.60	-79.33	-224.69
Lancaster, PA	-	x	-	100	0.00	-10.80	-13.07	-21.43	-24.86	-31.01	-87.88	0.00	-10.82	-13.09	-21.46	-24.88	-31.04	-87.90
Las Vegas, NV	x	-	100	-	0.00	-35.68	-43.19	-70.85	-82.19	-102.53	-290.61	0.00	-35.75	-43.26	-70.93	-82.26	-102.60	-290.65
Libby, MT	-	x	-	100	0.00	-0.18	-0.21	-0.35	-0.41	-0.51	-1.44	0.00	-0.18	-0.21	-0.35	-0.41	-0.51	-1.44
Liberty-Clairton, PA	-	x	-	100	0.00	-0.36	-0.43	-0.70	-0.82	-1.02	-2.88	0.00	-0.36	-0.43	-0.71	-0.82	-1.02	-2.88
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-413.37	-500.72	-811.74	-940.96	-1,171.79	-3,283.65	0.00	-414.14	-501.55	-812.58	-941.83	-1,172.70	-3,284.18
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-18.51	-22.41	-36.73	-42.61	-53.15	-150.53	0.00	-18.55	-22.45	-36.77	-42.65	-53.19	-150.55
Louisville, KY-IN	-	x	-	100	0.00	-27.93	-33.80	-55.54	-64.43	-80.39	-228.23	0.00	-27.98	-33.86	-55.60	-64.49	-80.45	-228.26
Macon, GA	-	x	-	100	0.00	-5.19	-6.28	-10.32	-11.98	-14.94	-42.44	0.00	-5.20	-6.29	-10.33	-11.99	-14.95	-42.44
Manitowoc Co., WI	x	-		-	0.00	-2.72	-3.30	-5.40	-6.27	-7.82	-22.14	0.00	-2.73	-3.30	-5.41	-6.27	-7.82	-22.14
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-2.65	-3.20	-5.25	-6.09	-7.60	-21.54	0.00	-2.65	-3.21	-5.26	-6.10	-7.61	-21.54
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-10.35	-12.53	-20.55	-23.83	-29.73	-84.25	0.00	-10.37	-12.55	-20.57	-23.85	-29.75	-84.26
Memphis, TN-AR	x	-	100	-	0.00	-30.84	-37.38	-59.94	-69.44	-86.33	-239.26	0.00	-30.90	-37.45	-60.00	-69.50	-86.40	-239.30
Milwaukee-Racine, WI	x	-	100	-	0.00	-44.53	-53.90	-88.39	-102.52	-127.88	-362.35	0.00	-44.61	-53.99	-88.47	-102.61	-127.98	-362.40
Nevada (Western Part), CA	x	-	100	-	0.00	-2.52	-3.05	-5.00	-5.80	-7.23	-20.49	0.00	-2.52	-3.05	-5.00	-5.80	-7.24	-20.49
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-376.69	-456.06	-745.43	-864.49	-1,077.86	-3,044.60	0.00	-377.39	-456.81	-746.19	-865.28	-1,078.68	-3,045.08
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-3.98	-4.82	-7.91	-9.18	-11.45	-32.47	0.00	-3.99	-4.83	-7.92	-9.19	-11.46	-32.48
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-213.00	-258.17	-414.28	-479.96	-596.79	-1,655.48	0.00	-213.40	-258.60	-414.72	-480.41	-597.26	-1,655.76

Table B2-85
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VOCs 2015

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-98.06	-118.69	-194.96	-226.16	-282.18	-800.89	0.00	-98.24	-118.88	-195.15	-226.36	-282.40	-801.02
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-49.67	-60.12	-98.61	-114.38	-142.68	-404.38	0.00	-49.76	-60.22	-98.71	-114.48	-142.79	-404.44
Poughkeepsie, NY	x	x	100	100	0.00	-32.24	-39.03	-64.00	-74.24	-92.60	-262.40	0.00	-32.30	-39.09	-64.06	-74.30	-92.67	-262.45
Providence (All RI), RI	x	-	100	-	0.00	-23.33	-28.24	-46.31	-53.72	-67.01	-189.87	0.00	-23.37	-28.29	-46.36	-53.77	-67.06	-189.90
Reading, PA	-	x	-	100	0.00	-9.47	-11.47	-18.80	-21.81	-27.21	-77.10	0.00	-9.49	-11.49	-18.82	-21.83	-27.23	-77.11
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-18.86	-22.83	-37.42	-43.41	-54.14	-153.38	0.00	-18.89	-22.87	-37.46	-43.45	-54.19	-153.40
Rochester, NY	x	-	100	-	0.00	-32.67	-39.55	-64.85	-75.22	-93.84	-265.90	0.00	-32.73	-39.61	-64.92	-75.29	-93.91	-265.94
Rome, GA	-	x	-	100	0.00	-2.86	-3.46	-5.67	-6.58	-8.20	-23.25	0.00	-2.86	-3.46	-5.68	-6.58	-8.21	-23.25
Sacramento Metro, CA	x	-	50	-	0.00	-54.83	-66.37	-108.86	-126.27	-157.52	-446.39	0.00	-54.94	-66.48	-108.97	-126.39	-157.63	-446.46
San Diego, CA	x	-	100	-	0.00	-76.81	-92.98	-152.48	-176.87	-220.63	-625.21	0.00	-76.96	-93.13	-152.64	-177.03	-220.80	-625.31
San Francisco Bay Area, CA	x	-	100	-	0.00	-183.76	-222.57	-361.36	-418.92	-521.81	-1,464.41	0.00	-184.10	-222.94	-361.73	-419.31	-522.21	-1,464.64
San Joaquin Valley, CA	x	x	50	100	0.00	-115.26	-139.55	-228.06	-264.48	-329.75	-931.32	0.00	-115.47	-139.78	-228.29	-264.72	-330.00	-931.47
Sheboygan, WI	x	-	100	-	0.00	-3.04	-3.68	-6.04	-7.00	-8.73	-24.74	0.00	-3.05	-3.69	-6.04	-7.01	-8.74	-24.74
Springfield (Western MA), MA	x	-	100	-	0.00	-23.45	-28.38	-46.54	-53.99	-67.35	-190.84	0.00	-23.49	-28.43	-46.59	-54.04	-67.40	-190.87
St. Louis, MO-IL	x	x	100	100	0.00	-87.78	-106.35	-171.97	-199.31	-248.12	-693.54	0.00	-87.94	-106.52	-172.15	-199.50	-248.31	-693.65
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-3.36	-4.07	-6.53	-7.56	-9.40	-26.04	0.00	-3.37	-4.08	-6.54	-7.57	-9.41	-26.05
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-16.20	-19.61	-32.14	-37.28	-46.49	-131.67	0.00	-16.23	-19.64	-32.17	-37.31	-46.53	-131.69
Washington, DC-MD-VA	x	x	100	100	0.00	-123.89	-149.97	-245.83	-285.15	-355.68	-1,007.46	0.00	-124.12	-150.22	-246.08	-285.40	-355.94	-1,007.62
Wheeling, WV-OH	-	x	-	100	0.00	-4.30	-5.21	-8.54	-9.90	-12.35	-35.00	0.00	-4.31	-5.21	-8.55	-9.91	-12.36	-35.01
York, PA	-	x	-	100	0.00	-10.01	-12.12	-19.88	-23.06	-28.76	-81.49	0.00	-10.03	-12.14	-19.90	-23.08	-28.78	-81.51

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-86
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-113.97	-121.85	-188.85	-218.95	-268.15	-780.87	0.00	-151.31	-161.36	-231.31	-263.81	-315.77	-796.45
Allegan Co., MI	x	-	100	-	0.00	-12.46	-13.32	-20.65	-23.94	-29.32	-85.39	0.00	-16.55	-17.64	-25.29	-28.85	-34.53	-87.09
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-12.07	-12.91	-20.00	-23.19	-28.40	-82.70	0.00	-16.03	-17.09	-24.50	-27.94	-33.45	-84.35
Atlanta, GA	x	x	100	100	0.00	-660.32	-705.97	-1,094.24	-1,268.67	-1,553.76	-4,524.91	0.00	-876.59	-934.82	-1,340.17	-1,528.49	-1,829.63	-4,615.13
Baltimore, MD	x	x	100	100	0.00	-250.95	-268.32	-415.78	-482.04	-590.32	-1,718.70	0.00	-333.22	-355.38	-509.32	-580.86	-695.23	-1,753.08
Baton Rouge, LA	x	-	100	-	0.00	-115.78	-126.16	-182.18	-209.19	-251.70	-681.39	0.00	-162.31	-175.84	-234.12	-263.37	-308.23	-707.36
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-149.39	-164.51	-228.07	-260.33	-309.78	-798.23	0.00	-215.65	-235.52	-301.46	-336.48	-388.63	-839.06
Birmingham, AL	-	x	-	100	0.00	-89.28	-95.45	-147.98	-171.58	-210.15	-612.17	0.00	-118.50	-126.36	-181.21	-206.68	-247.42	-624.33
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-393.02	-420.21	-651.21	-755.00	-924.62	-2,692.32	0.00	-521.80	-556.49	-797.65	-909.71	-1,088.88	-2,746.10
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-53.69	-57.35	-89.19	-103.45	-126.79	-370.35	0.00	-71.09	-75.76	-108.99	-124.39	-149.04	-377.47
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-93.94	-100.43	-155.64	-180.45	-220.99	-643.49	0.00	-124.72	-133.01	-190.65	-217.43	-260.25	-656.34
Canton-Massillon, OH	-	x	-	100	0.00	-34.26	-36.94	-55.50	-64.09	-77.90	-220.11	0.00	-46.60	-50.06	-69.42	-78.69	-93.28	-226.12
Charleston, WV	-	x	-	100	0.00	-24.64	-26.34	-40.82	-47.33	-57.97	-168.80	0.00	-32.71	-34.88	-50.00	-57.03	-68.26	-172.17
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-162.63	-173.52	-270.90	-314.38	-385.69	-1,130.74	0.00	-214.63	-228.49	-330.19	-377.12	-452.44	-1,151.48
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-45.45	-48.59	-75.32	-87.33	-106.97	-311.57	0.00	-60.32	-64.32	-92.24	-105.21	-125.94	-317.77
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-690.37	-741.11	-1,131.75	-1,309.58	-1,598.16	-4,588.72	0.00	-927.39	-992.50	-1,400.05	-1,592.16	-1,896.93	-4,695.92
Chico, CA	x	-	100	-	0.00	-16.90	-18.07	-28.01	-32.47	-39.77	-115.82	0.00	-22.44	-23.93	-34.31	-39.13	-46.83	-118.13
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-158.54	-169.45	-262.91	-304.86	-373.46	-1,088.64	0.00	-210.29	-224.20	-321.78	-367.07	-439.53	-1,110.10
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-14.41	-15.40	-23.87	-27.68	-33.90	-98.70	0.00	-19.13	-20.40	-29.24	-33.35	-39.92	-100.68
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-223.18	-238.61	-369.80	-428.74	-525.07	-1,528.93	0.00	-296.30	-315.99	-452.95	-516.58	-618.33	-1,559.46
Columbus, OH	x	x	100	100	0.00	-154.17	-164.83	-255.48	-296.20	-362.76	-1,056.43	0.00	-204.67	-218.27	-312.90	-356.87	-427.18	-1,077.50
Dallas-Fort Worth, TX	x	-	100	-	0.00	-654.76	-700.03	-1,084.97	-1,257.91	-1,540.57	-4,486.24	0.00	-869.24	-927.00	-1,328.87	-1,515.59	-1,814.15	-4,575.76
Dayton-Springfield, OH	-	x	-	100	0.00	-67.85	-72.54	-112.43	-130.35	-159.64	-464.88	0.00	-90.07	-96.06	-137.70	-157.05	-187.99	-474.15
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-303.04	-324.38	-500.54	-579.99	-709.57	-2,057.76	0.00	-403.73	-431.01	-614.88	-700.68	-837.54	-2,100.87
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-424.14	-453.89	-701.08	-812.46	-994.20	-2,885.88	0.00	-564.63	-602.64	-860.66	-980.93	-1,172.90	-2,945.70
Door Co., WI	x	-	100	-	0.00	-2.75	-2.94	-4.56	-5.29	-6.48	-18.86	0.00	-3.65	-3.90	-5.59	-6.37	-7.63	-19.23
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.11	-0.12	-0.19	-0.22	-0.27	-0.79	0.00	-0.15	-0.16	-0.23	-0.27	-0.32	-0.81
Evansville, IN	-	x	-	100	0.00	-28.60	-30.53	-47.61	-55.24	-67.75	-198.43	0.00	-37.78	-40.23	-58.07	-66.31	-79.53	-202.12
Greater Connecticut, CT	x	-	100	-	0.00	-153.67	-164.32	-254.57	-295.13	-361.41	-1,052.05	0.00	-204.08	-217.66	-311.88	-355.67	-425.68	-1,073.14
Greene Co., PA	x	-	100	-	0.00	-3.28	-3.51	-5.44	-6.31	-7.73	-22.50	0.00	-4.36	-4.65	-6.66	-7.60	-9.10	-22.94
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-69.47	-74.27	-115.12	-133.47	-163.46	-476.00	0.00	-92.23	-98.36	-141.00	-160.81	-192.48	-485.50

Table B2-86
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Emission Changes a/ by Nonattainment Area

VOCs 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-62.02	-66.31	-102.77	-119.15	-145.93	-424.94	0.00	-82.34	-87.81	-125.88	-143.57	-171.85	-433.42
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.42	-0.45	-0.70	-0.81	-0.99	-2.90	0.00	-0.56	-0.59	-0.85	-0.97	-1.17	-2.95
Hickory, NC	-	x	-	100	0.00	-16.64	-17.80	-27.57	-31.97	-39.15	-113.98	0.00	-22.10	-23.57	-33.78	-38.52	-46.11	-116.26
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-688.66	-746.07	-1,101.30	-1,268.47	-1,535.00	-4,257.50	0.00	-949.68	-1,024.13	-1,394.12	-1,574.99	-1,856.33	-4,393.41
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-54.23	-58.70	-86.91	-100.14	-121.27	-337.42	0.00	-74.61	-80.41	-109.79	-124.11	-146.42	-347.92
Imperial Co., CA	x	-	100	-	0.00	-21.40	-22.88	-35.46	-41.11	-50.34	-146.60	0.00	-28.41	-30.29	-43.43	-49.53	-59.28	-149.53
Indianapolis, IN	-	x	-	100	0.00	-143.61	-153.54	-237.98	-275.91	-337.90	-984.00	0.00	-190.66	-203.32	-291.47	-332.42	-397.91	-1,003.64
Jamestown, NY	x	-	100	-	0.00	-12.48	-13.34	-20.67	-23.97	-29.35	-85.48	0.00	-16.57	-17.67	-25.32	-28.88	-34.57	-87.18
Jefferson Co., NY	x	-	100	-	0.00	-12.44	-13.30	-20.61	-23.89	-29.26	-85.18	0.00	-16.51	-17.61	-25.24	-28.78	-34.45	-86.89
Johnstown, PA	-	x	-	100	0.00	-10.00	-10.69	-16.57	-19.21	-23.52	-68.47	0.00	-13.28	-14.17	-20.30	-23.15	-27.71	-69.84
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-12.08	-12.95	-19.86	-22.99	-28.08	-80.95	0.00	-16.17	-17.29	-24.50	-27.88	-33.26	-82.77
Knoxville, TN	x	x	100	100	0.00	-96.02	-102.66	-159.13	-184.49	-225.96	-658.08	0.00	-127.46	-135.93	-194.88	-222.27	-266.07	-671.20
Lancaster, PA	-	x	-	100	0.00	-36.72	-39.25	-60.84	-70.54	-86.39	-251.56	0.00	-48.74	-51.98	-74.52	-84.99	-101.73	-256.58
Las Vegas, NV	x	-	100	-	0.00	-140.21	-149.88	-232.41	-269.47	-330.06	-961.57	0.00	-186.06	-198.40	-284.56	-324.58	-388.57	-980.66
Libby, MT	-	x	-	100	0.00	-0.61	-0.65	-1.00	-1.16	-1.42	-4.15	0.00	-0.80	-0.86	-1.23	-1.40	-1.68	-4.23
Liberty-Clairton, PA	-	x	-	100	0.00	-1.11	-1.19	-1.84	-2.13	-2.61	-7.56	0.00	-1.48	-1.58	-2.26	-2.57	-3.08	-7.72
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-1,459.53	-1,565.69	-2,397.21	-2,774.84	-3,388.44	-9,753.70	0.00	-1,956.59	-2,092.67	-2,960.29	-3,368.21	-4,016.25	-9,975.57
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-67.93	-72.65	-112.48	-130.39	-159.65	-464.45	0.00	-90.26	-96.29	-137.87	-157.20	-188.11	-473.83
Louisville, KY-IN	-	x	-	100	0.00	-93.14	-99.52	-154.56	-179.24	-219.62	-640.77	0.00	-123.44	-131.58	-189.05	-215.69	-258.35	-653.27
Macon, GA	-	x	-	100	0.00	-17.36	-18.55	-28.82	-33.42	-40.96	-119.56	0.00	-23.00	-24.51	-35.24	-40.21	-48.17	-121.88
Manitowoc Co., WI	x	-		-	0.00	-9.03	-9.66	-14.96	-17.35	-21.24	-61.81	0.00	-12.00	-12.80	-18.34	-20.91	-25.02	-63.05
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-9.98	-10.68	-16.54	-19.18	-23.49	-68.39	0.00	-13.26	-14.14	-20.26	-23.11	-27.66	-69.76
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-39.77	-42.52	-65.91	-76.41	-93.58	-272.53	0.00	-52.80	-56.31	-80.72	-92.07	-110.20	-277.96
Memphis, TN-AR	x	-	100	-	0.00	-102.33	-110.17	-166.45	-192.33	-234.10	-665.11	0.00	-138.62	-148.72	-207.40	-235.37	-279.48	-682.36
Milwaukee-Racine, WI	x	-	100	-	0.00	-149.59	-159.94	-247.86	-287.36	-351.92	-1,024.69	0.00	-198.61	-211.82	-303.60	-346.25	-414.44	-1,045.16
Nevada (Western Part), CA	x	-	100	-	0.00	-8.95	-9.57	-14.83	-17.19	-21.05	-61.30	0.00	-11.88	-12.67	-18.16	-20.72	-24.80	-62.53
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-1,266.72	-1,355.69	-2,093.38	-2,425.87	-2,968.33	-8,613.87	0.00	-1,686.69	-1,800.37	-2,570.37	-2,929.40	-3,502.37	-8,792.97
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-13.03	-13.93	-21.61	-25.05	-30.69	-89.43	0.00	-17.29	-18.44	-26.45	-30.17	-36.13	-91.20
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-727.77	-783.18	-1,185.28	-1,369.85	-1,668.06	-4,747.19	0.00	-984.56	-1,055.87	-1,475.20	-1,674.69	-1,989.58	-4,868.36

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VOCs 2020

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-378.23	-404.19	-627.56	-727.76	-891.65	-2,600.82	0.00	-501.42	-534.51	-767.72	-875.89	-1,049.02	-2,651.69
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-161.24	-172.38	-267.21	-309.81	-379.44	-1,105.13	0.00	-214.02	-228.23	-327.24	-373.23	-446.78	-1,127.14
Poughkeepsie, NY	x	x	100	100	0.00	-113.15	-120.97	-187.49	-217.37	-266.22	-775.23	0.00	-150.21	-160.20	-229.64	-261.90	-313.50	-790.70
Providence (All RI), RI	x	-	100	-	0.00	-78.17	-83.57	-129.52	-150.17	-183.90	-535.52	0.00	-103.78	-110.67	-158.64	-180.93	-216.57	-546.21
Reading, PA	-	x	-	100	0.00	-33.30	-35.60	-55.17	-63.97	-78.34	-228.12	0.00	-44.20	-47.14	-67.57	-77.07	-92.25	-232.68
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-79.33	-84.83	-131.39	-152.32	-186.52	-542.85	0.00	-105.37	-112.39	-161.00	-183.60	-219.72	-553.76
Rochester, NY	x	-	100	-	0.00	-110.30	-117.93	-182.78	-211.91	-259.53	-755.75	0.00	-146.44	-156.17	-223.87	-255.32	-305.62	-770.83
Rome, GA	-	x	-	100	0.00	-9.55	-10.21	-15.82	-18.34	-22.46	-65.42	0.00	-12.68	-13.52	-19.38	-22.10	-26.45	-66.72
Sacramento Metro, CA	x	-	50	-	0.00	-199.04	-212.80	-329.83	-382.40	-468.32	-1,363.80	0.00	-264.24	-281.80	-403.97	-460.73	-551.49	-1,391.01
San Diego, CA	x	-	100	-	0.00	-256.44	-274.17	-424.93	-492.67	-603.37	-1,757.06	0.00	-340.44	-363.06	-520.45	-593.58	-710.51	-1,792.12
San Francisco Bay Area, CA	x	-	100	-	0.00	-619.15	-664.03	-1,017.55	-1,177.97	-1,438.75	-4,144.82	0.00	-829.45	-886.96	-1,255.84	-1,429.13	-1,704.55	-4,238.29
San Joaquin Valley, CA	x	x	50	100	0.00	-431.12	-461.34	-712.68	-825.93	-1,010.72	-2,934.21	0.00	-573.85	-612.47	-874.82	-997.10	-1,192.29	-2,994.94
Sheboygan, WI	x	-	100	-	0.00	-10.34	-11.05	-17.12	-19.85	-24.31	-70.75	0.00	-13.73	-14.64	-20.98	-23.92	-28.63	-72.17
Springfield (Western MA), MA	x	-	100	-	0.00	-79.88	-85.40	-132.36	-153.46	-187.94	-547.31	0.00	-106.04	-113.09	-162.12	-184.90	-221.32	-558.23
St. Louis, MO-IL	x	x	100	100	0.00	-294.26	-315.97	-482.07	-557.75	-680.50	-1,952.14	0.00	-395.58	-423.44	-596.73	-678.48	-808.12	-1,998.17
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-10.78	-11.61	-17.52	-20.24	-24.62	-69.86	0.00	-14.62	-15.69	-21.85	-24.79	-29.42	-71.70
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventura Co., CA	x	-	100	-	0.00	-54.61	-58.40	-90.44	-104.85	-128.39	-373.61	0.00	-72.54	-77.38	-110.83	-126.38	-151.25	-381.13
Washington, DC-MD-VA	x	x	100	100	0.00	-435.53	-465.71	-721.46	-836.40	-1,024.22	-2,981.26	0.00	-578.43	-616.94	-883.92	-1,008.02	-1,206.41	-3,041.07
Wheeling, WV-OH	-	x	-	100	0.00	-14.02	-14.99	-23.23	-26.93	-32.98	-96.04	0.00	-18.61	-19.84	-28.45	-32.45	-38.84	-97.96
York, PA	-	x	-	100	0.00	-36.04	-38.53	-59.72	-69.23	-84.79	-246.90	0.00	-47.84	-51.02	-73.14	-83.42	-99.85	-251.83

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-87
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-196.61	-201.47	-317.42	-370.39	-453.20	-1,365.29	0.00	-291.09	-300.62	-426.30	-487.19	-579.44	-1,395.59
Allegan Co., MI	x	-	100	-	0.00	-21.48	-22.01	-34.68	-40.46	-49.51	-149.15	0.00	-31.80	-32.84	-46.57	-53.22	-63.30	-152.46
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-22.17	-22.72	-35.79	-41.77	-51.10	-153.93	0.00	-32.83	-33.91	-48.08	-54.94	-65.34	-157.36
Atlanta, GA	x	x	100	100	0.00	-1,255.08	-1,286.06	-2,026.33	-2,364.53	-2,893.19	-8,716.53	0.00	-1,857.98	-1,918.77	-2,721.24	-3,109.96	-3,698.93	-8,909.76
Baltimore, MD	x	x	100	100	0.00	-430.78	-441.47	-695.37	-811.39	-992.73	-2,990.07	0.00	-637.97	-658.91	-934.14	-1,067.49	-1,269.51	-3,056.68
Baton Rouge, LA	x	-	100	-	0.00	-192.50	-203.04	-294.79	-339.25	-406.89	-1,130.86	0.00	-314.39	-332.67	-431.44	-482.71	-557.73	-1,193.80
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-238.52	-256.07	-352.89	-402.25	-475.65	-1,241.71	0.00	-412.36	-441.93	-545.50	-602.56	-683.67	-1,345.49
Birmingham, AL	-	x	-	100	0.00	-150.45	-154.15	-242.95	-283.52	-346.93	-1,045.53	0.00	-222.63	-229.89	-326.16	-372.78	-443.43	-1,068.59
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-651.49	-667.61	-1,051.73	-1,227.23	-1,501.56	-4,523.23	0.00	-964.64	-996.26	-1,412.64	-1,614.37	-1,919.99	-4,623.76
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-92.02	-94.18	-148.89	-173.84	-212.87	-643.25	0.00	-135.64	-139.92	-199.24	-227.91	-271.40	-656.75
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-154.26	-158.08	-249.04	-290.59	-355.55	-1,071.03	0.00	-228.42	-235.91	-334.50	-382.26	-454.63	-1,094.83
Canton-Massillon, OH	-	x	-	100	0.00	-55.91	-58.05	-88.18	-102.28	-124.08	-361.40	0.00	-86.62	-90.50	-123.07	-139.30	-163.54	-374.36
Charleston, WV	-	x	-	100	0.00	-39.70	-40.68	-64.09	-74.79	-91.51	-275.69	0.00	-58.77	-60.70	-86.08	-98.37	-117.00	-281.81
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-305.66	-312.47	-495.55	-578.87	-709.35	-2,149.32	0.00	-448.71	-462.37	-660.93	-756.67	-902.08	-2,192.10
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-76.34	-78.26	-123.18	-143.71	-175.80	-529.16	0.00	-113.17	-116.91	-165.60	-189.20	-224.95	-541.08
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-1,174.45	-1,210.35	-1,877.08	-2,184.71	-2,663.37	-7,910.77	0.00	-1,773.73	-1,841.30	-2,563.21	-2,917.01	-3,449.87	-8,131.32
Chico, CA	x	-	100	-	0.00	-28.90	-29.62	-46.66	-54.45	-66.63	-200.72	0.00	-42.79	-44.19	-62.67	-71.62	-85.19	-205.17
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-271.50	-278.08	-438.65	-511.96	-626.58	-1,889.66	0.00	-401.33	-414.30	-588.37	-672.63	-800.34	-1,930.79
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-23.18	-23.75	-37.42	-43.66	-53.42	-160.93	0.00	-34.32	-35.44	-50.26	-57.43	-68.31	-164.51
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-365.40	-374.44	-589.89	-688.33	-842.20	-2,537.07	0.00	-541.01	-558.74	-792.29	-905.44	-1,076.86	-2,593.43
Columbus, OH	x	x	100	100	0.00	-271.18	-277.88	-437.82	-510.89	-625.11	-1,883.29	0.00	-401.46	-414.60	-587.98	-671.97	-799.22	-1,925.05
Dallas-Fort Worth, TX	x	-	100	-	0.00	-1,209.86	-1,239.75	-1,953.26	-2,279.24	-2,788.79	-8,401.63	0.00	-1,791.16	-1,849.80	-2,623.25	-2,997.93	-3,565.61	-8,588.03
Dayton-Springfield, OH	-	x	-	100	0.00	-111.32	-114.07	-179.72	-209.72	-256.60	-773.04	0.00	-164.81	-170.20	-241.37	-275.85	-328.08	-790.19
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-539.12	-553.39	-867.75	-1,011.79	-1,236.64	-3,709.94	0.00	-802.99	-830.59	-1,171.25	-1,336.84	-1,587.28	-3,798.48
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-705.14	-723.60	-1,135.53	-1,324.18	-1,618.74	-4,859.54	0.00	-1,049.24	-1,085.03	-1,531.43	-1,748.31	-2,076.40	-4,974.19
Door Co., WI	x	-	100	-	0.00	-4.51	-4.62	-7.28	-8.50	-10.40	-31.33	0.00	-6.68	-6.90	-9.78	-11.18	-13.30	-32.03
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.19	-0.19	-0.31	-0.36	-0.44	-1.34	0.00	-0.28	-0.29	-0.41	-0.47	-0.56	-1.36
Evansville, IN	-	x	-	100	0.00	-48.50	-49.58	-78.63	-91.85	-112.55	-340.98	0.00	-71.21	-73.38	-104.88	-120.07	-143.14	-347.78
Greater Connecticut, CT	x	-	100	-	0.00	-260.36	-266.84	-420.22	-490.31	-599.86	-1,806.46	0.00	-385.67	-398.36	-564.62	-645.19	-767.24	-1,846.82
Greene Co., PA	x	-	100	-	0.00	-5.19	-5.32	-8.38	-9.78	-11.97	-36.05	0.00	-7.69	-7.94	-11.26	-12.86	-15.30	-36.85
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-118.02	-120.94	-190.54	-222.34	-272.04	-819.57	0.00	-174.72	-180.44	-255.89	-292.44	-347.82	-837.75

Table B2-87
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-103.84	-106.41	-167.65	-195.63	-239.36	-721.08	0.00	-153.74	-158.78	-225.16	-257.32	-306.04	-737.08
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-0.70	-0.72	-1.14	-1.33	-1.63	-4.95	0.00	-1.03	-1.07	-1.52	-1.74	-2.08	-5.05
Hickory, NC	-	x	-	100	0.00	-28.78	-29.50	-46.46	-54.22	-66.33	-199.79	0.00	-42.63	-44.03	-62.42	-71.33	-84.83	-204.24
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-1,162.13	-1,214.67	-1,810.34	-2,092.96	-2,527.06	-7,221.87	0.00	-1,841.68	-1,934.84	-2,577.70	-2,903.24	-3,385.48	-7,538.05
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-88.43	-92.40	-137.82	-159.36	-192.44	-550.41	0.00	-140.00	-147.05	-196.08	-220.88	-257.64	-574.32
Imperial Co., CA	x	-	100	-	0.00	-40.15	-41.14	-64.81	-75.63	-92.54	-278.78	0.00	-59.43	-61.38	-87.04	-99.48	-118.31	-284.96
Indianapolis, IN	-	x	-	100	0.00	-252.39	-258.63	-407.48	-475.48	-581.78	-1,752.71	0.00	-373.66	-385.89	-547.25	-625.41	-743.84	-1,791.59
Jamestown, NY	x	-	100	-	0.00	-20.45	-20.95	-33.01	-38.52	-47.13	-141.97	0.00	-30.27	-31.27	-44.33	-50.67	-60.26	-145.12
Jefferson Co., NY	x	-	100	-	0.00	-21.86	-22.40	-35.29	-41.18	-50.38	-151.77	0.00	-32.37	-33.43	-47.40	-54.17	-64.43	-155.15
Johnstown, PA	-	x	-	100	0.00	-15.99	-16.39	-25.81	-30.11	-36.84	-110.91	0.00	-23.69	-24.47	-34.68	-39.63	-47.12	-113.40
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-23.01	-23.72	-36.76	-42.78	-52.14	-154.78	0.00	-34.78	-36.11	-50.23	-57.16	-67.58	-159.14
Knoxville, TN	x	x	100	100	0.00	-165.22	-169.29	-266.76	-311.29	-380.89	-1,147.63	0.00	-244.56	-252.55	-358.21	-409.39	-486.94	-1,173.03
Lancaster, PA	-	x	-	100	0.00	-61.67	-63.20	-99.56	-116.18	-142.15	-428.25	0.00	-91.31	-94.30	-133.72	-152.82	-181.75	-437.75
Las Vegas, NV	x	-	100	-	0.00	-272.19	-278.84	-439.64	-513.08	-627.88	-1,892.78	0.00	-402.60	-415.68	-590.00	-674.40	-802.31	-1,934.30
Libby, MT	-	x	-	100	0.00	-1.02	-1.05	-1.65	-1.92	-2.36	-7.10	0.00	-1.51	-1.56	-2.22	-2.53	-3.01	-7.25
Liberty-Clairton, PA	-	x	-	100	0.00	-1.72	-1.76	-2.76	-3.22	-3.93	-11.76	0.00	-2.57	-2.66	-3.73	-4.26	-5.05	-12.05
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-2,567.66	-2,643.79	-4,110.33	-4,785.92	-5,837.89	-17,379.25	0.00	-3,865.83	-4,009.89	-5,598.12	-6,375.02	-7,546.25	-17,847.82
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-123.45	-126.59	-199.06	-232.21	-283.99	-854.07	0.00	-183.23	-189.35	-267.89	-306.00	-363.68	-873.61
Louisville, KY-IN	-	x	-	100	0.00	-153.52	-157.18	-248.20	-289.73	-354.69	-1,070.66	0.00	-226.62	-233.87	-332.55	-380.28	-452.65	-1,093.57
Macon, GA	-	x	-	100	0.00	-28.69	-29.37	-46.41	-54.18	-66.34	-200.37	0.00	-42.31	-43.66	-62.13	-71.06	-84.61	-204.61
Manitowoc Co., WI	x	-		-	0.00	-14.80	-15.17	-23.88	-27.86	-34.09	-102.62	0.00	-21.94	-22.66	-32.10	-36.68	-43.61	-104.92
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-18.62	-19.08	-30.06	-35.08	-42.92	-129.27	0.00	-27.57	-28.48	-40.38	-46.14	-54.88	-132.15
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-75.69	-77.56	-122.19	-142.58	-174.46	-525.59	0.00	-112.05	-115.72	-164.10	-187.54	-223.06	-537.25
Memphis, TN-AR	x	-	100	-	0.00	-167.81	-173.82	-265.77	-308.60	-374.95	-1,099.02	0.00	-257.90	-268.91	-368.37	-417.65	-491.47	-1,135.59
Milwaukee-Racine, WI	x	-	100	-	0.00	-248.53	-254.68	-401.20	-468.15	-572.79	-1,725.41	0.00	-368.01	-380.07	-538.90	-615.85	-732.43	-1,763.77
Nevada (Western Part), CA	x	-	100	-	0.00	-15.72	-16.11	-25.37	-29.60	-36.22	-109.09	0.00	-23.28	-24.04	-34.08	-38.95	-46.32	-111.52
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-2,105.37	-2,160.77	-3,389.71	-3,952.66	-4,831.54	-14,500.31	0.00	-3,134.10	-3,241.35	-4,573.13	-5,220.29	-6,199.24	-14,844.09
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-21.06	-21.57	-34.02	-39.70	-48.59	-146.49	0.00	-31.15	-32.16	-45.65	-52.18	-62.08	-149.70
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-1,231.72	-1,274.52	-1,954.38	-2,270.42	-2,760.46	-8,113.20	0.00	-1,886.42	-1,965.24	-2,700.73	-3,064.35	-3,609.57	-8,374.14

Table B2-87
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2025

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-720.64	-737.92	-1,164.88	-1,359.71	-1,664.43	-5,022.84	0.00	-1,064.24	-1,098.37	-1,561.25	-1,785.17	-2,124.68	-5,130.88
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-258.82	-265.20	-417.91	-487.67	-596.72	-1,798.00	0.00	-383.09	-395.60	-561.14	-641.33	-762.82	-1,837.77
Poughkeepsie, NY	x	x	100	100	0.00	-196.20	-201.05	-316.75	-369.61	-452.24	-1,362.41	0.00	-290.48	-299.99	-425.41	-486.17	-578.23	-1,392.65
Providence (All RI), RI	x	-	100	-	0.00	-129.40	-132.60	-208.90	-243.76	-298.26	-898.49	0.00	-191.59	-197.86	-280.58	-320.65	-381.35	-918.44
Reading, PA	-	x	-	100	0.00	-57.81	-59.24	-93.33	-108.90	-133.25	-401.42	0.00	-85.58	-88.39	-125.34	-143.24	-170.36	-410.33
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-164.79	-168.92	-265.89	-310.21	-379.48	-1,142.27	0.00	-244.27	-252.35	-357.45	-408.40	-485.57	-1,168.00
Rochester, NY	x	-	100	-	0.00	-184.06	-188.61	-297.15	-346.74	-424.26	-1,278.10	0.00	-272.50	-281.42	-399.08	-456.08	-542.44	-1,306.47
Rome, GA	-	x	-	100	0.00	-15.77	-16.16	-25.45	-29.70	-36.34	-109.49	0.00	-23.34	-24.11	-34.19	-39.07	-46.47	-111.92
Sacramento Metro, CA	x	-	50	-	0.00	-358.39	-367.26	-578.57	-675.11	-826.02	-2,488.30	0.00	-530.65	-548.04	-777.10	-888.07	-1,056.20	-2,543.59
San Diego, CA	x	-	100	-	0.00	-422.90	-433.35	-682.75	-796.70	-974.81	-2,936.78	0.00	-626.08	-646.58	-916.94	-1,047.91	-1,246.34	-3,001.93
San Francisco Bay Area, CA	x	-	100	-	0.00	-1,031.58	-1,062.20	-1,651.24	-1,922.62	-2,345.16	-6,980.83	0.00	-1,553.32	-1,611.26	-2,249.17	-2,561.24	-3,031.69	-7,169.31
San Joaquin Valley, CA	x	x	50	100	0.00	-798.33	-819.01	-1,286.26	-1,500.14	-1,834.18	-5,510.17	0.00	-1,186.72	-1,226.88	-1,733.27	-1,979.15	-2,351.23	-5,638.62
Sheboygan, WI	x	-	100	-	0.00	-17.35	-17.78	-27.99	-32.66	-39.96	-120.33	0.00	-25.70	-26.55	-37.62	-42.99	-51.12	-123.02
Springfield (Western MA), MA	x	-	100	-	0.00	-134.44	-137.77	-217.05	-253.28	-309.90	-933.62	0.00	-199.04	-205.56	-291.50	-333.14	-396.22	-954.33
St. Louis, MO-IL	x	x	100	100	0.00	-488.95	-504.34	-780.24	-907.75	-1,105.99	-3,277.63	0.00	-740.70	-769.52	-1,068.20	-1,214.86	-1,435.52	-3,372.00
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-17.09	-17.71	-27.01	-31.35	-38.06	-111.28	0.00	-26.35	-27.49	-37.55	-42.54	-50.01	-115.10
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Ventura Co., CA	x	-	100	-	0.00	-90.94	-93.22	-146.74	-171.21	-209.45	-630.51	0.00	-134.79	-139.24	-197.26	-225.38	-267.98	-644.69
Washington, DC-MD-VA	x	x	100	100	0.00	-765.17	-784.24	-1,234.91	-1,440.88	-1,762.78	-5,308.05	0.00	-1,133.61	-1,170.94	-1,659.45	-1,896.20	-2,254.82	-5,426.84
Wheeling, WV-OH	-	x	-	100	0.00	-22.57	-23.13	-36.44	-42.52	-52.03	-156.75	0.00	-33.42	-34.51	-48.94	-55.93	-66.52	-160.23
York, PA	-	x	-	100	0.00	-64.07	-65.66	-103.44	-120.70	-147.68	-444.89	0.00	-94.86	-97.97	-138.92	-158.76	-188.82	-454.77

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-88
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Albany-Schenectady-Troy, NY	x	-	100	-	0.00	-322.11	-316.77	-497.95	-591.61	-735.24	-2,301.72	0.00	-476.03	-475.54	-683.53	-798.16	-968.09	-2,320.27
Allegan Co., MI	x	-	100	-	0.00	-35.05	-34.47	-54.18	-64.37	-80.00	-250.45	0.00	-51.79	-51.74	-74.37	-86.84	-105.34	-252.46
Amador and Calavaras Cos. (Central Mountain Cos.), CA	x	-	100	-	0.00	-41.16	-40.48	-63.62	-75.59	-93.94	-294.05	0.00	-60.83	-60.78	-87.34	-101.99	-123.70	-296.43
Atlanta, GA	x	x	100	100	0.00	-2,562.73	-2,520.17	-3,961.82	-4,707.08	-5,849.92	-18,314.51	0.00	-3,786.96	-3,782.97	-5,437.94	-6,350.02	-7,702.20	-18,461.62
Baltimore, MD	x	x	100	100	0.00	-699.41	-687.89	-1,081.10	-1,284.38	-1,596.10	-4,995.74	0.00	-1,034.09	-1,033.15	-1,484.53	-1,733.32	-2,102.12	-5,036.50
Baton Rouge, LA	x	-	100	-	0.00	-302.27	-308.90	-448.46	-522.32	-633.18	-1,826.22	0.00	-519.60	-538.52	-696.28	-786.51	-916.25	-1,922.49
Beaumont/Port Arthur, TX	x	-	100	-	0.00	-344.03	-361.77	-493.93	-565.70	-670.93	-1,786.15	0.00	-655.26	-693.76	-840.54	-928.04	-1,049.67	-1,964.82
Birmingham, AL	-	x	-	100	0.00	-239.40	-235.39	-370.16	-439.82	-546.65	-1,711.90	0.00	-353.55	-353.12	-507.83	-593.09	-719.49	-1,725.40
Boston-Lawrence-Worcester (E. MA), MA	x	-	100	-	0.00	-990.89	-974.50	-1,531.76	-1,819.85	-2,261.62	-7,079.72	0.00	-1,464.62	-1,463.17	-2,102.89	-2,455.46	-2,978.14	-7,137.00
Boston-Manchester-Portsmouth (SE), NH	x	-	100	-	0.00	-148.29	-145.62	-229.56	-272.92	-339.46	-1,065.40	0.00	-217.88	-217.32	-313.72	-366.79	-445.53	-1,072.57
Buffalo-Niagara Falls, NY	x	-	100	-	0.00	-228.60	-224.81	-353.37	-419.83	-521.74	-1,633.22	0.00	-337.89	-337.56	-485.14	-566.47	-687.05	-1,646.44
Canton-Massillon, OH	-	x	-	100	0.00	-82.50	-82.66	-125.09	-147.24	-180.91	-545.98	0.00	-131.45	-133.85	-182.24	-209.34	-248.98	-561.03
Charleston, WV	-	x	-	100	0.00	-56.85	-55.91	-87.89	-104.42	-129.77	-406.26	0.00	-84.02	-83.93	-120.64	-140.87	-170.87	-409.53
Charlotte-Gastonia-Rock Hill, NC-SC	x	-	100	-	0.00	-594.96	-584.01	-921.48	-1,095.78	-1,363.27	-4,282.27	0.00	-872.52	-869.83	-1,257.45	-1,470.78	-1,787.41	-4,309.23
Chattanooga, AL-TN-GA	-	x	-	100	0.00	-118.71	-116.93	-183.22	-217.52	-270.08	-843.05	0.00	-176.58	-176.70	-252.77	-294.74	-356.91	-851.12
Chicago-Gary-Lake Co., IL-IN	x	x	100	100	0.00	-1,929.38	-1,908.47	-2,964.71	-3,512.37	-4,349.91	-13,469.23	0.00	-2,920.75	-2,936.27	-4,146.47	-4,816.56	-5,806.14	-13,655.39
Chico, CA	x	-	100	-	0.00	-46.43	-45.66	-71.78	-85.28	-105.99	-331.80	0.00	-68.62	-68.55	-98.53	-115.05	-139.55	-334.47
Cincinnati-Hamilton, OH-KY-IN	x	x	100	100	0.00	-454.57	-446.80	-703.10	-835.56	-1,038.74	-3,255.01	0.00	-670.32	-669.23	-963.51	-1,125.63	-1,366.05	-3,279.59
Clearfield and Indiana Cos., PA	x	-	100	-	0.00	-32.95	-32.41	-50.94	-60.52	-75.22	-235.46	0.00	-48.71	-48.66	-69.94	-81.66	-99.04	-237.36
Cleveland-Akron-Lorain, OH	x	x	100	100	0.00	-539.77	-530.83	-834.41	-991.35	-1,232.00	-3,856.73	0.00	-797.78	-796.98	-1,145.47	-1,337.54	-1,622.28	-3,887.89
Columbus, OH	x	x	100	100	0.00	-469.56	-461.77	-725.91	-862.46	-1,071.86	-3,355.66	0.00	-693.89	-693.16	-996.39	-1,163.51	-1,411.26	-3,382.64
Dallas-Fort Worth, TX	x	-	100	-	0.00	-2,327.44	-2,288.82	-3,598.02	-4,274.81	-5,312.65	-16,631.97	0.00	-3,439.50	-3,435.93	-4,938.84	-5,767.13	-6,995.07	-16,765.82
Dayton-Springfield, OH	-	x	-	100	0.00	-164.69	-161.96	-254.59	-302.48	-375.92	-1,176.86	0.00	-243.38	-243.13	-349.47	-408.08	-494.97	-1,186.33
Denver-Boulder-Greeley-Ft. Collins, CO (EAC)	x	-	100	-	0.00	-958.46	-944.43	-1,478.67	-1,755.12	-2,178.67	-6,795.53	0.00	-1,428.13	-1,429.77	-2,042.67	-2,380.98	-2,881.87	-6,863.33
Detroit-Ann Arbor, MI	x	x	100	100	0.00	-1,076.95	-1,061.18	-1,661.49	-1,972.12	-2,448.05	-7,635.84	0.00	-1,604.65	-1,606.49	-2,295.18	-2,675.32	-3,238.16	-7,711.98
Door Co., WI	x	-	100	-	0.00	-6.66	-6.55	-10.30	-12.24	-15.21	-47.60	0.00	-9.85	-9.84	-14.14	-16.51	-20.02	-47.98
Essex Co., NY (Whiteface Mountain)	x	-	100	-	0.00	-0.29	-0.28	-0.45	-0.53	-0.66	-2.09	0.00	-0.42	-0.42	-0.61	-0.71	-0.87	-2.10
Evansville, IN	-	x	-	100	0.00	-76.59	-75.13	-118.73	-141.23	-175.79	-552.97	0.00	-111.96	-111.52	-161.61	-189.16	-230.07	-556.04
Greater Connecticut, CT	x	-	100	-	0.00	-410.85	-404.11	-635.01	-754.39	-937.43	-2,933.68	0.00	-607.66	-607.16	-872.20	-1,018.30	-1,234.86	-2,957.85
Greene Co., PA	x	-	100	-	0.00	-7.13	-7.01	-11.02	-13.09	-16.27	-50.94	0.00	-10.53	-10.52	-15.13	-17.66	-21.42	-51.35
Greensboro-Winston Salem-High Point, NC	-	x	-	100	0.00	-187.18	-184.08	-289.37	-343.80	-427.27	-1,337.62	0.00	-276.62	-276.33	-397.20	-463.82	-562.57	-1,348.38

Table B2-88
High Scenario Alternative CAFE Standards
Emission Changes a/ by Nonattainment Area

VOCs 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Harrisburg-Lebanon-Carlisle, PA	-	x	-	100	0.00	-160.09	-157.44	-247.48	-294.03	-365.41	-1,143.93	0.00	-236.60	-236.35	-339.72	-396.69	-481.15	-1,153.16
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	x	-	100	-	0.00	-1.10	-1.07	-1.71	-2.03	-2.54	-8.02	0.00	-1.59	-1.58	-2.31	-2.70	-3.30	-8.04
Hickory, NC	-	x	-	100	0.00	-47.30	-46.52	-73.12	-86.86	-107.95	-337.87	0.00	-69.94	-69.87	-100.40	-117.23	-142.17	-340.62
Houston-Galveston-Brazoria, TX	x	-	100	-	0.00	-1,893.43	-1,909.99	-2,849.52	-3,342.27	-4,088.01	-12,155.06	0.00	-3,098.57	-3,175.50	-4,243.96	-4,846.32	-5,722.76	-12,589.02
Huntington-Ashland, WV-KY-OH	-	x	-	100	0.00	-131.07	-132.60	-196.64	-230.29	-281.13	-830.47	0.00	-216.89	-222.85	-295.59	-336.71	-396.41	-863.10
Imperial Co., CA	x	-	100	-	0.00	-77.64	-76.35	-120.03	-142.60	-177.23	-554.83	0.00	-114.74	-114.62	-164.76	-192.39	-233.35	-559.29
Indianapolis, IN	-	x	-	100	0.00	-437.94	-430.67	-677.02	-804.37	-999.65	-3,129.55	0.00	-647.19	-646.52	-929.31	-1,085.17	-1,316.22	-3,154.73
Jamestown, NY	x	-	100	-	0.00	-30.17	-29.67	-46.63	-55.41	-68.86	-215.55	0.00	-44.59	-44.54	-64.02	-74.75	-90.67	-217.29
Jefferson Co., NY	x	-	100	-	0.00	-37.12	-36.51	-57.38	-68.17	-84.72	-265.19	0.00	-54.87	-54.82	-78.78	-91.98	-111.56	-267.34
Johnstown, PA	-	x	-	100	0.00	-22.45	-22.08	-34.69	-41.20	-51.20	-160.16	0.00	-33.23	-33.21	-47.67	-55.65	-67.47	-161.51
Kern Co. (Eastern Kern), CA	x	-	100	-	0.00	-45.45	-45.21	-69.43	-82.03	-101.24	-310.04	0.00	-70.39	-71.18	-98.87	-114.28	-136.95	-316.14
Knoxville, TN	x	x	100	100	0.00	-269.53	-265.05	-416.70	-495.09	-615.31	-1,926.50	0.00	-398.23	-397.79	-571.89	-667.83	-810.07	-1,941.91
Lancaster, PA	-	x	-	100	0.00	-95.59	-94.01	-147.78	-175.57	-218.20	-683.09	0.00	-141.27	-141.13	-202.85	-236.87	-287.31	-688.60
Las Vegas, NV	x	-	100	-	0.00	-563.85	-554.22	-872.12	-1,036.41	-1,288.41	-4,037.28	0.00	-831.52	-830.20	-1,195.19	-1,396.27	-1,694.46	-4,067.83
Libby, MT	-	x	-	100	0.00	-1.60	-1.57	-2.47	-2.94	-3.65	-11.43	0.00	-2.36	-2.36	-3.39	-3.96	-4.81	-11.52
Liberty-Clairton, PA	-	x	-	100	0.00	-2.23	-2.21	-3.44	-4.07	-5.04	-15.65	0.00	-3.37	-3.39	-4.79	-5.57	-6.72	-15.85
Los Angeles South Coast Air Basin, CA	x	x	25	100	0.00	-4,502.35	-4,452.76	-6,919.64	-8,198.58	-10,154.65	-31,453.87	0.00	-6,810.88	-6,845.78	-9,672.38	-11,237.26	-13,548.52	-31,882.98
Los Angeles-San Bernardino Cos (W Mojave Desert), CA	x	-	100	-	0.00	-225.50	-222.16	-347.96	-413.05	-512.79	-1,599.99	0.00	-335.76	-336.08	-480.41	-560.06	-678.01	-1,615.67
Louisville, KY-IN	-	x	-	100	0.00	-229.49	-225.45	-355.13	-422.14	-524.94	-1,646.46	0.00	-337.71	-336.97	-485.90	-567.90	-689.56	-1,658.11
Macon, GA	-	x	-	100	0.00	-43.05	-42.27	-66.65	-79.24	-98.57	-309.41	0.00	-63.22	-63.05	-91.05	-106.47	-129.34	-311.46
Manitowoc Co., WI	x	-		-	0.00	-21.83	-21.47	-33.73	-40.07	-49.79	-155.75	0.00	-32.31	-32.29	-46.36	-54.11	-65.61	-157.06
Mariposa and Tuolumne Cos. (Southern Mountain Cos.), CA	x	-	100	-	0.00	-35.69	-35.10	-55.16	-65.54	-81.45	-254.95	0.00	-52.75	-52.70	-75.74	-88.43	-107.25	-257.01
Martinsburg, WV-Hagerstown, MD	-	x	-	100	0.00	-151.69	-149.18	-234.51	-278.62	-346.26	-1,084.02	0.00	-224.17	-223.94	-321.90	-375.88	-455.91	-1,092.74
Memphis, TN-AR	x	-	100	-	0.00	-249.68	-249.29	-379.93	-448.01	-551.65	-1,676.77	0.00	-392.46	-398.31	-547.49	-630.77	-752.92	-1,716.53
Milwaukee-Racine, WI	x	-	100	-	0.00	-378.24	-371.99	-584.69	-694.65	-863.26	-2,702.26	0.00	-559.11	-558.56	-802.73	-937.31	-1,136.81	-2,724.17
Nevada (Western Part), CA	x	-	100	-	0.00	-26.62	-26.19	-41.15	-48.89	-60.75	-190.13	0.00	-39.37	-39.34	-56.52	-65.99	-80.02	-191.69
New York-N. New Jersey-Long Island, NY-NJ-CT	x	x	100	100	0.00	-3,202.95	-3,156.56	-4,940.54	-5,863.76	-7,278.10	-22,694.43	0.00	-4,775.69	-4,782.04	-6,828.55	-7,958.33	-9,630.90	-22,924.47
Parkersburg-Marietta, WV-OH	-	x	-	100	0.00	-30.21	-29.70	-46.73	-55.53	-69.02	-216.24	0.00	-44.58	-44.51	-64.06	-74.83	-90.80	-217.90
Philadelphia-Wilmington, Atlantic City, PA-DE-MD-	x	x	100	100	0.00	-1,963.60	-1,955.90	-2,995.32	-3,536.30	-4,360.77	-13,318.42	0.00	-3,057.67	-3,096.07	-4,284.05	-4,945.78	-5,918.20	-13,599.98

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Emission Changes a/ by Nonattainment Area

VOCs 2035

Nonattainment Area	Status b/		General Conformity Threshold c/		Emission Changes for Proposed Alternatives (tons/year)							Emission Changes for Cumulative Impacts (tons/year)						
					Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	O3	PM2.5	O3	PM2.5	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
NJ																		
Phoenix-Mesa, AZ	x	-	100	-	0.00	-1,436.42	-1,411.37	-2,222.54	-2,641.69	-3,284.70	-10,299.48	0.00	-2,115.14	-2,110.92	-3,042.37	-3,555.37	-4,316.30	-10,373.86
Pittsburgh-Beaver Valley, PA	x	x	100	100	0.00	-367.49	-361.36	-568.15	-675.05	-838.98	-2,626.95	0.00	-542.89	-542.27	-779.67	-910.50	-1,104.46	-2,647.88
Poughkeepsie, NY	x	x	100	100	0.00	-324.32	-318.94	-501.36	-595.67	-740.28	-2,317.51	0.00	-479.30	-478.81	-688.22	-803.64	-974.74	-2,336.19
Providence (All RI), RI	x	-	100	-	0.00	-194.94	-191.71	-301.36	-358.04	-444.96	-1,392.93	0.00	-288.12	-287.83	-413.70	-483.07	-585.90	-1,404.18
Reading, PA	-	x	-	100	0.00	-95.73	-94.15	-147.99	-175.83	-218.52	-684.09	0.00	-141.48	-141.33	-203.15	-237.22	-287.72	-689.60
Riverside Co., CA (Coachella Valley)	x	-	100	-	0.00	-390.44	-384.22	-603.17	-716.40	-889.97	-2,782.73	0.00	-578.60	-578.43	-829.73	-968.29	-1,173.63	-2,806.93
Rochester, NY	x	-	100	-	0.00	-281.97	-277.30	-435.90	-517.89	-643.62	-2,014.91	0.00	-416.72	-416.29	-598.36	-698.71	-847.47	-2,031.15
Rome, GA	-	x	-	100	0.00	-23.62	-23.23	-36.52	-43.39	-53.92	-168.80	0.00	-34.91	-34.87	-50.12	-58.53	-70.99	-170.16
Sacramento Metro, CA	x	-	50	-	0.00	-646.90	-636.25	-999.91	-1,187.91	-1,476.20	-4,620.27	0.00	-956.54	-955.69	-1,373.13	-1,603.22	-1,944.30	-4,658.06
San Diego, CA	x	-	100	-	0.00	-631.87	-621.38	-976.81	-1,160.55	-1,442.32	-4,515.41	0.00	-933.76	-932.78	-1,340.81	-1,565.68	-1,899.05	-4,551.73
San Francisco Bay Area, CA	x	-	100	-	0.00	-1,581.79	-1,566.30	-2,427.91	-2,874.90	-3,558.14	-10,995.03	0.00	-2,404.95	-2,420.43	-3,407.26	-3,954.16	-4,761.22	-11,158.90
San Joaquin Valley, CA	x	x	50	100	0.00	-1,514.02	-1,490.44	-2,338.06	-2,776.46	-3,448.42	-10,775.08	0.00	-2,247.08	-2,247.33	-3,220.03	-3,756.55	-4,551.39	-10,872.59
Sheboygan, WI	x	-	100	-	0.00	-26.84	-26.41	-41.49	-49.28	-61.24	-191.62	0.00	-39.71	-39.69	-57.00	-66.54	-80.68	-193.21
Springfield (Western MA), MA	x	-	100	-	0.00	-209.30	-205.83	-323.57	-384.43	-477.76	-1,495.70	0.00	-309.31	-308.99	-444.15	-518.63	-629.06	-1,507.74
St. Louis, MO-IL	x	x	100	100	0.00	-752.21	-746.37	-1,152.10	-1,362.82	-1,684.59	-5,184.76	0.00	-1,153.23	-1,163.14	-1,627.50	-1,885.30	-2,265.18	-5,273.05
Steubenville-Weirton, OH-WV	-	x	-	100	0.00	-23.74	-23.76	-36.03	-42.43	-52.16	-157.72	0.00	-37.69	-38.35	-52.34	-60.17	-71.63	-161.90
Sutter County (Sutter Buttes), CA	x	-	100	-	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01
Ventura Co., CA	x	-	100	-	0.00	-138.59	-136.35	-214.16	-254.39	-316.07	-988.73	0.00	-205.18	-205.07	-294.37	-343.61	-416.58	-997.09
Washington, DC-MD-VA	x	x	100	100	0.00	-1,345.11	-1,323.12	-2,078.87	-2,469.61	-3,068.72	-9,602.56	0.00	-1,989.90	-1,988.40	-2,855.90	-3,334.10	-4,042.91	-9,682.19
Wheeling, WV-OH	-	x	-	100	0.00	-32.18	-31.65	-49.75	-59.11	-73.45	-229.96	0.00	-47.56	-47.51	-68.29	-79.74	-96.72	-231.81
York, PA	-	x	-	100	0.00	-111.26	-109.42	-172.00	-204.35	-253.96	-795.02	0.00	-164.44	-164.27	-236.11	-275.70	-334.40	-801.43

a/ Reductions are shown as negative values. Positive values are emission increases. Values of less than 0.005 tons/year are rounded to zero.
b/ Pollutants for which the area is designated nonattainment or maintenance as of 2008. Source: 40 CFR 81.
c/ Emissions thresholds in tons/year of: VOCs or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the proposed actions. (See section 3.3.1.)
EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S. Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed June 12, 2008.

Table B2-89

Mid-1 Scenario Alternative CAFE Standards
Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions from Passenger Cars and Light Trucks (cases/year)

Health Outcome and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Mortality (ages 30 and older)							
2015	0 a/	-27 b/	-35	-39	-40	-54	-101
2020	0	-91	-106	-113	-116	-145	-277
2025	0	-145	-164	-175	-177	-219	-418
2035	0	-206	-231	-246	-248	-304	-592
Chronic Bronchitis							
2015	0	-23	-31	-34	-35	-47	-88
2020	0	-79	-92	-99	-101	-126	-241
2025	0	-126	-143	-152	-154	-190	-363
2035	0	-179	-201	-214	-216	-265	-515
Emergency Room Visits for Asthma							
2015	0	-6	-7	-8	-8	-11	-21
2020	0	-19	-22	-24	-24	-30	-58
2025	0	-30	-34	-37	-37	-46	-87
2035	0	-43	-48	-51	-52	-63	-124
Work Loss Days							
2015	0	-4,786	-6,286	-6,869	-7,214	-9,579	-18,055
2020	0	-16,252	-18,887	-20,226	-20,632	-25,842	-49,452
2025	0	-25,777	-29,269	-31,195	-31,616	-38,995	-74,497
2035	0	-36,751	-41,123	-43,781	-44,239	-54,224	-105,514

a/ Changes in health outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.
b/ Negative changes indicate reductions; positive emissions changes are increases.

Table B2-90

Mid-1 Scenario Alternative CAFE Standards
Nationwide Changes in Health Costs from Criteria Pollutant Emissions
from Passenger Cars and Light Trucks (US million dollars/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
2015	0 a/	-44 b/	-54	-66	-77	-98	-223
2020	0	-219	-250	-292	-320	-409	-990
2025	0	-375	-416	-485	-524	-694	-1,808
2035	0	-580	-628	-730	-775	-1,074	-2,985

a/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.
b/ Negative changes indicate economic benefit; positive emissions changes are economic costs.

Table B2-91

Mid-1 Scenario Alternative CAFE Standards
Nationwide Changes in Health Outcomes from Criteria Air Pollutant Emissions
from Passenger Cars and Light Trucks – Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards (cases/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Health Outcome and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Mortality (ages 30 and older)							
2015	0 a/	-27 b/	-35	-39	-41	-54	-101
2020	0	-149	-168	-175	-177	-209	-300
2025	0	-297	-326	-336	-336	-385	-470
2035	0	-484	-527	-540	-537	-608	-682
Chronic Bronchitis							
2015	0	-23	-31	-34	-35	-47	-88
2020	0	-130	-146	-152	-154	-182	-261
2025	0	-258	-283	-292	-292	-335	-408
2035	0	-421	-458	-470	-467	-528	-593
Emergency Room Visits for Asthma							
2015	0	-6	-7	-8	-8	-11	-21
2020	0	-31	-35	-37	-37	-44	-63
2025	0	-62	-68	-70	-70	-80	-98
2035	0	-101	-110	-113	-112	-127	-142
Work Loss Days							
2015	0	-4,804	-6,305	-6,889	-7,235	-9,601	-18,070
2020	0	-26,583	-29,884	-31,209	-31,481	-37,220	-53,440
2025	0	-52,861	-58,086	-59,891	-59,835	-68,617	-83,728
2035	0	-86,346	-93,877	-96,257	-95,754	-108,319	-121,611

a/ Changes in health outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.
b/ Negative changes indicate reductions; positive emissions changes are increases.

Table B2-92

Mid-1 Scenario Alternative CAFE Standards
Nationwide Changes in Health Costs from Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks – Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards (US million dollars/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
2015	0 a/	-44 b/	-54	-66	-77	-98	-223
2020	0	-355	-395	-438	-468	-564	-1,079
2025	0	-729	-793	-867	-908	-1,105	-2,019
2035	0	-1,210	-1,300	-1,415	-1,463	-1,838	-3,322

a/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.
b/ Negative changes indicate economic benefit; positive emissions changes are economic costs.

Table B2-93

Mid-2 Scenario Alternative CAFE Standards
Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions from Passenger Cars and Light Trucks (cases/year)

Health Outcome and Year	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Mortality (ages 30 and older)							
2015	0 a/	-31 b/	-35	-39	-41	-54	-101
2020	0	-78	-90	-103	-109	-142	-277
2025	0	-116	-134	-155	-165	-214	-418
2035	0	-158	-184	-214	-229	-295	-592
Chronic Bronchitis							
2015	0	-27	-31	-34	-35	-47	-88
2020	0	-68	-78	-89	-95	-124	-241
2025	0	-101	-117	-135	-144	-186	-363
2035	0	-137	-160	-187	-199	-257	-515
Emergency Room Visits for Asthma							
2015	0	-7	-7	-8	-8	-11	-21
2020	0	-16	-19	-21	-23	-30	-58
2025	0	-24	-28	-32	-35	-45	-87
2035	0	-33	-38	-45	-48	-62	-124
Work Loss Days							
2015	0	-5,578	-6,319	-6,882	-7,240	-9,687	-18,055
2020	0	-13,891	-16,030	-18,338	-19,499	-25,371	-49,452
2025	0	-20,659	-23,936	-27,681	-29,495	-38,089	-74,497
2035	0	-28,142	-32,723	-38,236	-40,877	-52,607	-105,514

a/ Changes in health outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.
b/ Negative changes indicate reductions; positive emissions changes are increases.

Table B2-94

Mid-2 Scenario Alternative CAFE Standards
Nationwide Changes in Health Costs from Criteria Pollutant Emissions
from Passenger Cars and Light Trucks (US million dollars/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
2015	0 a/	-48 b/	-55	-65	-76	-94	-223
2020	0	-197	-224	-266	-300	-370	-990
2025	0	-322	-363	-435	-485	-600	-1,809
2035	0	-480	-536	-647	-710	-891	-2,987

a/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.
b/ Negative changes indicate economic benefit; positive emissions changes are economic costs.

Table B2-95

Mid-2 Scenario Alternative CAFE Standards
Nationwide Changes in Health Outcomes from Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks – Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards (cases/year)

Health Outcome and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Mortality (ages 30 and older)							
2015	0 a/	-31 b/	-36	-39	-41	-54	-101
2020	0	-130	-146	-161	-169	-207	-300
2025	0	-254	-280	-308	-320	-381	-470
2035	0	-411	-451	-494	-512	-601	-682
Chronic Bronchitis							
2015	0	-27	-31	-34	-35	-47	-88
2020	0	-113	-127	-140	-147	-180	-261
2025	0	-221	-244	-268	-279	-331	-408
2035	0	-357	-392	-430	-445	-522	-593
Emergency Room Visits for Asthma							
2015	0	-7	-7	-8	-8	-11	-21
2020	0	-27	-30	-34	-35	-43	-63
2025	0	-53	-58	-64	-67	-80	-98
2035	0	-86	-94	-103	-107	-125	-142
Work Loss Days							
2015	0	-5,595	-6,338	-6,902	-7,260	-9,709	-18,070
2020	0	-23,238	-25,942	-28,747	-30,080	-36,839	-53,440
2025	0	-45,256	-49,966	-54,943	-57,097	-67,915	-83,728
2035	0	-73,235	-80,409	-88,131	-91,321	-107,056	-121,611

a/ Changes in health outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.
b/ Negative changes indicate reductions; positive emissions changes are increases.

Table B2-96

Mid-2 Scenario Alternative CAFE Standards
Nationwide Changes in Health Costs from Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks – Cumulative Effects with MY 2011-2015 Standards and Potential MY 2016-2020 Standards
(US million dollars/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
2015	0 a/	-48 b/	-55	-65	-76	-94	-223
2020	0	-321	-356	-405	-444	-524	-1,079
2025	0	-645	-705	-797	-857	-1,003	-2,019
2035	0	-1,055	-1,145	-1,295	-1,376	-1,624	-3,322

a/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.
b/ Negative changes indicate economic benefit; positive emissions changes are economic costs.

Mid-1 Scenario Alternative CAFE Standards

Criteria Pollutants

Table B2-97

Mid-1 Scenario Alternative CAFE Standards
Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Carbon Monoxide (CO)							
2015	18,861,709	18,835,680	18,816,491	18,789,216	18,776,753	18,721,534	18,198,147
2020	16,619,854	16,458,256	16,430,977	16,340,575	16,309,581	16,052,513	14,015,233
2025	16,403,499	16,065,661	16,044,287	15,886,507	15,841,194	15,327,327	11,538,880
2035	17,713,991	17,119,445	17,113,141	16,881,947	16,839,209	15,958,532	9,913,291
Nitrogen Oxides (NOx)							
2015	2,148,052	2,144,736	2,143,994	2,142,982	2,142,008	2,140,513	2,131,158
2020	1,530,682	1,517,579	1,515,603	1,512,403	1,510,275	1,503,934	1,458,868
2025	1,292,315	1,267,801	1,265,212	1,259,315	1,256,219	1,241,533	1,139,549
2035	1,228,251	1,186,912	1,184,073	1,174,794	1,171,422	1,141,971	949,127
Particulate Matter (PM2.5)							
2015	74,919	74,568	74,459	74,416	74,391	74,218	73,597
2020	75,571	74,382	74,189	74,091	74,062	73,681	71,953
2025	79,258	77,372	77,117	76,976	76,945	76,405	73,807
2035	89,447	86,758	86,438	86,244	86,210	85,480	81,727
Sulfur Oxides (SO_x)							
2015	194,594	192,447	191,956	191,394	190,895	189,826	183,320
2020	199,331	192,099	191,192	190,039	189,188	186,662	171,340
2025	210,380	198,886	197,662	196,047	194,936	191,245	168,860
2035	238,442	222,172	220,622	218,537	217,194	212,220	182,153
Volatile Organic Compounds (VOC)							
2015	2,107,357	2,100,168	2,098,265	2,094,906	2,092,438	2,086,535	2,036,819
2020	1,738,318	1,711,810	1,708,599	1,700,636	1,696,030	1,676,716	1,531,670
2025	1,646,853	1,600,847	1,596,881	1,583,857	1,577,197	1,541,937	1,284,617
2035	1,709,979	1,633,344	1,628,654	1,608,312	1,600,418	1,534,803	1,081,653

Table B2-98

Mid-1 Scenario Alternative CAFE Standards
Nationwide Changes in Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Carbon Monoxide (CO)							
2015	0 a/	-26,029 b/	-45,217	-72,492	-84,955	-140,175	-663,562
2020	0	-161,598	-188,877	-279,278	-310,273	-567,341	-2,604,621
2025	0	-337,839	-359,212	-516,992	-562,305	-1,076,172	-4,864,620
2035	0	-594,546	-600,849	-832,044	-874,782	-1,755,459	-7,800,700
Nitrogen Oxides (NO_x)							
2015	0	-3,316	-4,058	-5,069	-6,044	-7,538	-16,893
2020	0	-13,103	-15,079	-18,279	-20,407	-26,748	-71,814
2025	0	-24,513	-27,103	-33,000	-36,095	-50,781	-152,765
2035	0	-41,339	-44,177	-53,457	-56,828	-86,279	-279,123
Particulate Matter (PM2.5)							
2015	0	-350	-460	-503	-528	-701	-1,321
2020	0	-1,189	-1,382	-1,480	-1,510	-1,891	-3,618
2025	0	-1,886	-2,142	-2,283	-2,313	-2,853	-5,451
2035	0	-2,689	-3,009	-3,203	-3,237	-3,968	-7,721
Sulfur Oxides (SO_x)							
2015	0	-2,147	-2,638	-3,200	-3,699	-4,768	-11,274
2020	0	-7,231	-8,139	-9,292	-10,142	-12,668	-27,991
2025	0	-11,494	-12,718	-14,333	-15,444	-19,135	-41,521
2035	0	-16,270	-17,820	-19,906	-21,248	-26,222	-56,289
Volatile Organic Compounds (VOC)							
2015	0	-7,190	-9,092	-12,452	-14,920	-20,823	-70,539
2020	0	-26,508	-29,719	-37,682	-42,288	-61,602	-206,648
2025	0	-46,006	-49,973	-62,997	-69,657	-104,916	-362,236
2035	0	-76,635	-81,325	-101,667	-109,560	-175,176	-628,326

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

Table B2-99

Mid-1 Scenario Alternative CAFE Standards
Cumulative Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)
with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Carbon Monoxide (CO)							
2015	18,861,709	18,835,676	18,816,487	18,789,212	18,776,749	18,721,529	18,198,144
2020	16,619,854	16,476,152	16,449,846	16,355,482	16,325,123	16,046,278	14,057,662
2025	16,403,499	16,137,915	16,120,862	15,946,493	15,902,717	15,301,041	11,706,038
2035	17,713,991	17,306,263	17,311,609	17,036,710	16,996,553	15,888,952	10,338,916
Nitrogen Oxides (NOx)							
2015	2,148,052	2,144,723	2,143,980	2,142,969	2,141,994	2,140,499	2,131,148
2020	1,530,682	1,509,982	1,507,511	1,504,253	1,502,093	1,495,444	1,454,741
2025	1,292,315	1,248,710	1,244,869	1,238,642	1,235,541	1,218,882	1,131,426
2035	1,228,251	1,154,483	1,149,489	1,138,976	1,135,665	1,099,173	940,625
Particulate Matter (PM2.5)							
2015	74,919	74,567	74,457	74,415	74,389	74,216	73,596
2020	75,571	73,626	73,385	73,288	73,268	72,848	71,661
2025	79,258	75,391	75,008	74,876	74,880	74,238	73,132
2035	89,447	83,129	82,578	82,404	82,441	81,521	80,549
Sulfur Oxides (SO_x)							
2015	194,594	192,441	191,949	191,387	190,888	189,819	183,315
2020	199,331	187,353	186,126	184,893	183,972	181,170	167,666
2025	210,380	186,293	184,222	182,411	181,138	176,698	159,282
2035	238,442	199,015	195,907	193,473	191,849	185,489	164,654
Volatile Organic Compounds (VOC)							
2015	2,107,357	2,100,151	2,098,248	2,094,888	2,092,419	2,086,516	2,036,807
2020	1,738,318	1,701,609	1,697,890	1,689,499	1,684,500	1,664,131	1,527,120
2025	1,646,853	1,574,849	1,569,635	1,555,313	1,547,684	1,508,613	1,275,275
2035	1,709,979	1,589,720	1,583,037	1,559,441	1,549,832	1,472,687	1,073,784

Table B2-100

Mid-1 Scenario Alternative CAFE Standards
Cumulative Nationwide Changes in Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Carbon Monoxide (CO)							
2015	0 a/	-26,033 b/	-45,221	-72,496	-84,959	-140,179	-663,565
2020	0	-143,701	-170,008	-264,372	-294,731	-573,575	-2,562,191
2025	0	-265,585	-282,638	-457,006	-500,782	-1,102,458	-4,697,461
2035	0	-407,727	-402,382	-677,281	-717,438	-1,825,039	-7,375,075
Nitrogen Oxides (NO_x)							
2015	0	-3,328	-4,071	-5,083	-6,058	-7,553	-16,904
2020	0	-20,699	-23,171	-26,429	-28,589	-35,238	-75,941
2025	0	-43,605	-47,445	-53,672	-56,773	-73,432	-160,889
2035	0	-73,768	-78,761	-89,275	-92,585	-129,078	-287,626
Particulate Matter (PM2.5)							
2015	0	-352	-461	-504	-529	-702	-1,322
2020	0	-1,945	-2,187	-2,284	-2,304	-2,723	-3,910
2025	0	-3,868	-4,250	-4,382	-4,378	-5,021	-6,126
2035	0	-6,318	-6,869	-7,043	-7,006	-7,926	-8,898
Sulfur Oxides (SO_x)							
2015	0	-2,154	-2,645	-3,207	-3,707	-4,776	-11,280
2020	0	-11,977	-13,204	-14,437	-15,358	-18,161	-31,665
2025	0	-24,087	-26,159	-27,969	-29,243	-33,682	-51,098
2035	0	-39,428	-42,535	-44,969	-46,594	-52,954	-73,788
Volatile Organic Compounds (VOC)							
2015	0	-7,206	-9,109	-12,469	-14,938	-20,841	-70,550
2020	0	-36,709	-40,427	-48,819	-53,817	-74,187	-211,198
2025	0	-72,004	-77,219	-91,541	-99,170	-138,240	-371,578
2035	0	-120,259	-126,942	-150,538	-160,147	-237,292	-636,195

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

Hazardous Air Pollutants

Table B2-101

Mid-1 Scenario Alternative CAFE Standards
Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Acetaldehyde							
2015	11,165	11,170	11,176	11,176	11,174	11,186	11,268
2020	8,634	8,646	8,648	8,646	8,638	8,659	8,784
2025	7,613	7,612	7,613	7,603	7,592	7,592	7,586
2035	7,364	7,328	7,331	7,309	7,298	7,246	6,938
Acrolein a/							
2015	530	534	535	537	538	543	583
2020	393	407	409	414	416	431	547
2025	336	359	360	368	371	395	575
2035	315	349	350	360	364	399	646
Benzene							
2015	60,125	60,009	59,965	59,901	59,861	59,736	58,661
2020	47,458	46,962	46,888	46,705	46,624	46,133	42,385
2025	42,930	41,994	41,912	41,594	41,476	40,510	33,469
2035	42,626	40,990	40,911	40,416	40,290	38,510	26,306
1,3-Butadiene							
2015	6,134	6,134	6,133	6,134	6,134	6,134	6,141
2020	4,698	4,692	4,689	4,686	4,685	4,677	4,617
2025	4,092	4,070	4,067	4,058	4,057	4,027	3,815
2035	3,885	3,830	3,827	3,810	3,811	3,735	3,231
Diesel Particulate Matter (DPM)							
2015	88,405	87,414	87,200	87,066	86,914	86,578	85,735
2020	90,085	86,819	86,354	86,081	85,807	85,273	83,498
2025	94,782	89,613	88,948	88,567	88,201	87,535	85,050
2035	107,203	99,901	99,026	98,526	98,063	97,264	93,876
Formaldehyde							
2015	16,197	16,211	16,232	16,247	16,245	16,301	16,790
2020	12,928	13,002	13,017	13,055	13,050	13,234	14,641
2025	11,716	11,834	11,842	11,898	11,893	12,168	14,238
2035	11,694	11,856	11,860	11,933	11,926	12,295	15,022

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

Table B2-102

Mid-1 Scenario Alternative CAFE Standards
Nationwide Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Acetaldehyde							
2015	0 /a	5 /b	10	11	9	20	103
2020	0	12	14	12	4	25	151
2025	0	-1	1	-10	-21	-20	-27
2035	0	-36	-33	-55	-66	-118	-426
Acrolein a/							
2015	0	3	5	7	8	13	53
2020	0	14	15	20	22	37	153
2025	0	23	24	32	35	59	239
2035	0	34	35	45	49	84	330
Benzene							
2015	0	-115	-159	-224	-263	-388	-1,463
2020	0	-496	-570	-753	-834	-1,325	-5,073
2025	0	-936	-1,018	-1,336	-1,454	-2,419	-9,461
2035	0	-1,635	-1,715	-2,210	-2,336	-4,116	-16,320
1,3-Butadiene							
2015	0	0	-1	0	0	0	7
2020	0	-6	-9	-12	-13	-21	-81
2025	0	-22	-26	-34	-35	-65	-277
2035	0	-55	-58	-75	-74	-150	-654
Diesel Particulate Matter (DPM)							
2015	0	-991	-1,205	-1,338	-1,490	-1,826	-2,670
2020	0	-3,266	-3,731	-4,004	-4,278	-4,811	-6,587
2025	0	-5,168	-5,834	-6,215	-6,581	-7,247	-9,732
2035	0	-7,302	-8,177	-8,676	-9,140	-9,939	-13,326
Formaldehyde							
2015	0	14	34	50	48	104	592
2020	0	75	89	128	122	307	1,714
2025	0	118	126	183	177	453	2,522
2035	0	162	166	239	232	601	3,328

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

c/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

Table B2-103

Mid-1 Scenario Alternative CAFE Standards
Cumulative Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Acetaldehyde							
2015	11,165	11,170	11,176	11,176	11,174	11,186	11,268
2020	8,634	8,644	8,647	8,646	8,639	8,666	8,808
2025	7,613	7,618	7,621	7,614	7,606	7,617	7,673
2035	7,364	7,363	7,371	7,353	7,349	7,296	7,153
Acrolein a/							
2015	530	534	535	537	538	543	583
2020	393	410	412	417	420	436	552
2025	336	367	369	379	382	412	591
2035	315	366	369	382	388	433	680
Benzene							
2015	60,125	60,009	59,965	59,901	59,861	59,736	58,661
2020	47,458	46,839	46,758	46,566	46,482	45,953	42,348
2025	42,930	41,707	41,607	41,258	41,132	40,020	33,465
2035	42,626	40,579	40,476	39,894	39,757	37,564	26,566
1,3-Butadiene							
2015	6,134	6,134	6,133	6,134	6,134	6,134	6,141
2020	4,698	4,691	4,688	4,685	4,685	4,678	4,625
2025	4,092	4,074	4,070	4,062	4,063	4,031	3,850
2035	3,885	3,852	3,850	3,832	3,837	3,744	3,331
Diesel Particulate Matter (DPM)							
2015	88,405	87,410	87,196	87,063	86,911	86,574	85,732
2020	90,085	84,312	83,681	83,392	83,088	82,520	81,614
2025	94,782	82,961	81,859	81,448	81,017	80,266	80,139
2035	107,203	87,669	85,991	85,445	84,871	83,922	84,904
Formaldehyde							
2015	16,197	16,211	16,231	16,247	16,245	16,301	16,789
2020	12,928	12,954	12,967	13,012	13,009	13,221	14,660
2025	11,716	11,724	11,731	11,805	11,807	12,156	14,332
2035	11,694	11,692	11,694	11,802	11,814	12,308	15,281

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

Table B2-104

Mid-1 Scenario Alternative CAFE Standards
Cumulative Nationwide Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Acetaldehyde							
2015	0 /a	5 /b	10	11	9	20	103
2020	0	10	13	12	5	32	174
2025	0	5	9	2	-6	5	60
2035	0	-1	7	-11	-15	-68	-211
Acrolein a/							
2015	0	3	5	7	8	13	53
2020	0	16	18	24	26	43	158
2025	0	31	33	43	46	76	255
2035	0	51	54	67	73	118	365
Benzene							
2015	0	-116	-159	-224	-264	-388	-1,463
2020	0	-619	-700	-892	-976	-1,505	-5,110
2025	0	-1,223	-1,323	-1,672	-1,798	-2,910	-9,465
2035	0	-2,046	-2,150	-2,732	-2,869	-5,062	-16,060
1,3-Butadiene							
2015	0	0	-1	0	0	0	7
2020	0	-7	-10	-13	-13	-20	-73
2025	0	-18	-22	-30	-29	-61	-242
2035	0	-34	-35	-53	-48	-141	-555
Diesel Particulate Matter (DPM)							
2015	0	-994	-1,208	-1,342	-1,494	-1,830	-2,673
2020	0	-5,773	-6,403	-6,692	-6,997	-7,565	-8,471
2025	0	-11,821	-12,923	-13,334	-13,765	-14,516	-14,643
2035	0	-19,534	-21,212	-21,758	-22,331	-23,281	-22,299
Formaldehyde							
2015	0	14	34	50	48	104	592
2020	0	26	39	85	81	293	1,732
2025	0	8	15	89	91	440	2,616
2035	0	-1	0	108	120	614	3,587

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

c/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

Mid-2 Scenario Alternative CAFE Standards

Criteria Pollutants

Table B2-105

Mid-2 Scenario Alternative CAFE Standards
Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

Pollutant and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Carbon Monoxide (CO)							
2015	18,861,709	18,814,670	18,811,274	18,792,788	18,777,406	18,736,309	18,198,147
2020	16,619,854	16,441,954	16,436,732	16,367,374	16,326,970	16,208,067	14,015,233
2025	16,403,499	16,073,264	16,068,721	15,942,747	15,883,299	15,679,950	11,538,880
2035	17,713,991	17,176,090	17,172,587	16,977,632	16,914,309	16,581,815	9,913,291
Nitrogen Oxides (NOx)							
2015	2,148,052	2,144,437	2,143,883	2,143,055	2,142,058	2,140,777	2,131,158
2020	1,530,682	1,518,343	1,516,796	1,513,932	1,511,463	1,507,093	1,458,868
2025	1,292,315	1,270,295	1,267,998	1,262,610	1,258,840	1,250,716	1,139,549
2035	1,228,251	1,192,739	1,189,619	1,180,701	1,176,125	1,161,590	949,127
Particulate Matter (PM2.5)							
2015	74,919	74,510	74,456	74,415	74,389	74,210	73,597
2020	75,571	74,555	74,399	74,230	74,145	73,715	71,953
2025	79,258	77,747	77,507	77,233	77,100	76,471	73,807
2035	89,447	87,388	87,053	86,649	86,456	85,598	81,727
Sulfur Oxides (SO_x)							
2015	194,594	192,250	191,923	191,453	190,942	190,095	183,320
2020	199,331	193,095	192,187	190,894	189,865	187,761	171,340
2025	210,380	200,917	199,540	197,583	196,156	193,051	168,860
2035	238,442	225,514	223,601	220,896	219,058	214,800	182,153
Volatile Organic Compounds (VOC)							
2015	2,107,357	2,098,877	2,097,887	2,095,334	2,092,712	2,088,579	2,036,819
2020	1,738,318	1,713,586	1,711,101	1,703,967	1,698,791	1,687,948	1,531,670
2025	1,646,853	1,605,832	1,602,197	1,590,227	1,582,597	1,564,921	1,284,617
2035	1,709,979	1,643,563	1,638,616	1,619,383	1,609,834	1,579,256	1,081,653

Table B2-106

Mid-2 Scenario Alternative CAFE Standards
Nationwide Changes in Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Carbon Monoxide (CO)							
2015	0 a/	-47,039 b/	-50,435	-68,920	-84,303	-125,399	-663,562
2020	0	-177,900	-183,122	-252,479	-292,884	-411,786	-2,604,621
2025	0	-330,235	-334,778	-460,752	-520,200	-723,549	-4,864,620
2035	0	-537,901	-541,404	-736,359	-799,682	-1,132,175	-7,800,700
Nitrogen Oxides (NO_x)							
2015	0	-3,614	-4,169	-4,997	-5,994	-7,275	-16,893
2020	0	-12,339	-13,886	-16,750	-19,219	-23,589	-71,814
2025	0	-22,020	-24,317	-29,705	-33,474	-41,599	-152,765
2035	0	-35,511	-38,632	-47,549	-52,125	-66,661	-279,123
Particulate Matter (PM2.5)							
2015	0	-408	-462	-504	-530	-709	-1,321
2020	0	-1,016	-1,173	-1,342	-1,427	-1,856	-3,618
2025	0	-1,512	-1,751	-2,025	-2,158	-2,787	-5,451
2035	0	-2,059	-2,394	-2,798	-2,991	-3,849	-7,721
Sulfur Oxides (SO_x)							
2015	0	-2,344	-2,672	-3,142	-3,653	-4,499	-11,274
2020	0	-6,235	-7,143	-8,436	-9,466	-11,569	-27,991
2025	0	-9,463	-10,841	-12,797	-14,225	-17,329	-41,521
2035	0	-12,929	-14,841	-17,547	-19,385	-23,642	-56,289
Volatile Organic Compounds (VOC)							
2015	0	-8,481	-9,470	-12,024	-14,645	-18,778	-70,539
2020	0	-24,732	-27,217	-34,351	-39,527	-50,369	-206,648
2025	0	-41,021	-44,656	-56,626	-64,256	-81,932	-362,236
2035	0	-66,416	-71,363	-90,596	-100,145	-130,723	-628,326

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

Table B2-107

Mid-2 Scenario Alternative CAFE Standards
Cumulative Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	No Action	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs Equal Total Benefits	Technology Exhaustion
Carbon Monoxide (CO)							
2015	18,861,709	18,814,667	18,811,270	18,792,784	18,777,402	18,736,305	18,198,144
2020	16,619,854	16,460,267	16,456,238	16,384,062	16,343,572	16,216,663	14,057,662
2025	16,403,499	16,147,244	16,147,526	16,009,963	15,949,565	15,714,680	11,706,038
2035	17,713,991	17,367,387	17,376,352	17,151,134	17,084,525	16,671,469	10,338,916
Nitrogen Oxides (NOx)							
2015	2,148,052	2,144,426	2,143,871	2,143,042	2,142,044	2,140,762	2,131,148
2020	1,530,682	1,511,287	1,509,337	1,506,131	1,503,475	1,498,626	1,454,741
2025	1,292,315	1,252,538	1,249,274	1,242,886	1,238,670	1,228,946	1,131,426
2035	1,228,251	1,162,736	1,158,035	1,146,861	1,141,449	1,122,758	940,625
Particulate Matter (PM2.5)							
2015	74,919	74,509	74,455	74,414	74,387	74,208	73,596
2020	75,571	73,871	73,673	73,468	73,370	72,876	71,661
2025	79,258	75,947	75,602	75,238	75,081	74,289	73,132
2035	89,447	84,089	83,564	82,999	82,765	81,614	80,549
Sulfur Oxides (SO_x)							
2015	194,594	192,244	191,916	191,446	190,935	190,087	183,315
2020	199,331	188,807	187,612	186,037	184,836	182,276	167,666
2025	210,380	189,508	187,381	184,691	182,834	178,542	159,282
2035	238,442	204,515	201,233	197,188	194,576	188,149	164,654
Volatile Organic Compounds (VOC)							
2015	2,107,357	2,098,862	2,097,871	2,095,317	2,092,695	2,088,560	2,036,807
2020	1,738,318	1,704,349	1,701,288	1,693,431	1,687,746	1,675,780	1,527,120
2025	1,646,853	1,582,298	1,577,246	1,563,290	1,554,362	1,533,457	1,275,275
2035	1,709,979	1,604,445	1,597,203	1,573,769	1,561,807	1,523,833	1,073,784

Table B2-108

Mid-2 Scenario Alternative CAFE Standards
Cumulative Nationwide Changes in Criteria Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Carbon Monoxide (CO)							
2015	0 a/	-47,042 b/	-50,438	-68,924	-84,307	-125,404	-663,565
2020	0	-159,587	-163,615	-235,792	-276,282	-403,191	-2,562,191
2025	0	-256,255	-255,973	-393,536	-453,934	-688,819	-4,697,461
2035	0	-346,604	-337,639	-562,857	-629,466	-1,042,522	-7,375,075
Nitrogen Oxides (NO_x)							
2015	0	-3,626	-4,181	-5,010	-6,008	-7,290	-16,904
2020	0	-19,395	-21,345	-24,550	-27,207	-32,056	-75,941
2025	0	-39,776	-43,041	-49,429	-53,645	-63,369	-160,889
2035	0	-65,515	-70,216	-81,389	-86,802	-105,492	-287,626
Particulate Matter (PM2.5)							
2015	0	-409	-464	-505	-531	-710	-1,322
2020	0	-1,700	-1,898	-2,103	-2,201	-2,696	-3,910
2025	0	-3,311	-3,656	-4,020	-4,178	-4,969	-6,126
2035	0	-5,359	-5,884	-6,449	-6,682	-7,833	-8,898
Sulfur Oxides (SO_x)							
2015	0	-2,350	-2,678	-3,149	-3,660	-4,507	-11,280
2020	0	-10,523	-11,718	-13,293	-14,494	-17,054	-31,665
2025	0	-20,873	-23,000	-25,689	-27,547	-31,839	-51,098
2035	0	-33,927	-37,210	-41,254	-43,866	-50,293	-73,788
Volatile Organic Compounds (VOC)							
2015	0	-8,496	-9,486	-12,040	-14,662	-18,797	-70,550
2020	0	-33,969	-37,030	-44,887	-50,571	-62,537	-211,198
2025	0	-64,556	-69,608	-83,564	-92,492	-113,396	-371,578
2035	0	-105,534	-112,776	-136,210	-148,172	-186,146	-636,195

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

Hazardous Air Pollutants

Table B2-109

Mid-2 Scenario Alternative CAFE Standards
Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Acetaldehyde							
2015	11,165	11,175	11,176	11,176	11,174	11,184	11,268
2020	8,634	8,641	8,641	8,643	8,638	8,654	8,784
2025	7,613	7,602	7,603	7,601	7,593	7,606	7,586
2035	7,364	7,320	7,321	7,311	7,303	7,300	6,938
Acrolein a/							
2015	530	535	535	537	538	541	583
2020	393	406	407	412	414	422	547
2025	336	356	358	365	368	379	575
2035	315	344	346	355	360	374	646
Benzene							
2015	60,125	59,972	59,956	59,909	59,865	59,774	58,661
2020	47,458	46,965	46,927	46,773	46,674	46,414	42,385
2025	42,930	42,062	42,008	41,733	41,583	41,138	33,469
2035	42,626	41,183	41,113	40,664	40,485	39,714	26,306
1,3-Butadiene							
2015	6,134	6,133	6,133	6,133	6,134	6,133	6,141
2020	4,698	4,689	4,689	4,687	4,685	4,680	4,617
2025	4,092	4,069	4,068	4,061	4,059	4,044	3,815
2035	3,885	3,834	3,834	3,818	3,815	3,781	3,231
Diesel Particulate Matter (DPM)							
2015	88,405	87,361	87,202	87,065	86,920	86,564	85,735
2020	90,085	87,353	86,885	86,437	86,073	85,196	83,498
2025	94,782	90,651	89,932	89,230	88,691	87,398	85,050
2035	107,203	101,576	100,571	99,569	98,827	97,070	93,876
Formaldehyde							
2015	16,197	16,234	16,235	16,244	16,245	16,288	16,790
2020	12,928	13,005	13,003	13,039	13,043	13,138	14,641
2025	11,716	11,820	11,816	11,872	11,879	12,009	14,238
2035	11,694	11,828	11,822	11,897	11,905	12,072	15,022

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

Table B2-110

Mid-2 Scenario Alternative CAFE Standards
Nationwide Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Acetaldehyde							
2015	0 /a	10 /b	10	11	9	19	103
2020	0	7	7	9	4	20	151
2025	0	-10	-9	-11	-19	-7	-27
2035	0	-44	-43	-53	-61	-64	-426
Acrolein a/							
2015	0	5	5	7	8	11	53
2020	0	13	14	18	21	28	153
2025	0	20	22	28	32	43	239
2035	0	29	30	40	44	59	330
Benzene							
2015	0	-153	-169	-215	-260	-351	-1,463
2020	0	-493	-531	-685	-784	-1,044	-5,073
2025	0	-868	-922	-1,197	-1,346	-1,792	-9,461
2035	0	-1,442	-1,513	-1,962	-2,141	-2,912	-16,320
1,3-Butadiene							
2015	0	-1	-1	-1	-1	-1	7
2020	0	-9	-10	-12	-13	-19	-81
2025	0	-23	-24	-31	-33	-48	-277
2035	0	-51	-52	-67	-70	-104	-654
Diesel Particulate Matter (DPM)							
2015	0	-1,043	-1,203	-1,340	-1,485	-1,841	-2,670
2020	0	-2,732	-3,200	-3,648	-4,012	-4,889	-6,587
2025	0	-4,131	-4,850	-5,552	-6,091	-7,384	-9,732
2035	0	-5,627	-6,631	-7,634	-8,376	-10,133	-13,326
Formaldehyde							
2015	0	37	37	47	48	91	592
2020	0	77	75	111	115	210	1,714
2025	0	104	100	156	163	293	2,522
2035	0	134	128	203	211	378	3,328

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

c/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

Table B2-111

Mid-2 Scenario Alternative CAFE Standards
Cumulative Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

Pollutant and Year	Alt. 1 No Action	Alt. 2 25% Below Optimized	Alt. 3 Optimized	Alt. 4 25% Above Optimized	Alt. 5 50% Above Optimized	Alt. 6 Total Costs Equal Total Benefits	Alt. 7 Technology Exhaustion
Acetaldehyde							
2015	11,165	11,175	11,176	11,176	11,174	11,184	11,268
2020	8,634	8,636	8,637	8,641	8,637	8,659	8,808
2025	7,613	7,600	7,603	7,607	7,603	7,629	7,673
2035	7,364	7,338	7,347	7,345	7,345	7,361	7,153
Acrolein a/							
2015	530	535	535	537	538	541	583
2020	393	408	410	415	418	426	552
2025	336	362	364	373	378	393	591
2035	315	357	361	374	381	403	680
Benzene							
2015	60,125	59,972	59,956	59,909	59,865	59,773	58,661
2020	47,458	46,856	46,811	46,645	46,539	46,254	42,348
2025	42,930	41,810	41,741	41,428	41,261	40,736	33,465
2035	42,626	40,839	40,748	40,209	39,998	39,029	26,566
1,3-Butadiene							
2015	6,134	6,133	6,133	6,133	6,134	6,133	6,141
2020	4,698	4,688	4,687	4,686	4,685	4,680	4,625
2025	4,092	4,071	4,071	4,065	4,064	4,050	3,850
2035	3,885	3,852	3,854	3,839	3,839	3,803	3,331
Diesel Particulate Matter (DPM)							
2015	88,405	87,358	87,198	87,061	86,916	86,560	85,732
2020	90,085	85,080	84,461	83,886	83,441	82,363	81,614
2025	94,782	84,603	83,491	82,462	81,723	79,917	80,139
2035	107,203	90,445	88,723	87,126	86,026	83,338	84,904
Formaldehyde							
2015	16,197	16,234	16,235	16,244	16,245	16,288	16,789
2020	12,928	12,952	12,949	12,991	12,997	13,109	14,660
2025	11,716	11,696	11,692	11,765	11,780	11,958	14,332
2035	11,694	11,632	11,630	11,738	11,766	12,021	15,281

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

Table B2-112

Mid-2 Scenario Alternative CAFE Standards
Cumulative Nationwide Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year) with MY 2011-2015 Standards and Potential MY 2016-2020 Standards

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Pollutant and Year	**No Action**	**25% Below Optimized**	**Optimized**	**25% Above Optimized**	**50% Above Optimized**	**Total Costs Equal Total Benefits**	**Technology Exhaustion**
Acetaldehyde							
2015	0 /a	10 /b	10	11	9	19	103
2020	0	2	3	7	3	25	174
2025	0	-13	-9	-6	-10	17	60
2035	0	-26	-17	-19	-19	-2	-211
Acrolein a/							
2015	0	5	5	7	8	11	53
2020	0	15	16	21	24	33	158
2025	0	26	28	37	42	57	255
2035	0	42	45	59	65	88	365
Benzene							
2015	0	-153	-169	-216	-260	-351	-1,463
2020	0	-602	-647	-813	-919	-1,203	-5,110
2025	0	-1,119	-1,188	-1,502	-1,669	-2,194	-9,465
2035	0	-1,787	-1,878	-2,416	-2,628	-3,596	-16,060
1,3-Butadiene							
2015	0	-1	-1	-1	-1	-1	7
2020	0	-10	-11	-12	-13	-18	-73
2025	0	-22	-21	-27	-28	-43	-242
2035	0	-33	-31	-46	-46	-82	-555
Diesel Particulate Matter (DPM)							
2015	0	-1,046	-1,206	-1,343	-1,488	-1,845	-2,673
2020	0	-5,005	-5,623	-6,199	-6,644	-7,721	-8,471
2025	0	-10,179	-11,291	-12,320	-13,058	-14,865	-14,643
2035	0	-16,758	-18,480	-20,077	-21,177	-23,865	-22,299
Formaldehyde							
2015	0	37	37	47	48	91	592
2020	0	24	21	63	70	182	1,732
2025	0	-20	-24	49	64	243	2,616
2035	0	-62	-64	44	73	328	3,587

a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

c/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the change in tailpipe emissions.

Appendix B-3

CLIMATE CHANGE MODELING DATA

This appendix accompanies Sections 3.4 and 4.4 of the Final Environmental Impact Statement (FEIS). It presents the results from the Model for Assessment of Greenhouse Gas-induced Climate Change (MAGICC) for the CAFE Alternatives for the Mid-1 and the Mid-2 Scenarios and compares the results to the Reference Case. The CAFE Alternatives use the A1B marker scenario from the Intergovernmental Panel on Climate Change (IPCC) as a reference case, equivalent to the A1B-AIM scenario in MAGICC. Tables B3-1 through B3-8 provide the results for the 2011-2015 CAFE Alternatives (Section 3.4 of the EIS) and Tables B3-9 through B3-16 provide the results for the MY 2011-2020 CAFE Alternatives (Section 4.4 of the EIS).

Mid 1 Scenario – 2011-2015

Table B3-1

Mid 1 Scenario Emissions and Emission Reductions (compared to the No Action Alternative) Due to the MY 2011-2015 CAFE Standard Alternatives from 2010-2100 (MMTCO2)

Alternative	Emissions	Emission Reductions Compared to No Action Alternative
No Action	195,501	0
25 Percent Below Optimized	182,893	12,608
Optimized	181,509	13,992
25 Percent Above Optimized	180,401	15,100
50 Percent Above Optimized	179,464	16,037
Total Costs Equal Total Benefits	177,743	17,759
Technology Exhaustion	170,829	24,672

Table B3-2

Mid 1 Scenario MY 2011-2015 CAFE Standard Alternatives Impact on CO_2 Concentration, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
Totals by Alternative	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**
No Action (A1B – AIM)a/	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
25 Percent Below Optimized	455.4	573.2	716.1	0.873	1.942	2.954	7.99	19.28	37.06
Optimized	455.4	573.1	715.9	0.873	1.942	2.954	7.99	19.28	37.05
25 Percent Above Optimized	455.4	573.1	715.8	0.873	1.942	2.953	7.99	19.28	37.05
50 Percent Above Optimized	455.4	573.0	715.7	0.873	1.941	2.953	7.99	19.28	37.05
Total Costs Equal Total Benefits	455.4	572.9	715.6	0.873	1.941	2.952	7.99	19.27	37.04
Technology Exhaustion	455.3	572.6	714.9	0.872	1.938	2.948	7.99	19.26	37.00
Reduction from CAFE Alternatives									
25 Percent Below Optimized	0.1	0.5	1.1	0.001	0.002	0.005	0.00	0.02	0.04
Optimized	0.1	0.6	1.3	0.001	0.003	0.005	0.00	0.02	0.05
25 Percent Above Optimized	0.1	0.6	1.4	0.001	0.003	0.006	0.00	0.02	0.05
50 Percent Above Optimized	0.1	0.7	1.5	0.001	0.003	0.006	0.00	0.02	0.05
Total Costs Equal Total Benefits	0.1	0.8	1.6	0.001	0.004	0.007	0.00	0.03	0.06
Technology Exhaustion	0.2	1.1	2.3	0.002	0.006	0.011	0.00	0.04	0.10

a/ The A1B-AIM scenario is the SRES marker scenario used by the IPCC WGI to represent the SRES A1B (medium) storyline.

Mid 2 Scenario – 2011-2015

Table B3-3

Mid 2 Scenario Emissions and Emission Reductions (compared to the No Action Alternative) Due to the MY 2011-2015 CAFE Standard Alternatives from 2010-2100 (MMTCO2)

Alternative	Emissions	Emission Reductions Compared to No Action Alternative
No Action	195,501	0
25 Percent Below Optimized	185,761	9,740
Optimized	184,038	11,463
25 Percent Above Optimized	182,281	13,221
50 Percent Above Optimized	180,886	14,615
Total Costs Equal Total Benefits	178,093	17,408
Technology Exhaustion	170,829	24,672

Table B3-4

Mid 2 Scenario 2011-2015 CAFE Standard Alternatives Impact on CO_2 Concentration, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
Totals by Alternative	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**
No Action (A1B-AIM)a/	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
25 Percent Below Optimized	455.4	573.3	716.3	0.873	1.943	2.955	7.99	19.28	37.07
Optimized	455.4	573.2	716.2	0.873	1.942	2.955	7.99	19.28	37.06
25 Percent Above Optimized	455.4	573.1	716.0	0.873	1.942	2.954	7.99	19.28	37.06
50 Percent Above Optimized	455.4	573.1	715.9	0.873	1.942	2.953	7.99	19.28	37.05
Total Costs Equal Total Benefits	455.4	573	715.6	0.873	1.941	2.952	7.99	19.27	37.04
Technology Exhaustion	455.3	572.6	714.9	0.872	1.938	2.948	7.99	19.26	37.00
Reduction from CAFE Alternatives									
25 Percent Below Optimized	0.1	0.4	0.9	0.000	0.002	0.004	0.00	0.02	0.03
Optimized	0.1	0.5	1.0	0.001	0.002	0.004	0.00	0.02	0.04
25 Percent Above Optimized	0.1	0.6	1.2	0.001	0.002	0.005	0.00	0.02	0.04
50 Percent Above Optimized	0.1	0.6	1.3	0.001	0.003	0.006	0.00	0.02	0.05
Total Costs Equal Total Benefits	0.1	0.7	1.6	0.001	0.003	0.007	0.00	0.03	0.06
Technology Exhaustion	0.2	1.1	2.3	0.002	0.006	0.011	0.00	0.04	0.10

a/ The A1B-AIM scenario is the SRES marker scenario used by the IPCC WG1 to represent the SRES A1B (medium) storyline.

Mid 1 Scenario – 2011-2020

Table B3-5

Mid 1 Scenario Cumulative Emissions and Emission Reductions (compared to the No Action Alternative) Due to the MY 2011-2015 CAFE Standard and Potential MY 2011-2020 CAFE Standard Alternatives from 2010-2100 (MMTCO2)

Alternative	Emissions	Emission Reductions Compared to No Action Alternative
No Action	195,501	0
25 Percent Below Optimized	160,992	34,510
Optimized	158,054	37,447
25 Percent Above Optimized	156,749	38,752
50 Percent Above Optimized	155,685	39,816
Total Costs Equal Total Benefits	152,907	42,594
Technology Exhaustion	152,290	43,211

Table B3-6

Mid 1 Scenario MY 2011-2015 CAFE Standard and Potential MY 2016-2020 CAFE Standard Alternatives Cumulative Impact on CO_2 Concentration, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
Totals by Alternative	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**
No Action (A1B-AIM)a/	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
25 Percent Below Optimized	455.3	572.3	714	0.873	1.938	2.946	7.99	19.26	36.99
Optimized	455.2	572.2	713.7	0.872	1.938	2.945	7.99	19.25	36.98
25 Percent Above Optimized	455.2	572.1	713.6	0.872	1.937	2.944	7.99	19.25	36.97
50 Percent Above Optimized	455.2	572.1	713.5	0.872	1.937	2.944	7.99	19.25	36.97
Total Costs Equal Total Benefits	455.2	571.9	713.2	0.872	1.937	2.943	7.99	19.25	36.96
Technology Exhaustion	455.2	571.9	713.1	0.872	1.935	2.941	7.99	19.24	36.94
Reduction from CAFE Alternatives									
25 Percent Below Optimized	0.2	1.4	3.2	0.001	0.006	0.013	0.00	0.04	0.11
Optimized	0.3	1.5	3.5	0.001	0.007	0.014	0.00	0.05	0.12
25 Percent Above Optimized	0.3	1.6	3.6	0.001	0.007	0.015	0.00	0.05	0.13
50 Percent Above Optimized	0.3	1.6	3.7	0.001	0.007	0.015	0.00	0.05	0.13
Total Costs Equal Total Benefits	0.3	1.8	4.0	0.001	0.008	0.016	0.00	0.05	0.14
Technology Exhaustion	0.3	1.8	4.1	0.002	0.009	0.018	0.00	0.06	0.16

a/ The A1B-AIM scenario is the SRES marker scenario used by the IPCC WG1 to represent the SRES A1B (medium) storyline.

Mid 2 Scenario- 2011-2020

Table B3-7

Mid 2 Scenario Cumulative Emissions and Emission Reductions (compared to the No Action Alternative) Due to the MY 2011-2015 CAFE Standard and Potential MY 2011-2020 CAFE Standard Alternatives from 2010-2100 (MMTCO2)

Alternative	Emissions	Emission Reductions Compared to No Action Alternative
No Action	195,501	0
25 Percent Below Optimized	165,957	29,544
Optimized	162,913	32,589
25 Percent Above Optimized	159,943	35,558
50 Percent Above Optimized	157,891	37,610
Total Costs Equal Total Benefits	153,159	42,342
Technology Exhaustion	152,290	43,211

Table B3-8

Mid 2 Scenario MY 2011-2015 CAFE Standards and Potential MY 2016-2020 CAFE Standard Alternatives Cumulative Impact on CO_2 Concentration, Global Mean Surface Temperature Increase, and Sea-level Rise in 2100 Using MAGICC

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
Totals by Alternative	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**
No Action (A1B-AIM)a/	455.5	573.7	717.2	0.874	1.944	2.959	7.99	19.30	37.10
25 Percent Below Optimized	455.3	572.5	714.5	0.873	1.939	2.948	7.99	19.26	37.00
Optimized	455.3	572.4	714.2	0.873	1.939	2.947	7.99	19.26	36.99
25 Percent Above Optimized	455.3	572.2	713.9	0.872	1.938	2.945	7.99	19.26	36.98
50 Percent Above Optimized	455.2	572.2	713.7	0.872	1.938	2.945	7.99	19.25	36.97
Total Costs Equal Total Benefits	455.2	572	713.3	0.872	1.937	2.943	7.99	19.25	36.96
Technology Exhaustion	455.2	571.9	713.1	0.872	1.935	2.941	7.99	19.24	36.94
Reduction from CAFE Alternatives									
25 Percent Below Optimized	0.2	1.2	2.7	0.001	0.005	0.011	0.00	0.04	0.10
Optimized	0.2	1.3	3.0	0.001	0.006	0.012	0.00	0.04	0.11
25 Percent Above Optimized	0.2	1.5	3.3	0.001	0.006	0.014	0.00	0.04	0.12
50 Percent Above Optimized	0.3	1.5	3.5	0.001	0.007	0.014	0.00	0.05	0.13
Total Costs Equal Total Benefits	0.3	1.7	3.9	0.001	0.008	0.016	0.00	0.05	0.14
Technology Exhaustion	0.3	1.8	4.1	0.002	0.009	0.018	0.00	0.06	0.16

a/ The A1B-AIM scenario is the SRES marker scenario used by the IPCC WG1 to represent the SRES A1B (medium) storyline.

APPENDIX C

FEIS Benefit-Cost Information, October 2, 2008

For each alternative under all scenarios, NHTSA calculated the costs and the benefits. This information replaces the benefit-cost information discussed in the DEIS which relied on the PRIA.

Reference Case

Table C-1

Estimated Required Average for the Fleet (in mpg)
Reference Case

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below Optimized (7%)	30.0	31.8	32.3	32.9	33.3
Optimized (7%)	30.1	31.9	32.3	32.9	33.4
25% Above Optimized (7%)	30.2	31.9	32.3	32.9	33.5
50% Above Optimized (7%)	30.2	32.0	32.3	32.9	33.7
TC = TB (7%)	30.4	32.3	32.4	32.9	33.9
Technology Exhaustion (7%)	35.5	45.9	47.1	47.2	47.1
Light Trucks					
25% Below Optimized (7%)	22.8	24.3	25.0	25.0	25.8
Optimized (7%)	22.8	24.4	25.1	25.3	26.0
25% Above Optimized (7%)	22.9	24.6	25.1	25.6	26.2
50% Above Optimized (7%)	22.9	24.7	25.2	25.9	26.5
TC = TB (7%)	22.9	25.0	25.3	26.5	27.0
Technology Exhaustion (7%)	29.0	30.7	34.0	34.2	37.2
Passenger Cars and Light Trucks Combined					
25% Below Optimized (7%)	26.4	28.1	28.7	28.9	29.4
Optimized (7%)	26.5	28.3	28.7	29.1	29.6
25% Above Optimized (7%)	26.6	28.4	28.7	29.3	29.8
50% Above Optimized (7%)	26.6	28.5	28.8	29.5	30.0
TC = TB (7%)	26.7	28.8	28.9	29.8	30.4
Technology Exhaustion (7%)	32.4	38.0	40.5	40.5	42.0

Table C-2

Average Incremental Cost Per Vehicle – Consumer Perspective (2007 Dollars)
Reference Case a/

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below Optimized (7%)	45	129	176	220	256
Optimized (7%)	45	131	177	221	266
25% Above Optimized (7%)	61	144	182	225	282
50% Above Optimized (7%)	61	159	192	238	352
TC = TB (7%)	124	267	272	313	455
Technology Exhaustion (7%)	949	1,963	2,327	2,534	2,691
Light Trucks					
25% Below Optimized (7%)	(95)	(62)	14	(17)	94
Optimized (7%)	(95)	(29)	7	(3)	114
25% Above Optimized (7%)	(36)	211	224	267	330
50% Above Optimized (7%)	(36)	222	237	379	470
TC = TB (7%)	(36)	419	447	713	796
Technology Exhaustion (7%)	598	1,481	1,848	2,357	3,092
Passenger Cars and Light Trucks Combined					
25% Below Optimized (7%)	(15)	49	106	117	183
Optimized (7%)	(15)	64	104	123	197
25% Above Optimized (7%)	20	172	200	243	304
50% Above Optimized (7%)	20	185	211	299	405
TC = TB (7%)	56	331	347	487	609
Technology Exhaustion (7%)	800	1,760	2,122	2,457	2,872

a/ Negative numbers in this table reflect a standard that is lower than the baseline.

Table C-3

Incremental Total Cost – Consumer Perspective (Millions of 2007 Dollars)
Reference Case a/

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	415	1,247	1,686	2,064	2,330	7,742
Optimized (7%)	417	1,266	1,697	2,077	2,422	7,878
25% Above Optimized (7%)	569	1,392	1,744	2,113	2,573	8,391
50% Above Optimized (7%)	569	1,532	1,844	2,232	3,204	9,381
TC = TB (7%)	1,148	2,579	2,613	2,939	4,145	13,423
Technology Exhaustion (7%)	8,811	18,952	22,340	23,788	24,524	98,415
Light Trucks						
25% Below Optimized (7%)	(651)	(433)	99	(121)	709	(397)
Optimized (7%)	(651)	(204)	51	(25)	852	23
25% Above Optimized (7%)	(245)	1,475	1,606	1,933	2,474	7,242
50% Above Optimized (7%)	(245)	1,552	1,700	2,739	3,525	9,270
TC = TB (7%)	(245)	2,934	3,208	5,158	5,979	17,033
Technology Exhaustion (7%)	4,098	10,373	13,257	17,056	23,210	67,994
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	(236)	814	1,785	1,943	3,039	7,345
Optimized (7%)	(235)	1,062	1,748	2,052	3,274	7,902
25% Above Optimized (7%)	323	2,868	3,350	4,045	5,047	15,633
50% Above Optimized (7%)	323	3,083	3,544	4,971	6,729	18,651
TC = TB (7%)	902	5,513	5,821	8,097	10,123	30,456
Technology Exhaustion (7%)	12,909	29,325	35,598	40,844	47,734	166,410

a/ Negative numbers in this table reflect a standard that is lower than the baseline.

Table C-4

Present Value of Lifetime Societal Benefits by Alternative (Millions of 2007 Dollars)
Reference Case a/

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	634	1,611	2,120	2,567	3,174	10,106
Optimized (7%)	662	1,699	2,150	2,599	3,314	10,423
25% Above Optimized (7%)	748	1,773	2,183	2,624	3,447	10,775
50% Above Optimized (7%)	748	1,898	2,224	2,659	3,681	11,209
TC = TB (7%)	941	2,310	2,367	2,729	3,756	12,103
Technology Exhaustion (7%)	3,320	6,874	8,567	10,093	10,777	39,631
Light Trucks						
25% Below Optimized (7%)	(292)	718	1,865	1,970	3,320	7,582
Optimized (7%)	(297)	1,112	2,145	2,472	3,867	9,298
25% Above Optimized (7%)	(238)	1,657	2,166	3,042	4,164	10,791
50% Above Optimized (7%)	(238)	1,866	2,379	3,513	4,914	12,434
TC = TB (7%)	(238)	2,712	3,136	4,563	5,833	16,007
Technology Exhaustion (7%)	1,384	5,462	7,249	9,322	12,753	36,170
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	343	2,330	3,986	4,537	6,494	17,688
Optimized (7%)	364	2,811	4,295	5,071	7,181	19,722
25% Above Optimized (7%)	510	3,430	4,349	5,666	7,611	21,566
50% Above Optimized (7%)	510	3,764	4,602	6,172	8,595	23,642
TC = TB (7%)	703	5,022	5,503	7,292	9,589	28,110
Technology Exhaustion (7%)	4,704	12,336	15,816	19,415	23,530	75,801

a/ Negative numbers in this table reflect a standard that is lower than the baseline.

Table C-5

Net Total Benefits Over the Vehicle's Lifetime – Present Value
Societal Perspective (Millions of 2007 Dollars)
Reference Case

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	314	553	584	670	1,004	3,124
Optimized (7%)	345	628	603	689	1,057	3,322
25% Above Optimized (7%)	284	566	588	678	1,044	3,160
50% Above Optimized (7%)	284	561	529	594	664	2,632
TC = TB (7%)	(92)	(51)	(91)	(46)	(164)	(443)
Technology Exhaustion (7%)	(3,699)	(5,935)	(7,869)	(8,486)	(9,116)	(35,106)
Light Trucks						
25% Below Optimized (7%)	-	1,166	1,810	2,117	2,640	7,733
Optimized (7%)	-	1,332	2,139	2,528	3,046	9,044
25% Above Optimized (7%)	-	207	592	1,150	1,724	3,674
50% Above Optimized (7%)	-	346	718	837	1,428	3,329
TC = TB (7%)	-	(147)	(19)	(486)	(101)	(753)
Technology Exhaustion (7%)	(751)	(2,991)	(3,090)	(5,287)	(7,299)	(19,419)
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	314	1,719	2,394	2,787	3,644	10,857
Optimized (7%)	345	1,960	2,741	3,217	4,104	12,366
25% Above Optimized (7%)	284	773	1,180	1,828	2,768	6,833
50% Above Optimized (7%)	284	907	1,247	1,431	2,092	5,961
TC = TB (7%)	(92)	(198)	(109)	(532)	(265)	(1,196)
Technology Exhaustion (7%)	(4,451)	(8,927)	(10,959)	(13,773)	(16,415)	(54,525)

Table C-6

Savings in Millions of Gallons of Fuel
Undiscounted Over the Lifetime of the Model Year
Reference Case a/

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	388	1,001	1,321	1,599	1,987	6,296
Optimized (7%)	404	1,054	1,339	1,619	2,074	6,491
25% Above Optimized (7%)	467	1,109	1,362	1,634	2,157	6,730
50% Above Optimized (7%)	467	1,186	1,388	1,656	2,308	7,006
TC = TB (7%)	588	1,482	1,524	1,748	2,443	7,785
Technology Exhaustion (7%)	2,285	4,710	5,839	6,771	7,215	26,820
Light Trucks						
25% Below Optimized (7%)	-	355	1,041	1,110	1,967	4,474
Optimized (7%)	-	605	1,214	1,419	2,306	5,544
25% Above Optimized (7%)	-	1,048	1,375	1,931	2,600	6,954
50% Above Optimized (7%)	-	1,180	1,511	2,245	3,094	8,030
TC = TB (7%)	-	1,693	1,970	2,872	3,678	10,213
Technology Exhaustion (7%)	902	3,569	4,743	6,215	8,376	23,806
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	388	1,356	2,363	2,709	3,954	10,770
Optimized (7%)	404	1,659	2,553	3,038	4,380	12,035
25% Above Optimized (7%)	467	2,157	2,738	3,565	4,757	13,684
50% Above Optimized (7%)	467	2,366	2,899	3,902	5,402	15,036
TC = TB (7%)	588	3,175	3,494	4,620	6,121	17,998
Technology Exhaustion (7%)	3,187	8,280	10,582	12,986	15,592	50,626

a/ Fuel savings are omitted in this table when the standard is lower than the baseline.

Mid-1 Scenario

Table C-7

Estimated Required Average for the Fleet (in mpg)
Mid-1 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below Optimized (7%)	29.7	31.6	33.8	34.8	36.7
Optimized (7%)	30.0	32.1	34.3	35.4	37.2
25% Above Optimized (7%)	30.4	32.7	34.8	36.0	37.8
50% Above Optimized (7%)	30.8	33.3	35.3	36.5	38.3
TC = TB (7%)	31.5	34.5	36.3	37.6	39.3
Technology Exhaustion (7%)	35.5	45.9	47.1	47.2	47.1
Light Trucks					
25% Below Optimized (7%)	24.1	24.7	25.4	26.0	29.3
Optimized (7%)	24.1	24.9	25.7	26.6	29.6
25% Above Optimized (7%)	24.2	25.1	26.0	27.1	29.9
50% Above Optimized (7%)	24.2	25.4	26.3	27.8	30.2
TC = TB (7%)	24.3	25.8	27.0	29.0	30.8
Technology Exhaustion (7%)	29.0	30.7	34.0	34.2	37.2
Passenger Cars and Light Trucks Combined					
25% Below Optimized (7%)	27.1	28.3	29.6	30.4	32.9
Optimized (7%)	27.2	28.6	30.0	30.9	33.3
25% Above Optimized (7%)	27.4	29.0	30.4	31.5	33.8
50% Above Optimized (7%)	27.6	29.5	30.8	32.1	34.2
TC = TB (7%)	28.0	30.2	31.6	33.3	35.0
Technology Exhaustion (7%)	32.4	38.0	40.5	40.5	42.0

Table C-8

Average Incremental Cost Per Vehicle – Consumer Perspective (2007 Dollars)
Mid-1 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below Optimized (7%)	25	108	389	542	846
Optimized (7%)	48	166	495	671	954
25% Above Optimized (7%)	114	391	692	965	1,220
50% Above Optimized (7%)	186	522	862	1,140	1,413
TC = TB (7%)	342	862	1,145	1,487	1,761
Technology Exhaustion (7%)	943	2,016	2,344	2,560	2,720
Light Trucks					
25% Below Optimized (7%)	121	268	302	384	1,209
Optimized (7%)	121	327	395	519	1,330
25% Above Optimized (7%)	170	402	571	903	1,716
50% Above Optimized (7%)	170	651	769	1,087	1,809
TC = TB (7%)	231	908	1,327	1,828	2,483
Technology Exhaustion (7%)	599	1,479	1,895	2,362	3,074
Passenger Cars and Light Trucks Combined					
25% Below Optimized (7%)	66	175	352	474	1,010
Optimized (7%)	79	234	453	605	1,124
25% Above Optimized (7%)	137	395	640	938	1,444
50% Above Optimized (7%)	179	576	822	1,117	1,592
TC = TB (7%)	295	881	1,223	1,636	2,087
Technology Exhaustion (7%)	797	1,790	2,152	2,474	2,880

Table C-9

Incremental Total Cost – Consumer Perspective (Millions of 2007 Dollars)
Mid-1 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	235	1,040	3,738	5,092	7,713	17,817
Optimized (7%)	447	1,607	4,754	6,303	8,693	21,805
25% Above Optimized (7%)	1,055	3,770	6,642	9,059	11,121	31,648
50% Above Optimized (7%)	1,723	5,035	8,278	10,704	12,878	38,618
TC = TB (7%)	3,172	8,320	10,995	13,964	16,045	52,496
Technology Exhaustion (7%)	8,757	19,460	22,500	24,034	24,786	99,537
Light Trucks						
25% Below Optimized (7%)	829	1,875	2,169	2,780	9,077	16,731
Optimized (7%)	829	2,293	2,835	3,751	9,981	19,690
25% Above Optimized (7%)	1,163	2,815	4,098	6,536	12,881	27,493
50% Above Optimized (7%)	1,163	4,557	5,516	7,866	13,582	32,684
TC = TB (7%)	1,584	6,360	9,521	13,229	18,644	49,337
Technology Exhaustion (7%)	4,103	10,360	13,592	17,089	23,077	68,221
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	1,064	2,915	5,907	7,872	16,790	34,548
Optimized (7%)	1,276	3,900	7,589	10,055	18,675	41,495
25% Above Optimized (7%)	2,218	6,585	10,740	15,595	24,002	59,141
50% Above Optimized (7%)	2,886	9,592	13,794	18,570	26,459	71,302
TC = TB (7%)	4,755	14,680	20,516	27,193	34,689	101,833
Technology Exhaustion (7%)	12,860	29,820	36,092	41,123	47,863	167,758

Table C-10

Present Value of Lifetime Societal Benefits by Alternative (Millions of 2007 Dollars)
Mid-1 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	600	1,977	4,970	7,269	10,266	25,082
Optimized (7%)	935	2,778	6,165	8,601	11,398	29,878
25% Above Optimized (7%)	1,300	3,902	7,181	9,926	12,452	34,762
50% Above Optimized (7%)	1,766	5,015	8,379	11,032	13,266	39,458
TC = TB (7%)	2,579	7,472	10,467	13,177	14,866	48,560
Technology Exhaustion (7%)	4,760	10,226	12,956	15,415	16,644	60,001
Light Trucks						
25% Below Optimized (7%)	949	2,865	3,806	5,126	12,609	25,356
Optimized (7%)	949	3,625	5,253	6,738	13,973	30,538
25% Above Optimized (7%)	1,051	4,069	6,394	8,269	15,107	34,890
50% Above Optimized (7%)	1,051	5,362	7,468	9,801	16,015	39,697
TC = TB (7%)	1,204	6,186	9,478	12,713	17,920	47,501
Technology Exhaustion (7%)	1,922	7,703	10,495	13,608	18,928	52,655
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	1,550	4,841	8,776	12,394	22,876	50,438
Optimized (7%)	1,884	6,403	11,418	15,339	25,371	60,416
25% Above Optimized (7%)	2,351	7,971	13,576	18,195	27,559	69,652
50% Above Optimized (7%)	2,817	10,378	15,847	20,833	29,281	79,155
TC = TB (7%)	3,782	13,657	19,945	25,890	32,786	96,061
Technology Exhaustion (7%)	6,682	17,929	23,451	29,023	35,572	112,657

Table C-11

Net Total Benefits Over the Vehicle's Lifetime – Present Value
Societal Perspective (Millions of 2007 Dollars)
Mid-1 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	445	1,098	1,570	2,519	3,201	8,833
Optimized (7%)	581	1,378	1,853	2,711	3,439	9,961
25% Above Optimized (7%)	357	379	1,073	1,340	2,170	5,320
50% Above Optimized (7%)	197	301	685	854	1,305	3,342
TC = TB (7%)	(330)	(246)	151	(99)	(80)	(604)
Technology Exhaustion (7%)	(2,214)	(3,143)	(3,674)	(3,434)	(3,523)	(15,989)
Light Trucks						
25% Below Optimized (7%)	336	1,022	1,692	2,417	4,083	9,550
Optimized (7%)	336	1,378	2,494	3,110	4,543	11,860
25% Above Optimized (7%)	131	1,314	2,406	1,908	2,804	8,563
50% Above Optimized (7%)	131	907	2,083	2,222	3,035	8,378
TC = TB (7%)	(111)	(8)	200	(31)	(53)	(3)
Technology Exhaustion (7%)	(218)	(747)	(179)	(1,046)	(986)	(3,177)
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	781	2,120	3,262	4,936	7,285	18,384
Optimized (7%)	917	2,756	4,347	5,821	7,982	21,822
25% Above Optimized (7%)	488	1,694	3,479	3,247	4,974	13,883
50% Above Optimized (7%)	328	1,208	2,768	3,076	4,340	11,720
TC = TB (7%)	(441)	(254)	351	(130)	(134)	(608)
Technology Exhaustion (7%)	(2,433)	(3,890)	(3,853)	(4,480)	(4,510)	(19,166)

Table C-12

Savings in Millions of Gallons of Fuel Undiscounted Over the Lifetime of the Model Year
Mid-1 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	252	812	2,016	2,887	4,051	10,018
Optimized (7%)	392	1,142	2,493	3,409	4,477	11,913
25% Above Optimized (7%)	559	1,651	2,952	3,991	4,922	14,074
50% Above Optimized (7%)	753	2,140	3,509	4,504	5,322	16,227
TC = TB (7%)	1,104	3,230	4,379	5,418	5,982	20,113
Technology Exhaustion (7%)	2,127	4,504	5,507	6,374	6,755	25,267
Light Trucks						
25% Below Optimized (7%)	408	1,207	1,571	2,079	5,002	10,268
Optimized (7%)	408	1,506	2,131	2,692	5,532	12,268
25% Above Optimized (7%)	452	1,693	2,614	3,309	5,987	14,055
50% Above Optimized (7%)	452	2,241	3,058	3,946	6,361	16,058
TC = TB (7%)	530	2,648	3,964	5,245	7,288	19,675
Technology Exhaustion (7%)	843	3,308	4,410	5,686	7,683	21,930
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	660	2,020	3,587	4,966	9,053	20,286
Optimized (7%)	800	2,648	4,624	6,100	10,008	24,182
25% Above Optimized (7%)	1,010	3,344	5,567	7,299	10,909	28,129
50% Above Optimized (7%)	1,204	4,381	6,567	8,450	11,683	32,285
TC = TB (7%)	1,635	5,878	8,343	10,662	13,270	39,788
Technology Exhaustion (7%)	2,970	7,812	9,917	12,060	14,438	47,197

Mid-2 Scenario

Table C-13

Estimated Required Average for the Fleet (in mpg)
Mid-2 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below Optimized (7%)	29.9	31.6	34.1	35.0	36.7
Optimized (7%)	30.2	32.1	34.4	35.4	37.1
25% Above Optimized (7%)	30.5	32.7	34.8	35.8	37.5
50% Above Optimized (7%)	30.9	33.3	35.3	36.2	37.9
TC = TB (7%)	31.5	34.4	36.2	37.0	38.7
Technology Exhaustion (7%)	35.5	45.9	47.1	47.2	47.1
Light Trucks					
25% Below Optimized (7%)	24.1	24.9	25.9	26.3	26.2
Optimized (7%)	24.1	25.1	26.1	26.7	27.1
25% Above Optimized (7%)	24.2	25.2	26.3	27.1	27.9
50% Above Optimized (7%)	24.2	25.4	26.5	27.5	28.8
TC = TB (7%)	24.3	25.7	26.9	28.3	30.6
Technology Exhaustion (7%)	29.0	30.7	34.0	34.2	37.2
Passenger Cars and Light Trucks Combined					
25% Below Optimized (7%)	27.2	28.4	30.0	30.6	31.1
Optimized (7%)	27.3	28.7	30.3	31.0	31.8
25% Above Optimized (7%)	27.5	29.1	30.6	31.4	32.5
50% Above Optimized (7%)	27.7	29.5	30.9	31.8	33.2
TC = TB (7%)	28.0	30.1	31.5	32.6	34.6
Technology Exhaustion (7%)	32.4	38.0	40.5	40.5	42.0

Table C-14

Average Incremental Cost Per Vehicle – Consumer Perspective (2007 Dollars)
Mid-2 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below Optimized (7%)	40	118	428	576	855
Optimized (7%)	64	180	508	681	958
25% Above Optimized (7%)	120	363	667	895	1,116
50% Above Optimized (7%)	193	547	871	1,059	1,294
TC = TB (7%)	310	857	1,083	1,269	1,542
Technology Exhaustion (7%)	1,445	3,403	4,188	4,634	4,938
Light Trucks					
25% Below Optimized (7%)	126	325	521	482	475
Optimized (7%)	126	372	579	553	644
25% Above Optimized (7%)	169	487	737	864	1,276
50% Above Optimized (7%)	169	661	905	1,082	1,501
TC = TB (7%)	242	883	1,249	1,580	2,236
Technology Exhaustion (7%)	1,177	3,443	5,068	6,318	8,821
Passenger Cars and Light Trucks Combined					
25% Below Optimized (7%)	77	205	468	535	683
Optimized (7%)	91	260	539	625	816
25% Above Optimized (7%)	141	415	697	882	1,188
50% Above Optimized (7%)	183	595	885	1,069	1,388
TC = TB (7%)	281	868	1,154	1,404	1,856
Technology Exhaustion (7%)	1,331	3,420	4,565	5,367	6,692

Table C-15

Incremental Total Cost – Consumer Perspective (Millions of 2007 Dollars)
Mid-2 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	375	1,143	4,106	5,409	7,789	18,822
Optimized (7%)	595	1,734	4,880	6,396	8,734	22,340
25% Above Optimized (7%)	1,117	3,501	6,403	8,402	10,167	29,591
50% Above Optimized (7%)	1,796	5,286	8,358	9,945	11,796	37,180
TC = TB (7%)	2,878	8,271	10,396	11,913	14,056	47,514
Technology Exhaustion (7%)	13,415	32,856	40,199	43,502	44,998	174,970
Light Trucks						
25% Below Optimized (7%)	865	2,279	3,739	3,487	3,569	13,939
Optimized (7%)	865	2,605	4,155	3,999	4,834	16,458
25% Above Optimized (7%)	1,157	3,409	5,287	6,254	9,582	25,689
50% Above Optimized (7%)	1,157	4,625	6,492	7,829	11,269	31,373
TC = TB (7%)	1,660	6,185	8,961	11,428	16,789	45,022
Technology Exhaustion (7%)	8,065	24,110	36,357	45,707	66,224	180,463
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	1,240	3,422	7,845	8,896	11,358	32,762
Optimized (7%)	1,460	4,339	9,035	10,395	13,568	38,798
25% Above Optimized (7%)	2,274	6,910	11,690	14,656	19,749	55,280
50% Above Optimized (7%)	2,953	9,911	14,850	17,774	23,065	68,553
TC = TB (7%)	4,538	14,456	19,356	23,341	30,845	92,536
Technology Exhaustion (7%)	21,480	56,966	76,555	89,209	111,222	355,433

Table C-16

Present Value of Lifetime Societal Benefits by Alternative (Millions of 2007 Dollars)
"Mid2" Case

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	786	2,047	5,061	7,149	9,661	24,705
Optimized (7%)	1,027	2,742	5,885	8,026	10,371	28,052
25% Above Optimized (7%)	1,332	3,768	6,756	8,956	11,081	31,893
50% Above Optimized (7%)	1,773	4,944	7,934	9,892	11,763	36,307
TC = TB (7%)	2,487	6,966	9,597	11,326	13,085	43,461
Technology Exhaustion (7%)	6,406	14,816	18,249	20,949	22,067	82,488
Light Trucks						
25% Below Optimized (7%)	921	3,385	5,515	5,922	6,382	22,125
Optimized (7%)	921	3,771	6,180	6,807	8,454	26,132
25% Above Optimized (7%)	989	4,183	6,724	7,811	10,877	30,584
50% Above Optimized (7%)	989	5,022	7,712	9,022	12,529	35,275
TC = TB (7%)	1,189	5,819	8,821	11,038	16,030	42,897
Technology Exhaustion (7%)	2,950	11,972	16,065	19,751	26,944	77,682
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	1,707	5,432	10,576	13,071	16,042	46,829
Optimized (7%)	1,948	6,513	12,066	14,833	18,825	54,184
25% Above Optimized (7%)	2,321	7,951	13,480	16,767	21,958	62,477
50% Above Optimized (7%)	2,763	9,966	15,646	18,913	24,293	71,581
TC = TB (7%)	3,676	12,785	18,418	22,364	29,115	86,358
Technology Exhaustion (7%)	9,356	26,788	34,314	40,701	49,011	160,170

Table C-17

Net Total Benefits Over the Vehicle's Lifetime – Present Value
Societal Perspective (Millions of 2007 Dollars)
Mid-2 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	496	1,051	1,348	2,093	2,468	7,457
Optimized (7%)	531	1,193	1,463	2,023	2,331	7,541
25% Above Optimized (7%)	329	496	869	977	1,670	4,341
50% Above Optimized (7%)	143	(34)	133	388	740	1,371
TC = TB (7%)	(132)	(721)	(131)	(44)	(31)	(1,058)
Technology Exhaustion (7%)	(5,501)	(12,942)	(17,464)	(19,018)	(20,047)	(74,972)
Light Trucks						
25% Below Optimized (7%)	272	1,147	1,864	2,524	2,842	8,650
Optimized (7%)	272	1,223	2,140	2,936	3,663	10,234
25% Above Optimized (7%)	75	838	1,573	1,724	1,380	5,589
50% Above Optimized (7%)	75	495	1,372	1,392	1,523	4,857
TC = TB (7%)	(202)	(216)	62	(81)	(133)	(570)
Technology Exhaustion (7%)	(3,264)	(10,716)	(18,106)	(24,404)	(37,450)	(93,940)
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	767	2,198	3,213	4,617	5,311	16,107
Optimized (7%)	802	2,416	3,603	4,959	5,994	17,774
25% Above Optimized (7%)	403	1,334	2,442	2,701	3,050	9,930
50% Above Optimized (7%)	218	461	1,505	1,781	2,263	6,227
TC = TB (7%)	(334)	(937)	(69)	(124)	(164)	(1,628)
Technology Exhaustion (7%)	(8,765)	(23,658)	(35,570)	(43,422)	(57,497)	(168,912)

Table C-18

Savings in Millions of Gallons of Fuel
Undiscounted Over the Lifetime of the Model Year
Mid-2 Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	352	900	2,212	3,082	4,165	10,711
Optimized (7%)	463	1,210	2,571	3,459	4,466	12,170
25% Above Optimized (7%)	598	1,688	2,975	3,891	4,780	13,932
50% Above Optimized (7%)	794	2,222	3,539	4,341	5,114	16,010
TC = TB (7%)	1,121	3,163	4,277	4,977	5,692	19,230
Technology Exhaustion (7%)	2,982	6,840	8,423	9,632	10,091	37,968
Light Trucks						
25% Below Optimized (7%)	424	1,513	2,438	2,585	2,756	9,716
Optimized (7%)	424	1,687	2,732	2,971	3,656	11,470
25% Above Optimized (7%)	456	1,876	2,980	3,423	4,743	13,477
50% Above Optimized (7%)	456	2,259	3,426	3,962	5,466	15,569
TC = TB (7%)	567	2,671	3,986	4,914	7,059	19,196
Technology Exhaustion (7%)	1,420	5,551	7,543	9,274	12,588	36,378
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	776	2,413	4,651	5,667	6,921	20,427
Optimized (7%)	887	2,897	5,303	6,430	8,122	23,640
25% Above Optimized (7%)	1,054	3,564	5,955	7,314	9,523	27,410
50% Above Optimized (7%)	1,250	4,481	6,965	8,302	10,581	31,579
TC = TB (7%)	1,687	5,834	8,263	9,891	12,751	38,426
Technology Exhaustion (7%)	4,402	12,392	15,967	18,906	22,679	74,346

High Scenario

Table C-19

Estimated Required Average for the Fleet (in mpg)
High Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below Optimized (7%)	31.1	31.4	33.9	34.8	37.2
Optimized (7%)	31.2	32.3	34.8	35.8	37.7
25% Above Optimized (7%)	31.4	33.2	35.7	36.8	38.2
50% Above Optimized (7%)	31.6	34.1	36.7	37.8	38.8
TC = TB (7%)	31.9	36.0	38.6	39.8	39.8
Technology Exhaustion (7%)	35.5	45.9	47.1	47.2	47.1
Light Trucks					
25% Below Optimized (7%)	23.7	24.8	25.8	26.2	28.9
Optimized (7%)	24.1	25.1	26.1	26.9	29.6
25% Above Optimized (7%)	24.5	25.4	26.4	27.6	30.3
50% Above Optimized (7%)	25.0	25.6	26.7	28.2	31.0
TC = TB (7%)	25.8	26.2	27.3	29.7	32.3
Technology Exhaustion (7%)	29.0	30.7	34.0	34.2	37.2
Passenger Cars and Light Trucks Combined					
25% Below Optimized (7%)	27.5	28.2	29.9	30.5	32.9
Optimized (7%)	27.8	28.8	30.5	31.3	33.6
25% Above Optimized (7%)	28.1	29.4	31.0	32.1	34.2
50% Above Optimized (7%)	28.4	29.9	31.6	32.9	34.8
TC = TB (7%)	29.0	31.1	32.8	34.7	36.1
Technology Exhaustion (7%)	32.4	38.0	40.5	40.5	42.0

Table C-20

Average Incremental Cost Per Vehicle – Consumer Perspective (2007 Dollars)
High Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below Optimized (7%)	212	160	418	545	966
Optimized (7%)	220	242	588	845	1,134
25% Above Optimized (7%)	276	476	984	1,374	1,552
50% Above Optimized (7%)	352	694	1,229	1,681	1,792
TC = TB (7%)	427	1,127	1,561	2,002	2,082
Technology Exhaustion (7%)	937	2,040	2,327	2,556	2,712
Light Trucks					
25% Below Optimized (7%)	61	277	482	458	1,137
Optimized (7%)	126	372	579	610	1,356
25% Above Optimized (7%)	293	716	894	1,050	1,836
50% Above Optimized (7%)	331	751	1,063	1,345	2,292
TC = TB (7%)	501	1,217	1,458	2,003	2,715
Technology Exhaustion (7%)	705	1,560	1,918	2,300	3,048
Passenger Cars and Light Trucks Combined					
25% Below Optimized (7%)	148	209	445	507	1,043
Optimized (7%)	180	296	584	743	1,234
25% Above Optimized (7%)	283	577	945	1,233	1,680
50% Above Optimized (7%)	343	718	1,158	1,535	2,018
TC = TB (7%)	458	1,165	1,517	2,002	2,368
Technology Exhaustion (7%)	839	1,838	2,152	2,445	2,864

Table C-21 Incremental Total Cost – Consumer Perspective (Millions of 2007 Dollars) High Scenario						
	MY 2011	**MY 2012**	**MY 2013**	**MY 2014**	**MY 2015**	**5-Year Total**
Passenger Cars						
25% Below Optimized (7%)	1,965	1,544	4,009	5,120	8,799	21,438
Optimized (7%)	2,042	2,334	5,640	7,932	10,338	28,286
25% Above Optimized (7%)	2,562	4,591	9,443	12,901	14,144	43,641
50% Above Optimized (7%)	3,269	6,697	11,797	15,780	16,334	53,876
TC = TB (7%)	3,967	10,876	14,988	18,795	18,978	67,603
Technology Exhaustion (7%)	8,704	19,693	22,339	23,998	24,713	99,447
Light Trucks						
25% Below Optimized (7%)	417	1,939	3,457	3,315	8,536	17,665
Optimized (7%)	865	2,605	4,155	4,414	10,179	22,219
25% Above Optimized (7%)	2,004	5,012	6,411	7,595	13,781	34,803
50% Above Optimized (7%)	2,267	5,257	7,623	9,734	17,208	42,088
TC = TB (7%)	3,431	8,524	10,460	14,492	20,385	57,292
Technology Exhaustion (7%)	4,830	10,921	13,759	16,638	22,884	69,031
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	2,382	3,484	7,466	8,435	17,336	39,103
Optimized (7%)	2,908	4,938	9,795	12,346	20,518	50,505
25% Above Optimized (7%)	4,566	9,603	15,854	20,496	27,924	78,444
50% Above Optimized (7%)	5,536	11,953	19,420	25,513	33,542	95,964
TC = TB (7%)	7,398	19,400	25,448	33,286	39,363	124,895
Technology Exhaustion (7%)	13,534	30,614	36,098	40,636	47,596	168,479

Table C-22 Present Value of Lifetime Societal Benefits by Alternative (Millions of 2007 Dollars) High Scenario						
	MY 2011	**MY 2012**	**MY 2013**	**MY 2014**	**MY 2015**	**5-Year Total**
Passenger Cars						
25% Below Optimized (7%)	2,609	2,921	6,287	8,643	13,014	33,473
Optimized (7%)	2,731	4,347	8,674	11,879	14,976	42,608
25% Above Optimized (7%)	3,072	6,306	10,829	14,224	16,108	50,538
50% Above Optimized (7%)	3,271	8,343	12,626	16,383	17,301	57,924
TC = TB (7%)	3,498	10,667	14,689	18,459	19,303	66,616
Technology Exhaustion (7%)	5,961	12,553	15,542	18,489	19,808	72,353
Light Trucks						
25% Below Optimized (7%)	643	3,759	6,646	7,383	14,669	33,099
Optimized (7%)	1,225	5,006	8,206	9,494	17,288	41,219
25% Above Optimized (7%)	1,748	6,624	9,826	11,748	19,745	49,690
50% Above Optimized (7%)	1,995	7,016	10,899	13,564	21,513	54,987
TC = TB (7%)	2,517	8,694	11,809	15,460	22,151	60,630
Technology Exhaustion (7%)	2,612	9,721	13,002	16,441	22,825	64,601
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	3,251	6,679	12,933	16,026	27,683	66,573
Optimized (7%)	3,956	9,353	16,880	21,374	32,265	83,827
25% Above Optimized (7%)	4,819	12,929	20,655	25,972	35,853	100,229
50% Above Optimized (7%)	5,267	15,359	23,525	29,947	38,814	112,912
TC = TB (7%)	6,015	19,360	26,498	33,919	41,453	127,246
Technology Exhaustion (7%)	8,573	22,274	28,545	34,930	42,632	136,954

Table C-23

Net Total Benefits Over the Vehicle's Lifetime – Present Value
Societal Perspective (Millions of 2007 Dollars)
High Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	851	1,502	2,624	3,858	5,016	13,850
Optimized (7%)	912	2,195	3,550	4,393	5,397	16,447
25% Above Optimized (7%)	754	1,976	2,073	1,870	2,758	9,431
50% Above Optimized (7%)	287	2,135	1,730	1,307	1,843	7,302
TC = TB (7%)	(103)	909	1,271	1,053	1,392	4,522
Technology Exhaustion (7%)	(965)	(1,063)	(925)	(337)	(286)	(3,577)
Light Trucks						
25% Below Optimized (7%)	330	1,854	3,277	4,146	6,577	16,183
Optimized (7%)	576	2,458	4,166	5,229	7,625	20,054
25% Above Optimized (7%)	55	1,709	3,539	4,376	6,583	16,262
50% Above Optimized (7%)	206	1,881	3,441	4,163	5,034	14,726
TC = TB (7%)	(187)	423	1,690	1,710	2,977	6,613
Technology Exhaustion (7%)	(279)	688	2,140	2,243	3,102	7,893
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	1,181	3,356	5,900	8,004	11,593	30,033
Optimized (7%)	1,487	4,653	7,716	9,622	13,021	36,501
25% Above Optimized (7%)	809	3,685	5,612	6,246	9,341	25,693
50% Above Optimized (7%)	494	4,016	5,171	5,470	6,878	22,028
TC = TB (7%)	(290)	1,332	2,960	2,763	4,369	11,135
Technology Exhaustion (7%)	(1,244)	(375)	1,215	1,905	2,816	4,316

Table C-24

Savings in Millions of Gallons of Fuel
Undiscounted Over the Lifetime of the Model Year
High Scenario

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5-Year Total
Passenger Cars						
25% Below Optimized (7%)	904	991	2,120	2,874	4,333	11,224
Optimized (7%)	946	1,479	2,919	3,944	4,961	14,249
25% Above Optimized (7%)	1,065	2,172	3,729	4,890	5,489	17,346
50% Above Optimized (7%)	1,148	2,906	4,382	5,657	5,899	19,992
TC = TB (7%)	1,240	3,780	5,090	6,365	6,569	23,044
Technology Exhaustion (7%)	2,155	4,539	5,499	6,407	6,769	25,370
Light Trucks						
25% Below Optimized (7%)	223	1,283	2,239	2,454	4,820	11,019
Optimized (7%)	424	1,687	2,732	3,120	5,675	13,638
25% Above Optimized (7%)	639	2,279	3,318	3,877	6,496	16,609
50% Above Optimized (7%)	724	2,413	3,686	4,517	7,159	18,500
TC = TB (7%)	925	3,065	4,093	5,311	7,465	20,859
Technology Exhaustion (7%)	959	3,420	4,500	5,628	7,674	22,181
Passenger Cars and Light Trucks Combined						
25% Below Optimized (7%)	1,128	2,274	4,360	5,328	9,153	22,243
Optimized (7%)	1,371	3,166	5,651	7,065	10,635	27,887
25% Above Optimized (7%)	1,704	4,452	7,047	8,767	11,984	33,954
50% Above Optimized (7%)	1,872	5,319	8,068	10,174	13,058	38,492
TC = TB (7%)	2,164	6,845	9,183	11,677	14,034	43,903
Technology Exhaustion (7%)	3,114	7,959	9,999	12,035	14,443	47,551

APPENDIX D

Comments Received on Draft EIS

On June 26, 2008, the National Highway Traffic Safety Administration (NHTSA) issued a draft Environmental Impact Statement (DEIS) to analyze and disclose the potential environmental impacts of the proposed new Corporate Average Fuel Economy (CAFE) standards and reasonable alternative standards in the context of NHTSA's CAFE program pursuant to Council on Environmental Quality (CEQ) National Environmental Policy Act (NEPA) implementing regulations, U.S. Department of Transportation Order 5610.1C, and NHTSA regulations. On July 2, 2008, NHTSA published a *Federal Register* Notice of Availability, announcing that the DEIS was available. NHTSA's Notice of Availability also made public the date and location of a public hearing, and invited the public to participate at the hearing on August 4, 2008, in Washington, DC. On July 3, 2008, the U.S. Environmental Protection Agency issued its Notice of Availability of the DEIS, triggering the 45-day public comment period. In accordance with CEQ implementing regulations, the public was invited to submit written comments on the DEIS until August 18, 2008.

NHTSA received 66 comment letters and statements on the DEIS, and 44 people provided oral comments and statements at the public hearing. The transcript from the public hearing and written comments submitted to the agency are part of the administrative record and are available on the Federal Docket, which can be found at http://www.regulations.gov. To review these comments, enter the docket number "NHTSA-2008-0060" into the "Search Documents" field.

This appendix includes a copy of each comment document NHTSA received, including the public-hearing transcript. The transcript is presented first, followed by the comment letters submitted to the Federal Docket.

The Federal Docket assigned an identification number to each comment document. For this appendix, the document identification number is indicated in the upper right-hand corner of the first page of each comment document. The Center for Biological Diversity submitted its primary comment document (identification number 0570) with multiple attachments. The attachments (each of which was assigned a document identification number) were placed into the docket out of order. Because in this appendix we present the attachments in the order in which they were placed into the docket, regardless of the document identification number, the assigned numbers are not necessarily sequential.

Comment Accession and Page Number						
Acc. No.	Pg. No.	Commenter		Acc. No.	Page No.	Commenter
0530	D-156	Dale Olson		0558	D-204	Marissa S. Knodel
0531	D-157	Notice of Availability		0559	D-206	Northeast States for Coordinated Air Use Management
0532	D-158	Deborah Weinischke		0560	D-210	American Jewish Committee
0533	D-159	Robert Buchard		0561	D-213	Consumer Federation of America
0534	D-160	Peggy Gilges		0561.1	D-215	Consumer Federation of America
0535	D-161	James Farrelly		0561.2	D-229	Duplicate 0561.1
0536	D-162	Ceribon		0562	D-250	Dennis McGinn
0537	D-163	Melissa Briese		0563	D-254	Adam Lee
0538	D-164	David Levin		0564	D-258	Duplicate 0561.2
0539	D-165	John Scheiber		0565	D-361	CBD Attachment Social Cost of Carbon
0540	D-166	Fred Korhne		0566	D-362	CBD Attachment Summer Arctic Ice
0541	D-167	Docket numbering error		0567	D-379	CBD Attachment IPCC 2007 Rpt.
0542	D-168	James Prescott		0568	D-489	CBD Attachment Ocean Acidification
0543	D-169	Michael Wadas		0569	D-490	CBD Attachment Health & Diesel Engines
0544	D-170	Michael Kirchner		0570	D-1159	CBD Attachment An Ocean Blueprint
0545	D-171	Mary Hamilton		0571	D-1266	CBD Attachment Traffic and Health
0546	D-172	Robert Keiter		0572 & 0572.1	D-259	Center for Biological Diversity
0547	D-173	Fred Marshall		0572.2	D-309	CBD Attachment Exhibit A
0548	D-174	Carl Henne		0572.3	D-360	CBD Attachment EPA Rule
0549	D-175	Nancy Miller		0573	D-1267	Duplicate of 0568
0550	D-176	Sarah Larsen		0574	D-1782	Alliance of Automobile Manufacturers
0551	D-178	James Derzon		0575	D-1810	Union of Concerned Citizens
0552	D-179	Alina Fortsen		0576	D-1814	Public Citizen
0553	D-181	Tara Morrow		0577	D-1268	Jaafar A. Rizvi
0554	D-183	James Adcock		0577.1 & 0577.2	D-1270	Jaafar A. Rizvi written statement
0555	D-188	Elizabeth McGurk (NCC)		0578	D-1273	CBD Attachment – Particle Pollution Report
0555.1	D-190	National Council of Churches, Eco		0579	D-1274	Docket numbering error – does not exist
0556	D-192	Catherine Easton		0580	D-1275	CBD Attachment Federal Register Polar Bear
0557	D-195	Natural Resources Defense Council		0581	D-1368	CBD Attachment Paleoclimate Sea Level

Comment Accession and Page Number						
Acc. No.	Pg. No.	Commenter		Acc. No.	Page No.	Commenter
0582	D-1369	CBD Attachment GHG and Hybrids		0594	D-1545	CBD Attachment Chrysler Web site
0583	D-1370	CBD Attachment Climate Change Economics		0595	D-1877	U.S. Environmental Protection Agency
0584	D-1371	CBD Attachment Global Climate Projections		0596	D-1890	Environmental Defense Fund (cover)
0585	D-1822	Attorneys General		0596.1	D-1901	Environmental Defense Fund (comment)
0586	D-1392	CBD Attachment NHTSA Ignored Market Demand		0596.2	D-1901	Environmental Defense Fund (Supplement)
0587	D-1430	CBD Attachment USGS Climate Change and Polar Bear		0597	D-1561	CBD Attachment 2008 Fuel Economy Guide
0588	D-1431	New York Department of Transportation		0598	D-1906	Sierra Club
0589	D-1435	CBD Attachment Global Climate Projections – Ocean Acidification		0599	D-1594	CBD Form Letter Master
0590	D-1492	CBD Attachment Global Climate Projections – Ocean Acidification continued		0600	D-1911	Centers for Disease Control - DEEHS
0591	D-1513	CBD Attachment Arctic Sea Ice		0601	D-1780	CBD Attachment Scientific Reticence and Sea Level Rise
0592	D-1543	CBD LA Times New Article		0602	D-1781	CBD Attachment Anthropogenic CO_2 in Oceans
0593 & 0593.1	D-1544	Duplicate of 0588		0603	D-6	U.S. DOT/NHTSA - Transcript of Public Forum dated August 4, 2008 (Revised Transcript)

Acc. No. 0603

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

PUBLIC FORUM

CORPORATE AVERAGE FUEL ECONOMY

DRAFT ENVIRONMENTAL IMPACT STATEMENT

NTSB

429 L'Enfant Plaza, SW, Washington, D.C. 20594

August 4, 2008

(Revised Transcript)

BEFORE:

Steve Kratzke

Julie Abraham

Michael Savonis

Carol Hammel Smith

Jessica Wilson

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C O N T E N T S

P R O C E E D I N G S

MR. KRATZKE: I'd like to welcome you to our public hearing on the draft environmental impact statement for our proposed corporate average fuel economy standards or CAFE rule for cars and light trucks for model years 2011 through 2015.

Before I start a brief overview of some ground rules, I'd like to ask you to please ensure that your cell phone is set to vibrate or silent. It can be distracting, especially if your ring tone is unique.

As you can see, we have nearly 60 people registered to present their thoughts and share their perspectives on this topic with us. So we'd like to get started right away. If you do the math of five minutes per speaker times 60, we have five hours worth of presentations.

Just so that it's clear to everyone, speakers will present in the order in which they registered with us. If you have not registered, we'd like to ask you to do so at the back of this room. We want to hear from everyone who has thoughts to share with us now.

If a speaker is not present for their scheduled time, they will be moved to the end of the list. They will be allowed to speak, but we are going to move ahead as quickly as we can to make sure we hear from everyone.

To begin, I'd like to introduce myself and the panel here to listen to your comments today. I am Steve Kratzke. I am the associate administrator for rulemaking for the National Highway Traffic Safety Administration. And my office is responsible for performing the environmental analysis for this rulemaking, and for doing the rulemaking on the corporate average fuel economy standards for those years.

On our panel today besides me we have four people who are much more aware than I am of our proposed rule and the draft environmental impact statement. And I'd like to introduce them.

On my right I have Julie Abraham, who is the director for our office of international policy, fuel economy, and consumer programs. Ms. Abraham led the effort to both put out our proposed standards for 2011 through 2015, and this environmental impact statement.

On my left I have Mr. Mike Savonis, who is the team leader for the CAFE rulemaking environmental impact statement team. Mr. Savonis is the one who has orchestrated and coordinated this large effort.

On the far right of the table is Ms. Carol Hammel Smith, who is a program analyst for NHTSA in our CAFE office. She specializes in environmental analysis. And on the far left we have Ms. Jessica Wilson who is an attorney in our chief counsel's office.

So we feel like we have the people here who really understand what we have put forward as our analysis, and we would like to hear the reactions of the interested public to that proposed analysis.

Our schedule for the day is going to begin with Ms. Abraham giving a brief overview of our environmental impact statement project. And then we are going to spend the rest of the day hearing from you.

We are going to have lunch from 12:30 to 1:30, and we will have breaks from time to time so that people don't have to run out and miss what's here.

Since we have a lot of people who would like to speak, I am going to call people up in groups of 12 to be seated near the podium. This will allow us to make a quicker transition when people are speaking.

We have a court reporter today here with us in front of the podium who is going to prepare a verbatim transcript of the testimony. The transcript will be available in our public docket.

We are going to videotape the proceedings as well, and so we ask for both of these sources so that when you begin to speak, please state your name and speak clearly for the record so that we can correctly identify you.

Due to the number of speakers, your comments are going to be limited to five minutes. We're going to notify you with a green card which will be held up in back when it is okay for you to start. And we will indicate to you when you have one minute remaining of your time by holding up a yellow card, and giving an audible remark of one minute.

When the five minutes are completed, we will hold up a red card and give an audible statement of time's up. At that point, we would appreciate it if you would wrap up your comments. We'd like to give everyone a chance to present today, so we're not going to be granting extensions of the five minutes of allotted time.

I would like to make clear that we're in the middle of a comment period. We want all of you to give us full comments where you can make sure that we have a record of what you believe needs to be conveyed. That is due in two weeks, on August 18th.

Today is for you to have five minutes to talk to the people who are going to prepare the environmental impact statement, and make sure that we understand your major points. We need to hold to that five minutes.

As this is our chance to hear from you, since you've already had the opportunity to read our hundreds of pages draft environmental impact statement, there aren't going to be questions and answers in this hearing. We want to hear from you.

We'd also like to thank you for your interest in this issue, and for taking the time out of your schedules to come to this hearing. We are really looking forward to hearing your perspectives, your suggestions, and your views of what are the most important things, good, bad, or just not covered in our draft environmental impact statement.

And with that, I would like Ms. Abraham now to give a brief overview of the draft environmental impact statement. I thank you.

MS. ABRAHAM: Thank you, Mr. Kratzke, and good morning everybody. I would like to begin by reviewing briefly the recent steps that brought us to this hearing.

In March and in April, NHTSA informed the public through notices in the Federal Register regarding our plans to prepare the draft environmental impact statement or for short, draft EIS.

First, on March 28th, we published a notice announcing our intent to prepare an EIS and requesting scoping comments. One month later we published a supplemental notice of public scoping.

The purpose of these notices was to request public views and comments on the scope of the agency's analysis, including the impacts and alternatives that the draft EIS should address, as well as to inform NHTSA of any available studies that would assist us in the impact analysis of global climate change and other issues.

On May 2nd we published our notice of proposed rulemaking, proposing fuel economy standards for model years 2011 through 2015 for both passenger cars and light trucks.

Under the proposal the average fuel economy for cars would begin at 31.2 miles per gallon for model year 2011, an increase to 35.7 miles per gallon for model year 2015; while the average fuel economy for light trucks would begin at 25 miles per gallon for model year 2011 and increase to 28.6 miles per gallon for model year 2015.

The agency also sought comment on a wide range of alternatives. On July 2nd we published a notice for this public hearing, and one day later, we published a notice announcing the availability of the draft EIS.

The draft EIS reflects our careful review and consideration of public comments that were provided, as well as the suggested studies. It compares the potential environmental impacts of the NHTSA's proposed standards and reasonable alternatives.

In developing its range of alternatives, NHTSA identified alternative stringencies that represent the full spectrum of potential environmental impacts. So for each of the alternatives, the draft EIS analyzes direct, indirect, and cumulative impacts, and analyzes impacts in proportion to their magnitude.

Based on climate models and other methods, the document analyzes the air pollutants, fuel savings, and greenhouse gas emissions for all alternatives. It also calculates the corresponding changes in sea level, precipitation, and temperature. In addition, it analyzes cumulative impacts on resources, ecosystems, human health, industries and settlements, among other things.

Following this public hearing, there will be an additional two week period as Mr. Kratzke indicated for interested parties to submit written comments on the draft EIS. I invite you to do so. This will ensure that we have the full benefits of your views and concerns.

The next steps will be our issuance of a final environmental impact statement, followed by a final rule for CAFE standards.

In conclusion, I and the rest of the panel look forward to hearing from you today. Thank you.

MR. KRATZKE: Thank you, Ms. Abraham. I would now like to call up the first 12 registered speakers and I would apologize in advance if I mispronounce your name. As someone named Kratzke, consonants are pretty tricky, so I will apologize.

The first 12 are, Julie Becker, Adam Lee, Dennis McGinn, David Westcott, Mark Cooper, Lena Pons, Eliza Berry, Ann Mesnikoff, Doug Molof, Matt Dernoga, Jazzlin Allen, and Sam Blodgett. So with that, I'd like to invite Ms. Becker to begin.

MS. BECKER: Good morning. My name is Julie Becker, and I am the vice president for environmental affairs at the Alliance of Automobile Manufacturers. The Alliance --

(Discussion off the record.)

MS. BECKER: My name is Julie Becker. I am the vice president for environmental affairs at the Alliance of Automobile Manufacturers.

The Alliance is a coalition of 10 car and light truck manufacturers, including the BMW Group, Chrysler LLC, Ford Motor Company, General Motors, Mazda, Mercedes Benz USA, Mitsubishi Motors, Porsche, Toyota and Volkswagon. We represent the largest group of companies directly impacted by NHTSA's CAFE rulemaking.

The Alliance shares with all Americans concerns about energy security and climate change. Last year Alliance members supported and they continue to support the Energy Independence and Security Act of 2007, a tough new national energy law that raises fuel economy to 35 miles per gallon by 2020, a 40 percent increase.

Higher mileage means low carbon, lower carbon dioxide emissions. Under the energy law, the United States auto industry will dramatically reduce CO_2 by 30 percent, which makes us the first industry to commit to such challenging CO_2 reductions.

The Alliance submitted in depth comments, and it's

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a scoping plan for this draft EIS and will submit comments further on August 18th. Today, I would like to recap several key issues that we believe NHTSA needs to address before it completes its work on the EIS.

The first issue relates to NHTSA's inclusion of a no action alternative in its array of options. In our scoping comments, the Alliance noted that the 2007 energy bill does not allow for a no action option. Instead the energy bill sets a clear trajectory for increasing fuel economy standards for the span of a decade, and requires at least steady progress toward a 35 mile per gallon goal in model year 2020. We do not think it is appropriate for NHTSA to continue to rely on no action as its starting point.

The next issue relates to NHTSA's ability to defend it's position in ongoing or future litigation. Let me explain. NHTSA petitioned the Ninth Circuit to review En Banc the Center for Biological Diversity decision. One question before the En Banc panel would be whether the reviewing Courts lack the power to order the preparation of an EIS as opposed to ordering the agency to reconsider whether an EIS is appropriate.

The En Banc petition has not yet been acted upon. Since the position NHTSA took there was sanctions by the solicitor general. It would seem that NHTSA needs to reserve its right not to perform an EIS at all.

In order to preserve that right, NHTSA should also produce an environmental assessment, a finding of no significant impact for the current rulemaking. If NHTSA decides to proceed in any other manner, it risks wounding its own En Banc petition. So it is critical for NHTSA to take this approach.

In its comments, the Alliance noted that NHTSA already considers environmental impact and energy conservation when it sets CAFE standards. Therefore, CAFE rulemaking is the functional equivalent of performing an EIS.

Under the functional equivalence doctrine, an agency need not prepare an EIS if it has already undertaken the functional equivalent of an EIS as part of its rulemaking process. However, in its draft EIS for the CAFE rulemaking, NHTSA takes the position that it cannot rely on the functional equivalence doctrine.

In our view there is a solid argument for the functional equivalence doctrine here, and NHTSA should reconsider its position on this issue. At a minimum, NHTSA should assert the functional equivalence doctrine as an alternative basis that supports its final course of action.

I have three additional points to make before concluding. First, the draft EIS appears to be setting a significant precedent regarding analysis of the trans-boundary effects.

On page 1-11 of the draft EIS NHTSA argues it should analyze trans-boundary effects of the CAFE standards quoting a 1997 CEQ guidance document stating that agencies must analyze such effects underneath them. The statement seems directly at odds with judicial precedent and agency precedent, and we would like for NHTSA to reconsider this.

Second, the draft EIS incorrectly disregards the environmental impact of the fleet turnover effect, and this was explained in our scoping comments. The Alliance asks NHTSA to consider the fleet turnover effect, and the air quality impacts that will result from heightened CAFE standards.

Instead, NHTSA is treating this as an economic impact and an indirect one, which we don't think is appropriate.

Finally, I would note that our scoping, in our scoping comments, we asked NHTSA to consider how to construe the term ratably, a term that the Energy Dependence and Security Act of 2007 makes central. And so we would ask you to reconsider that issue as well.

Thank you for this opportunity to testify.

MR. KRATZKE: Thank you, Ms. Becker. Mr. Lee.

MR. LEE: Members of the committee --

(Discussion off the record.)

MR. LEE: Thank you. My name is Adam Lee. I am president of Lee Auto Malls, which is located throughout the State of Maine. I am a third generation car dealer. I have been in this business my whole life.

Our company was founded in 1936 by my grandfather, with a small Chrysler dealership. Today, we have 12 new and used car dealerships throughout the State. We are the number one seller of hybrid cars in the State of Maine. We are also the largest Dodge and Jeep dealer in the State.

Last year we sold approximately 7,000 new and used cars. I am not an economist, nor am I a scientist. I don't know how to build a car, or run an automobile plant. I've never even changed the oil in my car. However, for most of my life I have been selling new and used cars and trucks. I still talk to customers every single day.

I came to Washington today because when I listen to the news I sometimes feel like I must be the only person in the car industry actually talking to real customers. Here is what I hear every single day.

How long is the wait for a Prius. Do you have any Honda Fits in stock? Why doesn't Chrysler offer a car that gets better than 30 miles per gallon? Or the other types of calls I get, what's my Tundra worth? Can I get rid of my Suburban?

The answer to these questions are simple. The wait for a Prius is six months. I have no Fits or Yaris. Your

Suburban is not worth enough for you to be able to trade out of it, because generally you owe more than it's worth.

Consumers want to buy vehicles that get more than 30 miles per gallon. And I'm not just talking hybrids. Car dealers have people waiting for good old fashioned small cars that get good fuel economy. They've been demanding them for years with very few choices, and almost no choices from Detroit.

This is not a new situation, but with gas at $4 per gallon, the demand is overwhelming and the lack of choices is dramatic.

Our big Chrysler dealership in Portland, Maine, has about half as many sales people as we had around a year ago. We have fewer people working in the office, fewer people working in our service department. They are no longer employed because we don't have the cars to sell that people want to buy.

This means fewer sales people frequenting the corner store, the dry cleaners, the hardware store. It's bad for the economy. General Motors just announced a loss of $15.5 billion. That's for the quarter. Ford just announced an $8.7 billion loss. Standard & Poor's just lowered to (indiscernible) the three's credit rating to junk status, and even Toyota who can do no wrong is shutting down its truck plant in Texas for three months. What they are doing is not working.

So how did we get here? In 1975 Congress mandated our first fuel economy standards. Unfortunately, in the last 20 years, these standards have not changed a bit. NHTSA could and should have done more. I believe our lack of progress is largely a regulatory failure.

Anyone who watches the auto industry knows that the manufacturers have never done anything in the name of safety or the environment unless they are forced to, whether it's seat belts, air bags, catalytic converters, Detroit has always insisted that they could not pay for them, until it becomes mandated, at which point you would think they invented the word unleaded gas.

NHTSA plays a real role in determining what our fuel economy will be. You analyze the impact of CAFE on Detroit. And I think that your assumptions are based on incorrect data. Gas costs $4 a gallon, not $2. The new technologies are coming down in price. Consumers have changed their habits and their view of the future.

Now is the time for NHTSA to act. Don't drag your feet. Don't look to Detroit for answers. Look to the American consumers. They are demanding change. They've cleaned our shelves of small cars, and they are desperate to trade in their gas guzzlers.

I've been selling Prius' since they came out seven years ago, and since that time every Toyota dealer I know has been selling them for list price and making a very nice profit. Demand is so strong, people have stopped negotiating. This is a car dealer's dream, a car people want so badly they don't negotiate.

It's frustrating to have a car sell this well and not have enough of them. I can't blame Toyota for having a hit, however, I can blame Detroit for not having one. If you want to know how bad it really is, read Automotive News. This is an editorial from two weeks ago.

It's distressing that some auto makers are back in Washington whining about meeting new fuel economy standards at a time when their customers are demanding vehicles that exceed the regulatory mandates. These cars that Detroit bet their future on and mine are not selling.

For over 70 years my family has been selling American made cars. I am a third generation running this family business. My 11 year old son thinks he will do what his father, grandfather, and great grandfather did to earn a living, sell American cars. Will there be anyone left still making cars in Detroit? We need your help. Thank you.

MR. KRATZKE: Thank you, Mr. Lee. Mr. Dennis McGinn.

MR. McGINN: Good morning. I'm retired Admiral Dennis McGinn. Mr. Kratzke, members of the panel, thank you for the opportunity to share my views which are based on over 35 years of service to the nation in the United States Navy, and more recently as a senior executive with extensive experience with the Science, Technology of Energy, Transportation and the Environment.

The EPCA requires the Secretary of Transportation to establish average fuel economy standards and when setting "maximum feasible" fuel economy standards, the secretary is required to, "consider technological feasibility, economic practicability, the effect of motor vehicle standards of the government on fuel economy, and the need of the United States to conserve energy."

Today I'd like to focus on that last requirement, and specifically on the multiple national security costs of our present level of oil dependency. In the interest of time, and in consideration of the many witnesses schedule to appear before you, I will give you my bottom line up front.

Our continued dependency on oil constitutes a clear and present danger to our national security, economically, militarily, and diplomatically. These dangers involve real, quantifiable costs, and these costs do not appear to be adequately included in your assumptions for the proposed fuel economy rule.

As a result, your draft environmental impact statement is at best incomplete, and more importantly, fundamentally flawed by its reliance on outdated data and unsupported assumptions about the real costs of this nation's ever growing consumption of oil. Erroneous assumptions based on old data inevitably leads to fundamentally flawed conclusions.

Ignoring these costs is just not a mistake. It is a threat to our national security because it precludes fuel savings our citizens and nation critically need at this moment in our history.

Our burgeoning demand for oil weakens U.S. diplomatic leverage around the globe, burdens our armed forces, and leaves the United States' economy vulnerable to unpredictable price spikes and an ever growing trade imbalance.

Taken together, these dynamics create a daunting national security challenge that must be met immediately. With oil at over $130 a barrel, over a million dollars each minute is draining out of our economy, increasing our trade deficit, creating huge opportunity costs, and most significantly, putting money in the hands of regimes that are hostile to our interests.

OPEC recently warned that prices, oil prices would experience an unlimited increase in the event of a military conflict involving Iran over its nuclear program. A very real consequence of such confrontation is that Iran, in a bid to preempt or respond to U.S. military action would close the Straight of Hamus through which 20 percent of the world's oil supply passes. The impact would be swift and sure. Unprecedented spikes in oil costs, and a deep and lasting effect on the U.S. and world economy.

The ongoing impact of our oil dependency already threatens our national security economically. We lose over $35 billion from our economy every month, and oil imports now account for over half of our annual trade deficit. We are exposed on a daily basis to oil price shocks and supply disruptions.

Regardless of how they are caused, by global market dynamics, natural disasters, terrorist attacks, or politically motivated oil embargos, the trends of our growing oil demand in a business as usual mode will make those price shocks much more frequent, deeply felt, and longer lasting.

In addition, there are national security costs and risks involved in addressing climate change. Last year top retired three and four star military leaders in a report from the Center on Naval Analysis, global warming poses a "serious threat to America's national security, acting as a threat multiplier for instability in some of the world's most volatile regions, adding tension to stable regions, worsening terrorism, and likely dragging the U.S. into fights over water and other resource shortages.

Congress set a floor and not a ceiling on CAFE standards. Your rulemaking is intended to take a host of factors into account to set the right level. Throughout our history Americans have successfully met critical challenges in both war and peace. Building on a new, clean energy economy has become one of the greatest challenges and opportunities of our time.

The key questions for all of you and your colleagues in making this rule as you go forward are, how will the actions on CAFE by this agency and this administration be viewed in 10 or 20 years? Will we be able to look back and say that a bold, comprehensive, and enlightened mandate produced substantial oil savings, increased our national security, and helped our economy and significantly reduced carbon emissions.

We have less than 10 years to change our oil dependency course in significant ways. Our nation's security depends on the swift, serious, and thoughtful response to these challenges, and by the significant impact your deliberations rulemaking will have on carrying out the intent of Congress and to the benefit of the American people. Thank you, Mr. Kratzke, and members of the panel.

MR. KRATZKE: Thank you, Admiral McGinn. Mr. David Westcott.

MR. WESTCOTT: Good morning. My name is David

Westcott. I'm chairman of the NADA regulatory affairs committee, and a Buick, Pontiac, GMC, Isuzu, Suzuki dealer in Burlington, North Carolina.

NADA represents 19,000 franchise automobile and truck dealers who sell new and used vehicles in this country. While together we employee in excess of 1,100,000 people nationwide, a significant number are small businesses as defined by the SBA.

Before I get specific in my comments on the draft environmental impact statement, permit me to give you a feel for what is going on in the new vehicles sales marketplace. July was one of the worst months in the history in the last two decade in new vehicle sales.

This was due to a number of factors, including the sub-prime lending crisis that has now hit our industry. Consumers have less cash. Consumer debt is up. Financial institutions are much tighter on credit. Negative equity for consumers wanting to trade is at an all time high, often as much as $15,000 per vehicle. There are very few trade-ins on new vehicles. And used vehicle sales are far outnumbering new vehicle sales.

I urge you to keep these market realities in mind as you proceed with considering the testimony of everyone today and the issues you have to decide.

In the past, NHTSA has consistently and adequately

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assessed and accounted for the potential environmental impacts of its proposed CAFE standards. NADA therefore disagrees with the 2007 Ninth Circuit Court of Appeals decision in Center for Biological Diversity v. NHTSA, which reviewed NHTSA's '06 reform light truck standards, and suggests that it is incumbent upon NHTSA to conduct a formal EIS in conjunction with its model year 2011-2015 proposal, CAFE proposal.

I understand that NHTSA has petitioned the Ninth Circuit for rehearing, and the EIS issue is awaiting a response.

Importantly, CAFE standards equate the greenhouse gas emissions in that CAFE compliance is measured by capturing greenhouse gases emitted by regulated motor vehicles. Thus the draft EIS appropriately suggests that model year 2011 through '15 [sic] proposal likely will result in the overall motor vehicle greenhouse gas emission reduction below what will occur without standards.

Of course, this conclusion assumes that purchasers will buy new vehicles covered by CAFE proposal, and hereby bring them into the fleet at the rate assumed by NHTSA and that once introduced into the fleet, they will be driven to the same degree that NHTSA has assumed.

To that extent, purchasers do not buy -- to the extent that purchasers do not buy vehicles regulated by the

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CAFE proposal and bring them into the fleet as predicted, whether due to their higher cost or lack of desirability, the CAFE proposal will necessarily fail to achieve this hoped for level of environmental performance.

This jalopy affect phenomenon recently was demonstrated by the failed introduction of the '07 model year medium and heavy-duty truck rules governed by the new EPA emissions mandates that increase their costs and arguably compromise their fuel economy and reliability.

Similarly, to the extent vehicles regulated by the CAFE proposal are used by NHTSA predicts after introduction into the fleet, the proposal will necessarily fail to achieve its expected level of environmental benefit. Due to the rebound effect, vehicles with lower operating costs predictably will be used more than the vehicles they replace.

Environmental impacts that correlate with miles driven, traveled, such as those associated with greenhouse gases will be impacted to the degree of any such rebound effect, reducing any delay or forecast in environmental performance benefits.

In addition to recognizing the critical role of fleet turnover in vehicle miles traveled, play with respect to environmental performance, the final EIS should consider only those measured, real and measurable environmental impacts. Thank you very much for commenting time.

MR. KRATZKE: Thank you, Mr. Westcott. Mark Cooper, please.

MR. COOPER: Good morning. I am Dr. Mark Cooper, director of research at the Consumer Federation of America. We appreciate the opportunity to appear today and commend the National Highway Traffic Safety Administration for holding this hearing. My comments are sponsored by CFA and over two dozen of its member groups.

We urge the administration to hold hearings all across the country, not just here in Washington in the dead of August, so the public can weigh in on the issue of fuel economy, which is vital not only to consumer pocketbooks, but also to national security and the environment.

Consumer attitudes and behavior toward fuel economy play a vital role in NHTSA's market model and analysis, and as we show in our comments, NHTSA has completely misjudged the consumer. There would be no better way for NHTSA to correct this flaw than to hear directly, in person, from the people who it has failed to comprehend in its analysis.

There are two problems in the draft environmental impact statement that render it woefully inadequate to address the public policy of the act. First, the underlying analysis is so fundamentally flawed that the agency has not considered an appropriate range of policy options for which the environmental impact should be evaluated.

Erroneous assumptions about market fundamentals, about consumer behavior and attitudes towards fuel economy, auto making capabilities to incorporate fuel savings technologies, and the price and value of energy have led NHTSA to center its analysis on a level of fuel economy that is so low that it sheds little light on what the environmental impact of a reasonable fuel economy standard would be.

Consumers are looking for higher mileage in new vehicles today than NHTSA has mandated for seven years from now. The product plans on which NHTSA based its rule seven years in the future have already been torn up by the automakers, but belatedly recognize the shift in consumer behavior.

The mix of cars and trucks that NHTSA projects, there's no relationship to the vehicles that consumers are buying. Rules that are not connected to reality violate the act and the administrative procedures act.

If you don't think that people will buy and drive more fuel efficient vehicles, you must be living under a rock.

The crucial rule of higher fuel economy standards is to push the automakers to deliver vehicles that consumers want, and to push the auto industry to the maximum technologically feasible and economically practicable level.

NHTSA has failed to do so.

The second problem in the draft environmental impact statement stems from the fact that NHTSA takes a fundamentally flawed approach to its externality analysis. This was evident in the analysis of the military and strategic externalities in the proposed rule. There NHTSA engaged in reasoning that can at best be described as blind incrementalism.

Rather than see improvements in fuel economy as part of a broader solution to the national oil addiction, NHTSA argues that the cost to rule alone cannot solve the problem, it does not deserve to be counted as making a contribution to the solution.

Implementing a law entitled the Energy Independence and Security Act NHTSA arrived at the outrageous conclusions that oil consumption has no military or strategic value whatsoever.

The analysis of environmental impact suffers from the same affliction, because improvements in fuel economy alone do not solve the climate change problem. They are shown to have zero effect on the damage that global warming will do. Yet every reasonable analysis of the big picture and the global impact of greenhouse gas emissions recognizes that the reduction of emissions in the transportation sector must play a large role in the overall solution. Indeed, because of the nature of the sector, it is vital to get the maximum contribution from transportation sources.

NHTSA's approach embodies a myopic bias against action. Because no individual policy can solve the problem, this approach will reject every policy measure individually, even though taken together they can actually do the job. In NHTSA's view the whole is not even equal to the sum of the parts.

The challenge of national security and environmental impact that emanates from NHTSA's addiction, the nation's addiction to oil, are global and multifaceted. The analytic framer must recognize that fuel economy standards are an important part of the broader issue.

Our recommendation that you increase the level of the standards for 2011 and 2012, and that you withdraw the 2013 through 2015 proposals so that you can fix the fundamentally analytic flaws in the analytic framework and the erroneous economic assumptions is all the more compelling in light of the mounting evidence that the rule NHTSA has proposed fails to be a reasonable standard that comports with the act. Thank you.

MR. KRATZKE: Thank you, Dr. Cooper. Lena Pons, please.

MS. PONS: I'm Lena Pons, policy analyst at Public Citizen. We have a number, we appreciate the opportunity to testify, and we have a number of concerns about the draft environmental impact statement which will fall into three categories.

The first is the range of alternatives does not constitute the range of alternatives envisioned under the National Environmental Policy Act, and does not meet the requirements under the regulation.

Under the regulation set forth under the National Environmental Policy Act, agencies are required to consider a range of alternatives that include all reasonable regulatory alternatives. The regulatory alternatives that are considered in this proposal effectively are a confidence bound around the optimized scenario proposed in the regulation.

Additionally, under the regulations, agencies may consider regulatory alternatives that are not in the jurisdiction of the lead agency, which would include more protective types of regulations such as greenhouse gas regulations for motor vehicles, such as those envisioned by the State of California and other states, and also part of the EPA's proposed greenhouse case, economy wide greenhouse gas regulations.

Additionally, the no action alternative should not be considered to be an extension of the situation as it stands, but should be a reflection of what would happen were there no regulatory intervention.

Other reasonable alternatives would include a situation wherein there was additional increases in fuel economy standards beyond the period of the Energy Independence and Security Act, which would require only that vehicles reach a standard of 35 miles per gallon for the combined fleet, cars and light trucks by 2020.

However, given the fact that there are significant market incentive and also environmental incentive to extend the standards beyond that level, then there is a likely, there's likely a reasonable alternative to consider what would happen if you had standards that extended beyond that level.

Considering that this is a new type of environmental impact statement, because it considers global impacts, it's very important that the agency put the impacts in a proper context. The agency has not put the environmental impacts into a proper context, considering the issues of global warming.

Regardless of the target, NHTSA needs to provide some means of comparing the various alternatives. The way the draft environmental impact statement is currently contextualized, NHTSA states that fuel economy standards alone cannot stop global warming. But the issue is not whether fuel economy standards alone can stop global warming.

The issue is to evaluate various environmental impacts of the various regulatory alternatives.

NHTSA has not presented a regulatory alternative that would result in actually reducing greenhouse gas emissions from motor vehicles. This is unacceptable. NHTSA has the responsibility to use its expertise to pose a theory wherein there is a regulatory alternative that could result in producing impacts that actually reduce greenhouse gas emissions from the motor vehicle sector.

And considering again that there is leeway for the agency to consider impacts that are the result of regulations that are outside of the agency, lead agency's jurisdiction, then it could look at things that would address vehicle miles traveled reductions, or other types of policies that might, as a whole, result in reductions that will result in improving the situation in terms of global warming, which again goes to the issue of context.

It is very important that this environmental impact statement reflect the situation that we are currently in.

With my final minute I would like to make some statements about the Volpe model. All of the regulatory alternatives that are considered in the draft environmental impact statement are the result of modeling using the Volpe model. This is problematic because the Volpe model does not completely look at all of the available technologies. It does not look at, and it applies various optimization factors which do not reflect what the most aggressive possible control regulations would be.

Additionally, the Volpe model bars certain types of techniques, such as down weighting and performance reduction, which may seem like strange things to do, because we've traditionally considered them to be problematic. However, given the significant dangers to the environment as a result of global warming, it's important to consider these things as well. Thank you very much.

MR. KRATZKE: Thank you, Ms. Pons. Ms. Eliza Berry.

MS. BERRY: Good morning. My name is Eliza Berry. I grew up in New York and I'm currently a college student in Minnesota. I'm here today because like many of my peers I'm incredibly concerned about global warming.

The Intergovernment Panel on Climate Change reported in the 2007 fourth assessment report that the best action plan for avoiding the most severe impacts of global warming, such as widespread species lost and global declining food production requires reducing global greenhouse gas emissions by 80 percent by the year 2050.

The report states that to get on track towards achieving this goal, global greenhouse gas emissions must peak in no more than 10 years. As a 21 year old, I am fully aware that this 2050 deadline for cutting the majority of greenhouse gas emissions will occur during my lifetime.

With its draft environmental impact statement, NHTSA has unfortunately sent the message that global warming is such a massive problem that the agency can do little about it. The report says that despite the fact that the transportation sector is responsible for 20 percent of U.S. greenhouse gas emissions, the statement concludes that we should not increase fuel economy standards from 31.6 miles per gallon to 35 miles per gallon in 2015, because doing so will not reduce global ocean temperature in the year 2100.

I am here today because young people like me do not care to live a world where devastating global warming impacts are considered to be simply inevitable.

The draft environmental impact statement does not use the appropriate scale with which to measure the benefits of an increase in fuel economy standards. This scale has only allowed NHTSA to prove that a 3.4 mile per gallon increase in vehicle efficiency in the U.S. is not going to be the one thing to save the entire planet from global warming. I don't think that very many people would be surprised by this conclusion.

By measuring the importance of a shift in fuel economy standards like this, NHTSA has fundamentally missed something. Few people would claim that there is one silver bullet to solving global warming. Rather, we need to do everything in our power to cut greenhouse gas emissions in all sectors, the transportation sector included.

Together these seemingly small changes will make a major difference. And if the U.S. leads the way in cutting emissions, other countries will follow, thus making an even greater difference on a global scale.

I would like to ask NHTSA to acknowledge the power of collective action and take responsibility for greenhouse gas emissions from the transportation sector. As I have explained, the intergovernmental panel on climate change has emphasize the importance of requiring that greenhouse gas emissions reach their peak in no more than 10 years.

NHTSA is currently making a decision that will profoundly influence our emissions during the next 10 years and beyond. NHTSA should therefore contribute to the effort to peak emissions sooner rather than later. This means adopting the highest fuel economic standards economically and technologically possible.

In summary, I would like to ask NHTSA to reevaluate the conclusions drawn from their draft environmental impact statement, and encourage NHTSA to require a 35 mile per gallon fuel economy standard by 2015. Thank you for your time.

MR. KRATZKE: Thank you, Ms. Berry. Ann Mesnikoff, please.

MS. MESNIKOFF: Good morning. My name is Ann Mesnikoff. I'm a senior Washington representative with Sierra Club's global warming and energy program, and I am testifying today on behalf of Sierra Club.

If there ever was a need of the nation to conserve oil it is now. The headlines daily remind us of the consequences of oil dependence. Americans send nearly $2 billion dollars a day overseas for oil. Many can no longer afford to fuel the gas guzzlers they purchased, nor can they sell them as consumers flock to smaller cars.

Food prices are rising. Dollars are being drained from our economy, and are not being spent in our local businesses or in our communities, wrecking economic havoc. It took decades for Congress to finally pass the first mandated increase in fuel economy since the original CAFE law was passed. After writing standards language, NHTSA is finally ramping up mileage standards.

In the meantime, the industry has become addicted to selling SUV's and we have become addicted to oil. The biggest single step we can take to curbing global warming, saving oil, and helping consumers at the pump is to make new vehicles go farther on a gallon of gas.

But we see in the NOPR and the DEIS that fuel economy is only the biggest single step if the right standards are set and evaluated in the right context. Raising fuel economy standards to at least 35 miles per gallon in 2015 is a key step to curing our oil addiction and reducing global warming pollution.

I will make three points today and submit written comments for the record. First, Sierra Club's written comments and the proposed rule address the flawed process for arriving at the 31.6 mile per gallon proposed standard. The proposed rule and the PRIA both show that the gas prices are major forces in setting fuel economy. NHTSA short changes America by using gas price assumptions that are far too low, a price for carbon that is randomly selected, and artificially constraining technologies.

NHTSA must set the right optimized standard and then recalibrate the other bounds. The 35 mpg target in 2020 is a floor not a ceiling. The law directs that the standards be what is maximumly feasible. How can the public have confidence in NHTSA, that NHTSA is setting the right standards when some of the key inputs in its analysis are flawed.

Second, can the public have confidence in the range of options considered in the DEIS. NHTSA strictly adheres to a 35 by 2020 standard. At several points NHTSA recognizes the two critical words which proceed 35 in the 2007 energy bill, the words "at least."

In other places NHTSA says the standards must be set to 35 by 2020. NHTSA notes that the 2016 to 2020 standards are foreseeable in the draft environmental impact statement, but the law provides them for the maximum feasible thereafter. Increases beyond 2020 are foreseeable, perhaps just as foreseeable as the VMT increases NHTSA presumes through 2100.

NHTSA should first use more accurate values for gasoline prices and other inputs to justify a 35 in 2015 standard, and increases beyond that with greater hybrid penetration, accelerated introduction of plug-in electric hybrid vehicles, and other technologies.

The DEIS is premised upon a flawed proposed standard and the scenarios that must be addressed should be fixed before a final standard is issued and a final EIS is issued.

The third point I would like to raise concerns -- are concerns [sic] about the draft environmental impact statement and whether it meets the primary function to inform the public that the agency has indeed considered environmental concerns in its decision making process.

In this case the agency does not give a fair or reasonable evaluation of the environmental impacts of the proposed standards, nor does NHTSA provide a context that reasonably informs the public.

The draft environmental impact statement takes the real differences between the options considered and runs them out so far to 2100 that they cannot meaningfully be differentiated or evaluated. Faster fuel economy increases will help the U.S. cut the 20 percent of CO_2 emissions that come from vehicles.

The difference between 35 in 2015 and 35 in 2020 is real. It is worth noting that the draft environmental impact statement reveals that this one policy could affect climate in 2100. The problem with NHTSA's analysis is that if we hit 700 parts per million plus, referenced in the DEIS, we have not averted dangerous climate change.

There is no requirement that NHTSA run its analysis through 2100. NHTSA notes that it's Volpe model estimates emissions reductions through 2060. The agency provides as a simplifying assumption, annual emission reductions from 2061 to 2100 were held constant. NHTSA should assess how the correct scenarios will impact emissions from cars and trucks in a time frame that is meaningful to the public, and within the context of science, not simplifying assumptions.

Fuel economy is only one policy in the tool bag. It will diminish the 20 percent of CO2 that comes from cars and trucks, but we must achieve an 80 percent reduction below 2000 levels by 2050 if we are to avert dangerous climate change.

For too long, the industry has fought higher fuel economy standards and successfully constrained NHTSA and Congress. The purpose of fuel economy law has been undermined for too long, and NHTSA must not perpetuate this by setting tomorrow's standards using yesterday's gas prices.

Before NHTSA finalizes its standards and the EIS, it must ensure that it's meeting the intent of the CAFE law and of NEPA. We must end our addiction to oil. Raising fuel economy standards to at least 35 in 2015 will speed up oil savings, speed up CO_2 reductions.

Finally, NHTSA must evaluate the environmental impacts of these standards in science-based context that informs the public. Thank you for this opportunity.

MR. KRATZKE: Thank you, Ms. Mesnikoff. Mr. Doug Molof.

MR. MOLOF: Good morning. My name is Doug Molof. I'm here as a concerned young citizen that has seen people in my home state of Texas struggle over the past several months to fill up their cars with gasoline.

In Texas there is no real public transportation alternative. The state is large and people are regularly forced to travel long distances on a regular basis.

NHTSA must act now to address the devastating environmental and economic impacts of America's growing oil dependence and rising gas prices by setting fuel economy standards at the maximum feasible level.

The agency's current proposal relies on unrealistic gas price assumptions which result in insufficient fuel economy levels. The agency's proposal assumes future gasoline prices to be only $2.25 per gallon in 2016, when American future gasoline prices -- when American consumers are already paying prices nearly twice as much today. In fact, since NHTSA first released its draft CAFE rulemaking, the price of gasoline has jumped by over a dollar.

NHTSA's own analysis shows that between 2011 and 2015 significantly higher standards are technologically feasible and economically practical when higher gas prices are used. NHTSA's final rule should be, at a minimum, consistent with the analysis provided in the preliminary impact analysis that accompanied the notice of proposed rulemaking.

NHTSA's use of the low cost energy estimates is arbitrary and violates the agency's statutory charter to impose mandatory maximum feasible fuel economy standards based upon a review of economic and technological feasibility.

The high gas price scenario yields cost effective and technologically feasible standards that will help meet the nation's need to conserve energy, and will help lower gas prices for the average American consumer. NHTSA should ensure that final standards are set using this value at a minimum.

NHTSA's draft EIS fails to analyze, also, the benefits of greenhouse gas emissions reductions through various fuel economy standards in the proper context. Not surprisingly, when NHTSA tries to determine the difference in global ocean temperature rise in 2100, resulting from a 31.6 mile per gallon standard in 2015, versus a 35 mile per gallon standard in 2015, statistically there is no difference.

But emissions from the transportation sector in the United States account for roughly 20 percent of our country's greenhouse gas pollution. And as any projection, decreases in greenhouse gas emissions arising from increased fuel economy standards can never be greater than this. [Sic]. These reductions should be considered as a proportion of the 20 percent, not as a proportion of the entire planet's combined carbon admissions.

This can simply overwhelm any measurable progress. Success and progress should be measured by how close these fuel economy improvements get us to reducing the transportation sector's carbon emissions by 80 percent in 2050.

To do otherwise fails to realistically evaluate vehicle emission reductions as a key part of the overarching strategy to curb global climate change.

The debate is over on climate change. The scientists and the American public agree and have reached the same conclusion. It's happening now. We are already feeling the vast effects and we must act immediately to stave off the worst effects. Thank you so much for the opportunity to testify.

MR. KRATZKE: Thank you, Mr. Molof. Matt Dernoga, please.

MR. DERNOGA: Hi. My name is Matt Dernoga. And I wanted to first thank the National Highway Traffic Safety Administration for holding this hearing, and allowing me to give my input on the critical decision of what our CAFE standards should be set to the upcoming decade and beyond.

It's difficult to know where to begin because I find all this very perplexing. I find it perplexing that NHTSA would aspire to only a mere 35 miles per gallon by 2020, the bare minimum of what is required by the Energy Independence and Security Act.

I am confused that American auto makers would fight raising fuel economy standards, given the dire fiscal situation they find themselves in, as a direct result of their stubbornness.

I don't understand why the implications CAFE standards have on climate change do not appropriately reflect NHTSA's decision-making. [Sic].

Finally, I am baffled that our new CAFE standards are based on the presumption that the cost of a gallon of gas will be only $2.25 by 2016. I wonder if we are living on the same planet.

I'm going to hazard a guess that there have been hearings like this in the past, that years ago when the NHTSA was considering raising fuel economy standards they decided against it based on the presumption that gas would be cheap through the opening decade of the 21st century. NHTSA chose to assume the best, and failed to prepare America for the reality that awaited it.

As a result, we have become more dependent on oil than ever before, exporting hundreds of billions of dollars overseas each year with some of it going to hostile countries. Our economy is sputtering since everything costs more as a result of high fuel prices.

Businesses are having trouble staying afloat. Truckers can no longer make a living. All of the companies are posting billions of dollars in losses while cutting jobs, and food prices have risen because of shipping and production costs.

Americans find themselves barely able to hold their heads above the tide. The NHTSA is determined to respond to their mess by pushing their heads below that tide and holding them there. The notion of $2.25 a gallon gas by 2016 is laughable. It's a joke I could tell in a comedy club. There's no way that anyone in this room actually thinks that this will be the price. I'd be willing to bet anyone any amount that the price will be higher. Would anyone here take that bet?

NHTSA has already gambling, though. They're gambling with the future of our country. Planning our CAFE standards around the assumption of $2.25 a gallon of gas isn't a game. It's dangerous. You're playing a Russian roulette with the American economy. You're holding a loaded gun to its head and pulling the trigger with the hope that it fires a blank.

If you haven't noticed, our economy, our infrastructure, our lives and yes our cars are designed on the premise of cheap gas. That has to change or we will face hardship many times greater than what we are facing now.

I know that we can meet higher CAFE standards than 31.6 miles per gallon by 2015. I know this not only because of NHTSA's own analysis, but because I know the strength, determination, and good will of the American people. It's unnatural for us to aspire to meet only the bare minimum of what is required. That is not the American way. We do not reach for the ceiling. We reach for the stars.

The NHTSA needs to weigh the risk of being wrong by doing too little versus the reward of doing too much. It also needs to examine its conscience and factor in the implications of climate change appropriately in its decision making.

But undertaking those two simple tasks, I have faith that we can do something about CAFE that we have never done before, the right thing. Now or never is a false choice. If you love this country and if you love your children, the time is now. Thank you.

MR. KRATZKE: Thank you, Mr. Dernoga. Jazzlin Allen.

MS. ALLEN: Good morning. My name is Jazzlin Allen and I am a U.S. (indiscernible) intern and a resident of western New York, whose savings is being bled out by major oil companies and their outrageous gas prices.

This summer and over the past few years I have experienced how high fuel costs and the lack of more fuel efficient vehicles have affected the financial health of my state and this country. Even the ability for these people to feed their families has been affected.

More personally, gas prices have had an affect on my family. As a recent college graduate, I worked an entry level position and juggled the bills on my own. I have often had to choose between eating lunch and filling my gas tank just to get back to work for the next week. Without access to the funds to afford a more fuel efficient vehicle, mainly because no one wanted to give me a fair price on my SUV, and my only support system being my single working class mother, I was forced to continue to invest in the most lucrative rip off scheme in the world, big oil companies.

Where is the return on my investment? Where is the concern for the financial security of hard working Americans? Why isn't there a stricter system of check and balances?

Fuel prices are even adding to this nation's health crises, with common foods like milk, eggs, and vegetables being at record high prices, my family cannot afford many of these healthy everyday items. I mean, these billion dollar oil companies are snatching the food off American tables and out of our mouths.

The next time you visit New York City, make sure you close your eyes as the wind blows. The air is thick, polluted, and unpleasant to inhale. The affects of smog are incredible. As a person with asthma, I can no longer consistently frequent the city because the air is so dense, dirty and disgusting.

I am no scientist, and I am not able to scientifically analyze just how much global warming has affected the State of New York, but I know that I can feel the effects because I am living with them. I can feel them when I breathe the air, and I am often stuck in the car because of the congested and somewhat unreliable public transportation system.

As many other people have came [sic] and testified before you, the debate over climate change has ended, and we are feeling its effects on our communities today. It is more important now than ever to curb our greenhouse gas emissions and do our part to mitigate the affects of global climate change.

NHTSA's current proposed standards for cars and light trucks put us on a path to increasing fuel economy to only the bare minimum, 35 miles per gallon by 2020, required by the Energy and Security Act of 2007. NHTSA fails to take full advantage of available fuel saving technologies, and must reconsider the proposed standards and use its statutory authority to meet the urgent need of the United States to reduce carbon emissions, conserve oil, and meet the growing demand of American consumers for vehicles that go farther on a gallon of gas.

I'm pleading to you on behalf of American families and our economy to reconsider your EIS report. Thank you for your time.

MR. KRATZKE: Thank you, Ms. Allen. Mr. Sam Blodgett.

MR. BLODGETT: Good morning. My name is Sam Blodgett, and I am testifying today as a public citizen of the United States of America.

I have come here to voice my concerns with the National Highway Traffic Safety Administration's recent draft environmental impact statement or fuel economy standards, or CAFE.

I strongly believe that NHTSA must raise CAFE standards to 35 miles per gallon by the year 2015. Failure to do so would be a failure of the [sic] American people who are in desperate need of relief from rising gas prices.

I am a California native, born and raised. Although my parents divorced when I was just three years old, I grew up with parents who both had a real presence in my life. Soon after their divorce, my mother and I moved to a new city, roughly 180 miles from my father.

Despite the distance, my parents took turns driving seven hour round trips to ensure that I could grow up with both my mother and my father. And while I thank God they got divorced when they did, and you would feel the same if you knew them, I am forever indebted to my parents for sacrificing their time, energy, and money to keep my family together. I could not have come as far as I have without them.

So, why share this story with you? Gas prices, gas prices, gas prices. $1.50 gas, while not cheap, enabled my parents to make that 360 mile journey without burning a whole in their wallets. That same journey, given current gas prices and CAFE standards, would be inconceivable now.

My mother, who worked one-third time [sic] to raise me, could never have afforded that drive with $4.50 gas. Current gas prices would have forced my parents to choose between bare necessities and their child. American families should never have to make that choice.

Economists agree $2, even $3 gas price days are over. Your environmental impact statement must reflect this new reality. In your draft EIS you analyze two price projections for the cost of gasoline; one that predicts $2.25 [sic] gas prices by 2015, and another that predicts $3.14 [sic] gas prices by 2015.

In your EIS you chose to use the lower price estimation. Given current gas prices, this was an obvious misstep. It is only prudent to use the higher cost estimation. Even it undervalues gas by almost a dollar.

According to your analysis, if gasoline is $3.14 by 2015 then higher fuel economy standards are both technologically feasible and economically practicable. If true, then it is nonsensical to continue as planned.

You must raise CAFE standards to 35 miles per gallon by 2015. Doing so would save Americans more than 76 billion gallons of gas over five years, according to your own analysis. As an American, that's the first bit of good news I've heard in a while.

And a quick reminder, failure to utilize the higher cost projection violates NHTSA's statutory charter to impose mandatory feasible fuel economy standards based on economic and technological feasability.

But here's the bottom line. Assuming $2.25 gas in 2015 is insulting to the American people. Americans are craving gas price solutions. NHTSA has the power right now to relieve some of our pain at the pump. Passing up this opportunity would be shameful.

The National Highway Traffic Safety Administration is part of the federal government that was created by our founding fathers to serve Americans. By failing to raise efficiency standards, NHTSA is failing we the people. So do what's good for America. Raise CAFE standards to 35 miles per gallon by 2015 or as my mother would say, let's get this show on the road. Thank you.

MR. KRATZKE: Thank you, Mr. Blodgett. And thank you to the entire first panel. At this point I'd like to call the next six witnesses. We will take a break after these witnesses have had the opportunity to speak. I'd like to call Emanuel Figueroa, Sara Larson, Joseph Frewer, Annie Chau, Marissa Knodel, and Allison Bacon, please.

All right. Well, I can see there aren't six people up there. Clever. Emanuel Figueroa. We will move Mr. Figueroa to the end. Sara Larson. Ms. Larson likewise.

Joseph Frewer. Thank you, Mr. Frewer.

MR. FREWER: Good morning. My name is Joseph Frewer. I am a college student originally from Houston, Texas. I am in school at Pomona College in Southern California.

I am speaking today as a public citizen, also as a volunteer for the Sierra Club for the summer. Primarily, I am here because I'm concerned about global warming. As you've heard multiple times, the scientific conclusion is that to mitigate the worst effects we really need to cut our carbon pollutions by 80 percent by 2050.

And many of us are agreed that the best way to do this is by utilizing every tool we can. We've got to look at every aspect of our economy, not only the transportation sector, which is addressed here, but many other parts, industrial -- I don't need to go into them.

But this 20 percent is part of a bigger picture, and we must take that into account when looking at a global solution. Just because it's 20 percent doesn't mean that it's any less important and that it can be ignored, just because when you look at in the context of 100 percent global emissions picture, it doesn't seem that important as it is.

NHTSA's draft environmental impact statement fails to analyze the benefits and reduction for fuel economy standards in the proper context because it is going by the bare minimum. As we have said, I'll try not to go into the same statistics that we've heard, but 31.6 miles per gallon, the bare minimum, just won't cut it. There are already cars being released that promise to offer more than 31.6 miles per gallon of gasoline.

We have people wanting to better the environment, wanting to save money, wanting to reduce our dependence on nations that are not always stable, not always friendly. And I'd say conserving our gas is a lot better solution than trying to drill on our soil, for instance, because the problem with gas prices is a demand problem.

China and India and other developing nations are not going away. And as our oil consumption stabilizes, they're still growing at an exponential rate. And so what we can do to conserve gas right now not only will help us use less, it will help us decrease the price of a gallon of gas. But it will also, the technology we develop and our car makers develop in cutting down how much fuel our cars and trucks use can be transferred to other countries, and can help solve the global warming problem on a scale greater than our 20 percent transportation sector economy.

So as I said, the current estimation of the price of a gallon of gas, which is, I think $2.25, not counting inflation in 2016, is unrealistic. I mean, we all prices right now, while they've been fluctuating, they're not going to drop back down to what they used to be. They are definitely staying above $3, and I think that's what most economists are saying. So we need to at least take this into account when coming up with what our standards need to be.

And I'd say a personal reason why I'm here, I go to college in a suburb of Los Angeles. I had an internship in West LA. I'm from East LA. And it's a commute that probably a couple million people do every day. I did it twice a week and it turned out to be probably a quarter tank of gas every day that I drove to my internship. And as a student, I could barely afford that.

Luckily I was subsidized by my college, but I can't imagine having to pay for groceries and having to pay for dependent children and paying this much money for gas, especially people who are driving cars that are 10-15 years old. We need to start coming up with solutions preemptively so that by the time 10 or 20 years roll around, their 15 or 20 year old car won't be as bad as the car I was driving, for instance.

So for commuters, for grocery prices, for many reasons I can see as a student, and I'm concerned about for the future, we really need to up our standards. We need to take into account more factors than just this transportation sector. But we need to recognize that the transportation sector is essential and part of a bigger solution to combat global warming, part of a solution to save our economy, which right now is not looking so good, obviously.

So that's all I have to say. I urge you to take another look at your draft environmental impact statement, and thank you very much.

MR. KRATZKE: Thank you, Mr. Frewer. Annie Chau, please.

MS. CHAU: Good morning. My name is Annie Chau, and I'm a representative from U.S. Public Interest Research Group. On behalf of U.S. PIRG and our federation of state PIRGs representing over a million citizens in America, I urge the National Highway Transportation Safety Administration to strengthen CAFE standards, and to follow the Consumer Federation of America's recommendation.

That means first, correcting the conceptual flaws in the agency's model, and establishing clear tests and analytic procedures to evaluate standards.

Second, setting the 2011 to 2012 standards at a substantially higher level than previously proposed. And third, rescinding the 2013 to 2015 standards, which are based on incomplete information.

Consumers in America want, need, and deserve real and lasting solutions that improve the fuel economy of our cars and trucks, and reduce our nation's energy consumption.

The way we travel is a big part of our energy crisis. Two out of every three barrels of oil that America consumes each year are used to fuel our cars and trucks. Furthermore, our nation holds just 3 percent of the world's proven oil reserves, yet we use 25 percent of the world's oil.

Our dependence on oil has become increasingly painful for American families. We are now spending close to $100 a week on gasoline costs alone. This makes household spending on transportation the second highest expense for the average American family, more than food, clothing, and even health care.

NHTSA unrealistically predicts gasoline prices to be only $2.25 per gallon in 2016. But Americans are already paying nearly twice as much today. U.S. PIRG research from squandering to stimulus shows that in the last five months American families have spent the entirety of their stimulus checks filling their tanks, while the cost of gasoline skyrocketed more than 40 percent.

Rather than boosting our faltering economy, the economic stimulus money went straight to big oil companies like Exxon/Mobile who are now reporting record breaking profits.

The agencies of the federal government must serve the people and find long term solutions for our energy crisis. At U.S. PIRG we believe in solutions that allow

Americans to drive less, such as consistent and innovative investment in public transportation. The most fuel efficient trip will be the trip not taken.

Americans are driving less. We as a nation traveled fewer miles in the last year for the first time in over two decades, and we are taking public transportation in record numbers across the country.

Many Americans do have to drive, though, and we must make those trips more fuel efficient by improving and modernizing our cars and trucks. This should be a top priority for the industry, our nation's leaders, and our federal transportation agencies. Forward thinking today will save us energy for tomorrow.

We fully support the comments of the Consumer Federation of American and we agree that NHTSA has failed to prioritize the need to conserve energy, has undervalued the benefits of increased vehicle fuel economy, and has kept standards too low for too long.

By ignoring a critical situation that is facing our country, the rising cost of gasoline, and our limping economy, every American is burdened when the fuel economy of our cars and trucks falls short.

We strongly urge this body to follow the recommendations of the Consumer Federation of America. Our nation's energy future depends on it. Thank you.

MR. KRATZKE: Thank you, Ms. Chau. Marissa Knodel.

MS. KNODEL: Good morning. My name is Marissa Knodel, and I grew up in Rochester, Minnesota, and now go to school at Dartmouth in Hanover, New Hampshire.

I am having an extraordinary opportunity to work with a professor there in the creation of an international NGO that can better represent the interests of South Pacific Island nations in negotiations concerning global warming and climate change.

This is an issue of environmental justice, since these countries have contributed the least to global warming, and yet given their size, location, geography and lack of political power, will suffer the most from global warming.

The highest point on many of these islands is only a few years high. Now, with global warming causing sea levels to rise, and increasing the magnitude and severity of tropical storms, many of these nations already have agreements with the governments of New Zealand and Australia to evacuate their entire populations with the expectation that their homes will be under water within the next 50 years.

The United States, on the other hand, represents only 4 percent of the world's population, uses one quarter of the world's oil, and contributes the most to global warming pollution to the atmosphere.

The United States is very good at outsourcing the environmental responsibility for the energy that it uses, and the pollution that it creates. But now that Americans are starting to feel the financial burden from our addiction to oil through higher prices at the pump, and the environmental burden through storms like hurricane Katrina, the oil spill in the Mississippi a little over a week ago, and the threat of off shore drilling, we realize the consequences of oil dependence and are demanding change.

Oil companies have been reporting their second quarter earnings, and last week at $11.68 billion Exxon/Mobile earned the largest quarterly profit of any U.S. corporation ever.

Now, for those families earning less than $15,000 a year, oil expenses represent 10 to 13 percent of their annual income. This, too, is an environmental injustice.

We have the ability to both reduce the amount of greenhouse gases we put into the atmosphere, and move away from oil and other fossil fuels. About 69 percent of our oil consumption, and one-third of our global warming pollution comes from the transportation sector.

In order to reduce oil use and reach the goal of an 80 percent reduction in greenhouse gas pollution by 2050, we can increase fuel economy standards, make sure hybrid and plug in electric vehicles are available and affordable, and improve public transportation.

Increasing CAFE standards to 35 miles per gallon by 2015, instead of waiting for 2020 as currently required save 300,000 gallons of oil per day by 2020, which is equivalent to keeping 280 million metric tons of carbon dioxide out of the atmosphere.

Not only is global warming and the oil addition that contributes to it an environmental injustice for South Pacific nations, keeping CAFE at a minimum of what is possible is an injustice for Americans trying to live out their daily lives, and for all those who believe in a future of clean, renewable energy, cars that can get 100 miles per gallon, and a healthy, safe environment for everyone everywhere. Thank you very much.

MR. KRATZKE: Thank you, Ms. Knodel. Allison Bacon. All right. Ms. Bacon will be moved to the end of the program, too. At this point, I think we will take a 15-minute break. Can I ask you to come back at 10:40 and we will start up again. Thank you.

(Whereupon, at 10:29 a.m., a brief recess was taken.)

MR. KRATZKE: All right. If we can, we would like to get started now with the remainder of our morning session. Available slots at the table are for Reverend Dr. Mari E.

Castellanos, Matthew Du Pont, Barry Bernsten, Pamela Woodward, Eli Hopson, Henry Desilva, Caroline Keicher, Christina Marie Yagjian, Lois Dean, D.C. Amorison, Julie Locascio and Kara Miamosi. And I would like to begin with Reverend Dr. Castellanos. All right. We'll come back. Matthew Du Pont? Thank you, Mr. Du Pont.

MR. DU PONT: Hi. Thanks for taking the time to listen to me today. I'm Matt Du Pont, a college student, and I'm a citizen.

Now, I'm not an expert on environmental issues, and anything I could say about those realistically is going to be said better and with better sources by someone else that has spoken today or will speak after me. So I'll only take a few minutes of your time and make a very simple speech about an issue that wouldn't require much work on your part, but is very important. And that's the accessibility of this EIS report to the general public.

Now the speech structure is very simple. I'm going to show you firstly that you will find this issue important. Secondly, you have a duty to make that EIS report transparent to the public. And finally, that it's currently failing to do so.

And this leads to the conclusion that simply by throwing on a very accessible, readable, lower level two to three page summary in addition to what you already have in this report, you can make this much more accessible to the public who demand this information.

So first of all, I think it's not too controversial that people find this issue important, after all this directly impacts global warming which according to a March 2006 time pole, 88 percent of American's find relevant for future generations.

But more importantly for our purposes here, 49 percent of Americans think that this is one of the issues that is very important to them, one of the issues that they are going to find out of their way to actually find out information about, instead of just reading it in the papers. So we know it's important, we know it's important to Americans.

And secondly, it's very noncontroverial that the EIS is supposed to inform the public, not just policy makers. People look to the CEQ regulations governing the EIS creation, which cite a purpose of the EIS as "to encourage and facilitate public involvement in decisions which affect the quality of the human environment." And they are also several clarity and brevity requirements meant to make them more accessible to the public.

So we've got this demand for information. We've got this EIS with a burden to show the public how that information is being used. It sounds pretty good. But in reality right now, this particular environmental impact statement is failing to make itself accessible to the public.

I mean, first of all there is a length. Now, the CEQ guidelines say that reports should be less than 150 pages in most cases, in very special cases under 300. So if I, as an average citizen who is not getting paid to deal with these issues, am confronted with this 414 page monstrosity, it's highly likely I'm going to read more than the summary, if I read anything at all.

But this brings us to the second problem. Even if I got to that summary, the very first sentence in the forward, I am confronted with no less than nine acronyms, probably six of which I don't know. It's just not very encouraging for me as an average person trying to vote correctly, to advocate policy, to be able to read this report, although maybe it's applicable to policy makers. But I, you know, as just a regular citizen, it's hard for me to get through.

So, and it doesn't get much better from there on in because the summary assumes knowledge of a lot of things. It assumes that I know why rising sea levels are bad, which admittedly is explained in the report, but I'm probably not going to go to page 270 or wherever that's explained, if I'm not grabbed in the beginning.

And so we have this inaccessibility, and I think it's a huge problem. The citizens who are interested but don't have a career as a nonprofit policy wonk or an auto industry lobbyist are simply not going to read a 414 page report, or even a 25 page summary.

And this brings me to the point of my speech, something you could do very easily. It's not a solution, but it's certainly a step in the right direction. By simply providing a short jargon free summary, say just two to three pages long, in addition to what's already in the report, specifically labeled, for average citizens who don't know as much about the issue, you can allow people to make meaningful conclusions from this EIS, to be able to read it and perhaps talk to their neighbor about it, or talk to their Congress person. But whatever they do, advance a stated cause in the mandate of the EIS, to advance public discourse.

Now, because frankly, your job as the EIS author is not just to help policy makers, it's to interest me, an average citizen. And I stand before you today, right now, as an intelligent environmentally conscious citizen, the exact target audience for any EIS report. But because I and thousands of other people have no interest in slogging through the dense prose that makes up most of this EIS, it's failing in its duty to provide information to the public.

And as such, I would please ask you to add in this and future summaries a very short, a short, more accessible,

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clearly written piece that addresses the public. Thank you for your time.

MR. KRATZKE: Thank you, Mr. Du Pont. Barry Bernsten, please.

MR. BERNSTEN: My name is Barry Bernsten. I'm president of BG Automotive Group located in Philadelphia, Pennsylvania. We are building the first mass production facility in the world for the production and assembly of electric vehicles, a product that is now a necessity in the world, and not just an alternative.

First, I would like to thank NHTSA for giving me the opportunity to speak to this committee that appears to be interested in the public's opinion with regard to the environmental impact of the new CAFE rules. I might be one of the few people in this country that have read most of the 414 pages of the environmental impact statement with regard to the CAFE rules covering model years 2011 to 2015.

I must commend the team that prepared the document for their time commitment, but I do not commend them for their due diligence and their accuracy. They clearly forgot to include the direct human health care costs, as well as the quality of life issues in their report.

Every morning I turn on the news or I read the paper and I see the air quality report in the Philadelphia region. Needless to say, this report peaked my curiosity. After doing some further research, I found a government website called air now.gov that provide daily reports on the air quality around our nation.

I was shocked to see that their were color coded air warnings for the air quality based on where you reside in North America. The government calls it the AQI, air quality index. These are color coded, similar to our terror alert index, or terror alert codes.

Also, I noticed that there were existing real time alerts in our country today, this past weekend, that were orange, being unhealthy for sensitive groups, and even red, a strict statement of being just unhealthy to breath.

After further research on air quality elements, I found that approximately 17 million people have asthma in our country, of which 5 million are children, and one of them spoke with you here today.

What I did not read in the 414 pages of the environmental impact statement as it clearly relates to air quality, was the direct associated cost with the 1.5 million emergency room visits for asthma patients, or the $14 billion in health care costs related just to asthma related illnesses.

The report also did not include the direct costs associated with emphysema and/or chronic bronchitis due to

CO2 emissions or greenhouse cases. Why didn't the environmental impact statement consider the direct health costs associated with their study, and the quality of life costs associated with such an important report?

Saving billions on oil, reducing greenhouse gases, slowing global warming is a given. We are reminded and educated every day. This you covered in the report.

According to another government site from the National Institute of Environmental Health Sciences, "according to the Environmental Protection Agency's estimates on air pollution, the commitment to new air quality standards, and cleaner air will prevent 23,000 premature deaths in America. 1.7 million cases of asthma attacks will not occur. And 67,000 new cases of acute an aggravated bronchitis can be limited.

All Americans should be outraged at this agency's report, that it did not include the quality of life costs, and the billions of dollars of direct health care costs as it relates to their analysis as a result of the CO_2 greenhouse gases referred to in your report.

More Americans are not only walking and riding bicycles to work, but we now have to tell our children when and when not to play outside.

Instead of taking the latter issues into consideration, the study includes an environmental impact equation, the net cost benefit or detriment which includes input from the automotive companies and the lobbyists.

The auto companies complain that it is not economically feasible to produce more fuel efficient vehicles due to their retooling costs, and their extensive health care costs. The DOT demands that the industry finds themselves in a situation where they are negotiating with the automotive companies and the automotive lobbyist, which we don't understand as an American public.

This is not the auto industry's decision. This is your decision, NHTSA's decision on where and how to set these standards. The bottom line is that we all know of the strongest CAFE rule will lead to the strongest environmental impact for the air quality and the quality of our lives.

I thank you for the opportunity to speak to you. Thank you.

MR. KRATZKE: Thank you, Mr. Bernsten. Pamela Woodward, please.

MS. WOODWARD: Good morning, and thank you for giving me the opportunity to speak today. I am a local resident. I live in Silver Spring, Maryland, and I've never spoken in front of any type of board before, but I felt that this was a very important issue, one that has a very strong, that I have strong feelings for, so I decided to do this.

I'm an avid world traveler who likes to leave the bustling city for relatively wilderness areas, such as, I've traveled to Antarctica, to the Amazon, to the Galapagos Islands.

And I've seen some of the effects of global warming during my travels, and in particular in Antarctica where there are massive amount of ice breaking off from the ice shelf.

And I think it is important for us, as a country, to realize our responsibility in preserving the wilderness areas, and this includes getting away from our dependence on oil, both foreign and domestic. It also includes expanding existing technologies, such as hybrid technologies, electrical vehicles, rather than looking to drill in unspoiled wilderness areas like is being considered right now.

In addition, I've lived in foreign countries where the emission standards are negligible at best. And as was referred by the previous speaker, I have been subject to chronic throat and bronchial infections due to inhaling air from strong exhaust.

In addition, I've lived in parts of this country, this area and in Northern California where I can feel, taste, smell the air on days where it's code orange or code red. And I can feel it if I try to exert myself, I can feel the effects on my lungs.

In addition, a couple of years ago I was, I went to shop for a new car with my husband. And I wanted to get the most fuel efficient car possible, both from a cost perspective, since we're paying $3 to $4 dollars a gallon in gas, and also from an impact on the environment. And unfortunately, our choices were severely limited, due to the lack of availability of such vehicles. We couldn't even test drive a Toyota Prius because none were available, they were so popular.

I'm here today to ask you to really consider the environmental impact of any standards you set, and to take into account the quality of life for both the current population as well as future populations of this country and the world.

You need to use realistic gas prices, prices that are, that equal the current average, which is much higher than the $2 plus range. It's in the $4 plus range. And you also need to understand how many people would be interested in buying fuel efficient vehicles, were they both accessible and affordable.

The technology exists. There are companies that are using successfully, and other companies should be encouraged to develop the technology even further. Thank you very much for your time today.

MR. KRATZKE: Thank you, Ms. Woodward. Eli Hopson, please.

MR. HOPSON: Hi. First I'd like to thank NHTSA for holding this hearing, and for giving us the opportunity to offer comments on the draft EIS.

I'm the Washington representative for the Clean Vehicles Program of the Union of Concerned Scientists. UCS is a leading science-based nonprofit, and we've been working for a healthy environment and a safer world for over 30 years.

The topic of this hearing the, environmental impact fuel economy standards could not be more urgent. Put simply, global warming is the single largest environmental threat facing the country and the world today. $4 a gallon gasoline is strangling our economy.

But within these threats are varied opportunities. Increasing fuel economy standards will reduce global warming pollution from our cars and trucks. It will cut America's oil addiction, and it will save consumers billions.

At the same time, the investments we make in our domestic auto industry will strengthen our economy and our ailing domestic auto makers as we help them build the vehicles that are essential to avoiding the worst impacts of global warming.

There are two primary flaws in the draft EIS that must be fixed in order to give the public a true idea of the potential environmental impact of this rule. First, the fuel economy standards are being measured for their global impact, even though they only affect a portion of all manmade sources of global warming pollution.

Second, the methodology of a rule upon which this EIS is based is fundamentally flawed and improperly limits the potential environmental benefits from increasing fuel economy.

But first the scope. If we are to avoid the worst impacts of global planet change, our nation and the world must adopt a target that will keep global temperature from rising more than 2 degrees C above pre-industrial levels. That means stabilizing the concentration of global warming pollutants in our atmosphere at no more than 450 parts per million CO_2.

Analysis by UCS shows that one part of achieving that goal means the United States must cut its global warming pollution at least 80 percent compared to emissions levels in 2000. In addition, our analysis indicates that in order to effectively achieve such a long term goal, we have to start now. We have to reduce our pollution 20 percent below 2000 levels by 2020 and at least 50 percent below by 2030.

The need for these long term targets and immediate action is not effectively covered in the EIS, and the cost of inaction of the size of this challenge also should be better reflected.

Importantly, there is no single silver bullet that will dramatically cut U.S. global warming pollution, and no single sector will be able to carry the full burden. Instead, we're going to have to do a diverse set of policies that's going to cover every sector comprehensively.

Transportation, including the cars and trucks consumers drive every day will have to play a significant role in meeting this 80 percent reduction, minimum, and all options for cutting pollution from transportation must be on the table.

Unfortunately, the analysis done by NHTSA only presents the reductions from the fuel economy rule in the context of their direct impact relative to all manmade global emissions, rather than just the emissions from our cars and trucks.

Because higher fuel economy standards alone won't solve global warming does not discount the fact that they are a vital, necessary part of the solution. By stating them in terms of their percent reduction from the sector, approximately 30 percent, rather than a percent of world reductions which is .8 to 1.1 percent, according to the draft EIS, the value of the fuel economy in reducing global warming pollution and helping us meet those near term targets will be clear and less misleading to the public.

NHTSA's approach to the EIS is like arguing that we shouldn't worry about smoking in 16 year olds, because they're only a small percentage of the smoking population. Instead, this argument could be used against all persons in the sector to say, well, global warming is such a big problem, we can't use it in here, we can't use it here. We shouldn't deal with it at all. Instead a more comprehensive approach needs to be looked at, and the EIS reflect that need.

The second problem is with the announcements that the rule is based on. A recent UCS report indicates that auto makers can cut cost effectively their fleet wide average fuel economy of cars and trucks and improve it to 42 miles per gallon by 2020, and up to 50 and more than 50 by 2030, with a modest 25 percent penetration of hybrids by 2020.

The recent proposed notice rulemaking actually assumed that hybrids wouldn't be on the road until 2014. Let me just reiterate that. Despite the fact that there are more than 1 million hybrids on the road today, despite the fact that the Toyota Prius is the ninth best selling car in America, the announcements that NHTSA used assume hybrids won't be on the market until 2014.

People are not sitting around waiting for a hybrid to show up on a dealer's lot in six years. They're on six month waiting lists, as we heard today, because they are already that popular.

There's a number of other flaws in the base analysis that have been covered today, but I just want to point out one last one. The value of carbon dioxide that NHTSA used, they assume $7 per ton. Carbon dioxide is currently trading in the European futures market at $40 per ton.

The other list has been mentioned, but I just want to summarize and say your own analysis showed that if you use a more realistic gas price, or switch to an analysis based on total benefits, each of those would allow us to reach Congressionally mandated minimum five years earlier, so 35 miles per gallon by 2015, and would help us get a head start on solving our global warming problem. Thank you.

MR. KRATZKE: Thank you, Mr. Hopson. Henry D'Silva, please. All right. Caroline Keicher.

MS. KEICHER: Hi. Good morning. Thank you again for having us today and allowing us a chance to talk about this draft environmental impact statement.

My name is Caroline Keicher, and I am here because I am incredibly concerned about the impacts of global warming in this country, because I think that NHTSA has a responsibility to put into place the strongest fuel efficiency standards possible to help us reduce our global warming emissions from vehicles.

The debate is over on a time to change. The scientists and the American public have come to the same conclusion. It's happening now, and we are already feeling the vast repercussions. We must act immediately if we are going to stave off the worst effects.

The reports on climate change that pour in daily no longer focus on predictions for the far future, but on the consequences that we are already experiencing today, and how global warming will continue to disrupt our environment, our economy, and our very ability to survive if we don't act quickly to reduce our carbon emissions.

It's more important now than ever to curb our greenhouse gas emissions and to do our part to mitigate global climate change. The cost exacted on us if we do nothing is guaranteed to be worlds steeper than any possible cost prevention.

The scientists made it clear that to avoid the worst effects of global climate change, we must achieve 80 percent reduction in our emissions by 2050. This gives us approximately 40 years to get our act together, and we have no time to lose.

Unfortunately, there is no single thing that we can do, or single sector in our economy that we can cut to get us all the way there. We must instead start making manageable emission reductions from each single carbon emitting sector of our economy. And when considering the benefits of doing so, we must consider each reduction as part of the larger long term goal, both for the United States and globally. Each reduction that we fail to make in one area will have to come from somewhere else.

The most disappointing thing for me about NHTSA's draft environmental impact statement is that it fails to analyze the benefits of greenhouse gas emission reductions from various fuel economy standards in the proper context. Not surprisingly, when NHTSA tries to determine the global warming impacts resulting in 2100 from various standards, 31.6 miles per gallon in 2015 versus 35 miles per gallon, there isn't statistically much of a difference.

And this isn't surprising. It also doesn't mean that raising fuel economy standards faster will not have a significant impact in our struggle to reduce global warming pollution.

Emissions from the transportation sector in the United States account for roughly one-third of our greenhouse gas emissions, with cars and light trucks coming in at about 20 percent. That's a fairly large chunk of our contribution to this global problem.

So what is the proper context? How do we consider these various CAFE increases? Globally the science has called for long term reductions of emissions of about 50 percent for the entire world by 2050. Here in the U.S. as an industrialized nation that accounts for nearly a fourth of world carbon dioxide emissions, this translates for us into about 85, 80 to 95 percent needed reductions below 2000 levels by 2050.

In the short term this is going to mean that we need to reduce our emissions between 25 and 40 percent by 2020, so a much sooner time line. This is a much bigger number, and this is what's most relevant with these new CAFE increases.

If we're going to evaluate how an increase in corporate average fuel economy affects global warming, this is the target that we should be focused on, not some obscure number in 2100.

In addition, the proportion of emissions saved is much less important than the total cumulative carbon savings. The front end reductions are more important and have more cumulative impact than later emission reductions.

Taking this into account, it seems even more obvious that NHTSA should set new fuel economy standards to reach 35 miles per gallon by 2015. Not only is this standard economically and technologically feasible when a more accurate gas price is used, but it gets our cars and light trucks traveling an average of 35 miles per gallon five years sooner, the cumulative carbon savings of which is anything but insignificant.

NHTSA has proposed standards for both cars and light trucks in response to the energy independence and security act's mandate to achieve a fleet wide fuel economy average of at least 35 miles per gallon by 2020. NHTSA proposes to raise fuel economy of cars and light trucks to a combined average of 31.6 miles per gallon for model year 2015.

While this increase is more than half of what is required to meet the floor set by the EISA, NHTSA fails to take full advantage of the fuel saving technologies, and fails to fully and fairly evaluate the benefits of greenhouse gas emission reductions.

NHTSA must reconsider the proposed standards and use its statutory authority to meet the urgent need of the United States to reduce carbon emissions, conserve oil, and meet the growing demand of American consumers for vehicles that go farther on a gallon of gas. Thank you so much for your time.

MR. KRATZKE: Thank you, Ms. Keicher. Christina Marie Yagjian.

MS. YAGJIAN: Good morning. My name is Christina Yagjian, and I am here today as a concerned citizen. I'd like to start by thanking NHTSA for holding this hearing and for giving me the opportunity to speak today.

I'm here because I'm concerned about the effects that global climate change will have in my lifetime on my life and the lives of those that I care the most about, if we don't take the most rapid and comprehensive measures available to us to reduce global warming emissions now.

This draft EIS takes a step in the right direction, but fails to go the extra miles necessary to properly face the problem at hand. NHTSA's draft environmental impact statement fails to analyze the benefits of greenhouse gas emissions reductions from fuel economy standards in the proper context.

As a young professional with baby boomer parents approaching retirement, and hopes of one day having a family of my own, I'm concerned about the effects that climate change will have on the elderly and future generations.

My father, who lives outside of Austin, Texas, a state which is already hot and dry, has begun to see increased droughts. This summer alone he has had to purchase two truckloads of water for his home, which is not on the city's water system, whereas last year he only purchased one.

The IPCC estimates that average temperatures in Texas will rise 5.85 degrees by 2100 if global warming continues unabated. I am concerned about the effects that these temperatures and weather conditions will have on my father as he gets older and his health is more vulnerable.

As you have heard this morning, the debate on climate change has ended. And we see issues such as increased droughts, as I mentioned -- as we see issues such as increased droughts, as I mentioned, in Texas, we see that we are feeling the effects of climate change today.

The science has made it clear that to avoid the worst effects of global warming, we must achieve 80 percent reductions in global warming emissions by 2050. As cars and light trucks account for 20 percent of the country's global warming emissions, the single biggest step that we can take in this country to reduce global warming emissions, save consumers money at the gas pump, and reduce America's dependence on foreign oil is to make our cars and light trucks go further on a gallon of gas.

It has never been more important that we take the strongest measures available to us to curb global warming emissions, and to do our part to mitigate the effects of global climate change.

NHTSA's draft environmental impact statement fails to analyze the benefits of greenhouse gas emissions, emission reductions from fuel economy standards in the proper context. As I mentioned, we know that emissions from the transportation sector account for roughly 20 percent of the country's global warming pollution.

The EIS projected decreases in emissions rising from increased fuel economy standards are analyzed as a proportion of combined global carbon emissions. This figure is more clearly evaluated when presented as a proportion of the current 20 percent of domestic emissions.

An additional issue I would like to highlight is in this draft environmental impact statement is that NHTSA has arbitrarily picked 2100 as a time line for measuring the success of today's carbon reductions. A nearer term goal would help to ensure that the transportation sector does its part to achieve the goal set by the scientific community of 80 percent reductions by 2050.

In the EIS NHTSA presumes that fuel economy standards stop increasing after 35 miles per gallon in 2020. In order to properly evaluate carbon savings through 2100, NHTSA should extrapolate a curve of increasing fuel economy standards that continues to increase to 2100 at the same rate of increase as between 2011 and 2015. In order to ensure that we take the strongest measures available, NHTSA must do its part. It must begin by evaluating fuel economy standards in the correct context.

I am concerned about the effects of global warming that our planet will feel in my lifetime if our country does not show leadership and take the single most important step in reducing our carbon emissions, which is to reduce greenhouse gas emissions from our transportation sector as efficiently and effectively as possible.

In order to ensure that we take the strongest measures available, NHTSA must do its part. They must begin now by evaluating fuel economy standards in the correct context and setting fuel economy standards at the maximum feasible level, at least 35 miles per gallon by 2015. Thank you for this opportunity to testify.

MR. KRATZKE: Thank you, Ms. Yagjian. Are there any of the panelists who could come to the table who have appeared, Ms. Dean, Dr. Amarasing, Ms. Locascio or Ms. Massey, here? Please.

MS. LOCASCIO: My name is Julie Locascio. I have lived in several different cities, but have resided in Washington now for seven years. I have worked as both a planning consultant and an attorney. And I have extensive education and experience in environmental law, policy, and planning.

When I learned that NHTSA was using a CAFE cost benefit analysis based upon a projection that gasoline prices will be well below $3 a gallon in the next two decades, I was shocked. That is why I am testifying today.

I am trained as a planner to do cost benefit analyses. The NHTSA has been directed to regulate the private sector towards a 35 mile per gallon standard or better, i.e., a maximum feasible fuel economy. NHTSA is permitted to balance the cost of improving fuel saving technology against the benefits which will accrue by doing so, including the environmental benefits of reduced gasoline consumption.

The environmental benefits include reduced oil drilling on American land and off shore territories, reduced ground level air pollution emissions, and reduced carbon dioxide contribution to global warming.

Nonetheless, many consumers will look first to the impact on their own finances in assessing the value of increased CAFE standards. A higher priced vehicle will be worth the extra cost to the consumer, if the consumer gets higher fuel efficiency. But if NHTSA is saying that such a consumer will only save about $2.50 for every gallon of gas longer needed, well into the next two decades, this analysis is completely distorted.

As everyone knows the price of gasoline at the pump is current hovering around $4 a gallon, and one would be hard pressed to find a cross-section of economists who would predict that the price of gasoline is going to drop back down below $3 a gallon in the two decades to come.

Indeed, even Guy Caruso, EIA administrator has testified that the CAFE cost benefit analysis should be using an oil price between $2.96 and $3.63 per gallon. I don't see how NHTSA can ignore the expert recommendation of the man responsible for ensuring that the statutory and regulatory requirements for legally performing the environmental impact assessment are fulfilled.

I'm not going to use this testimony to explain to you the repercussions of your actions on global warming, because I think you already know them. I'm not even going to use this testimony to talk to you about the hundreds of thousands of urban children who cannot go outside to play during the most heavily polluted days of the year. I think you know that too.

What I am going to ask you to do is to stand up for common sense economics and state of the art science. I am going to ask you to stop worrying that this administration is going to fire you for doing the right thing.

I am going to ask you not to tow the line in promulgating regulations that make no sense, and which if promulgated will only lead to litigation and a lengthy delay until a federal court orders the administration to comply with the law.

In short, I am asking you to make a stand because we are all in this together, and none of us wants to be explaining to future generations why we continue trashing the air we breathe, when we all knew better. The more we refuse to pay today, the more we will all be paying tomorrow.

If realistic fuel costs are used in a CAFE cost benefit analysis, NHTSA could set mile per gallon standards high enough to be the carbon equivalent of taking an additional $10 million cars off our roads. Please do the right thing. Thank you for listening to my testimony. May I submit my written testimony also?

MR. KRATZKE: Thank you, Ms. Locascio. We have five more people who we had planned to have speak before lunch. If any of them are present, I would invite them to come up to the tables. Dennis Chestnut, Tara Morrow, Sarah Karlin, Heather Moyer, and Larry Menkes. Dennis Chestnut? No. Tara Morrow. Ms. Morrow.

MS. MORROW: Thank you and good morning. Thank you for the opportunity to speak today on this DEIS. My name is Tara Morrow, and I'm on the staff of Greater Washington Interfaith Power and Light. We are one of 28 interfaith power and light organizations across the United States, a growing movement of people of faith responding to global warming.

When religious people talk about responsible stewardship of our resources or care of the earth, it is toward abundant life for future generations that they measure the costs to their own lives.

As you set standards to meet the energy independence and security acts mandate to achieve a fleet wide fuel economy outreach of at least 35 miles per gallon by

2020, may you remember that 35 miles per gallon is a minimum, and future generations will applaud us for our boldness in implementing what is technologically feasible, or wonder how we lacked the creativity and will to respond to global warming and the challenges of energy security.

I did study physics in college before attending seminary, which does help me get through the statistics and tables of the DEIS. But I am here today as a person of faith, in particular, greatly concerned about the impact energy policies and activities resulting in increased global warming emissions have upon the poor and vulnerable.

As was demonstrated during the aftermath of hurricane Katrina and around the world in recent months with increased food prices, quantifying the impacts of global climate change is not simple, and will only increase in value as we more fully grasp its consequences.

The debate about whether climate change is real or caused by human activity is over. And as I witnessed from first hand accounts during a recent trip to the Philippines, the effects are already taking a toll upon our world.

While I was glad to see that the DEIS does assign a dollar value greater than zero to CO2 reductions, I ask you to take another look at the value range and price carbon more accurately given the most recent analysis, as others have referred to here today.

The costs of global warming exacted on us, or more accurately on our children and grandchildren, and generations to come, if we take only token action now is sure to be steeper than any costs that we will incur now.

Another matter for closer examination in the DEIS is the estimate of the price of gasoline used to determine what is cost effective. Many here have already referred to this, but I, too, was quite shocked to see an assumption of only in the $2 range for 2016, that's in terms of 2006 dollars, and it does seem quite unrealistic given current realities, at least given what I paid myself in my own Ford Focus yesterday on my way back from a family reunion in Pennsylvania, which I had bought because it got pretty good mileage at the time. But with the price of gasoline, I have to think about what trips I'm going to make.

When higher projections of gas prices are used, then significantly higher standards are technologically feasible and economically practical.

Given the recent soaring gas prices, we are seeing a change in the market by consumer demand for vehicles with greater fuel economy. However, I think the American people are ready for bold action, at least my generation is, and moving forward will take more than responding to market research.

It takes full measure of the costs to us if we do not take action or take only very modest action. Costs which the DEIS begins to address, but I hope will be more fully incorporated when the final fuel economy standards are issued for passenger cars and light trucks for 2011 to 2015. Thank you for your time.

MR. KRATZKE: Thank you, Ms. Morrow. Sarah Karlin. Heather Moyer.

MS. MOYER: Good morning. Thank you for having this hearing. My name is Heather Moyer. I'm here as a concerned citizen. Thank you for holding the hearing.

I just want to say, as I watch people struggle to pay higher gas prices and argue consistently over whether we should be drilling for more oil, I am continually frustrated by our government's seeming lack of appropriate action in trying to address these issues, especially when addressing these issues in a smart way can not only save Americans money, it can also address our addiction to oil and fight global warming.

And I know that we as Americans must also take personal responsibility when it comes to helping the environment and driving smart and finding solutions to global warming. But it also falls upon us to urge our government to take the major actions that can widely address these sorts of problems.

The government must take actions, and if you are waiting to hear from Americans to tell you to do something, well, here you go.

As others have said, the debate over climate change is done. People agree. And we are already feeling repercussions. We're no longer talking about far away possibilities. Things are happening right now. As a former reporter who covered disasters, I saw many of these situations up close and personal. And we must take action now.

The costs exacted on us if we do nothing now is guaranteed to be far worse than any possible cost of prevention.

Although there is no silver bullet to get us to an 80 percent reduction in carbon emissions by 2050, the single biggest step we can take in this country to reduce our global warming emissions, save consumers money at the pump, and reduce our dependence on foreign oil, is to make our cars and trucks go farther on a gallon of gasoline.

The technology exists today to safely and cost effectively make all passenger cars and light trucks reach a fleet wide fuel economy average of at least 35 miles per gallon by 2015. Taking this step will achieve the goals of the new fuel economy law, and is most pertinent to this hearing, will greatly reduce the global warming emissions from the transportation sector, which as you've heard others say, may currently make up 20 percent of our country's greenhouse gas emissions.

And again, as others have said, I also was surprised and shocked to see the proposal assuming that future gas prices would be only $2.25 in 2016 using 2006 dollars. I found that shocking and saddening, and also laughable. And I urge you to use realistic gas prices. We know, I mean, again, we talked about cars, I drive a '95 Saturn. It still gets really great gas mileage. It now costs $40 to fill up.

NHTSA's own analysis shows that between 2011 and 2015 significantly higher standards are feasible and economically practical when higher gas prices are used. NHTSA's final rule should be, at a minimum, consistent with the analysis provided in the preliminary impact analysis that accompanied this proposed, this notice of proposed rulemaking.

When it comes to oil savings, the U.S., our increased global warming emissions from vehicles and growing oil dependence put our entire country at risk. We see this daily as billions of dollars flow out of our economy to pay for oil, while the reports on global warming impacts continue to flow in. It is time to put existing fuel saving technology to work by increasing fuel economy standards to the levels that reflect the maximum achievable standards for vehicles produced in 2011 and 2015.

And by the agency's own estimation, the proposed standards will save more than 54 billion gallons of gasoline over the five model years addressed in this rulemaking. Setting standards to at least 35 miles per gallon in 2015 would save an additional 22 billion gallons of gas.

America holds just three percent of the world's proven oil reserves, yet we use 25 percent of the world's oil and so clearly we cannot drill our way to oil independence.

NHTSA understands the importance of conserving oil. It makes every effort to undercut the oil savings that fuel economy gains can achieve for this nation. The high gas price scenario yield cost effective and technologically feasible standards that will help met the nation's need to conserve energy.

NHTSA should ensure that final standards are set using this value as a minimum. I urge you, you have the power to make rules that make such a huge difference, and I urge you to use that power and really take a stand and make a difference. Thank you.

MR. KRATZKE: Thank you, Ms. Moyer. Mr. Menkes. All right. At this point are there people here who were supposed to present earlier? Mr. Figueroa? Please.

MR. FIGUEROA: Hi, everybody. My name is Emanuel Figueroa, and I am from Puerto Rico. I'm sorry I was a little bit late. It's really difficult to get around this city. It's like everything looks the same for me.

So I'm here as a concerned citizen for gas prices and off shore drilling. I'm here because as a Puerto Rico citizen I don't have a voice, representation, or a vote on this administration, the Congress and everything that is happening with this government, but still manage to affect us in the small island in the Caribbean, the Commonwealth of Puerto Rico, that is 110 miles by 32 miles, and it has a population of 4 million people.

I am here also as a recent graduate that is making its way into the job businesses, and like I'm trying to like cope here with like my income and how much I pay for gas and other expenses that I have.

I'm here to the matter of change because you, as NHTSA, have the power and responsibility to enforce fuel efficiency standards of at least 35 miles per gallon. And this is the biggest single step that you can do to create a better world, and this will save a lot of gasoline, and this will save us a lot of money. And that's a really good thing.

I'm not an expert on global warming and energy issues. Because I'm a recent graduate, so I know a lot about the theory, but I don't know how it gets opined to our government and the policy making and the decision making strategies, but it doesn't make sense when we assume that the price of gasoline is $2 or $3, when we go outside and see the first, any gas station, doesn't matter if it's an Exxon, Mobile, Shell, any. You can choose your brand. You can choose the one that you like for your car, but it's way over $4 right now.

And it's really difficult when people are willing to pay more for their car to have a higher fuel efficiency, but it doesn't make sense in the numbers, because maybe the numbers that we're using are for old information or don't take into consideration the whole picture.

So I encourage you into NHTSA to actually take into consideration the correct price or re-evaluate what is going to be the price of gasoline in the future. Because when you plug in the right numbers into the formula that you use, it will make a lot of sense to have a higher fuel efficiency in our cars. Thank you.

MR. KRATZKE: Thank you, Mr. Figueroa. Mari Castellanos.

DR. CASTELLANOS: Good morning, and thank you for holding this hearing. I'm Dr. Mari Castellanos. I am a minister with the United Church of Christ, a denomination of 1.6 million people.

I speak not only on behalf of the church, but on behalf of the children of the church, for it is to them that we are accountable. It is their future which will be greatly impacted by the decisions you make. I charge you with their responsibility for their future.

35 miles per gallon by 2015, an 80 percent reduction of greenhouse emissions by 2050, is the minimum that we must achieve, a commitment to their future. It is God's creation. It is our children's future. In their name and on behalf of Andrew, Christopher, and Thomas, my grandchildren ages 10, 8 and 6, it is in their name that I request that you aim as high as you possibly can in reducing greenhouse emissions.

Thank you very much. We will carefully await your decisions.

MR. KRATZKE: Thank you Reverend Castellanos. Sarah Karlin, please.

MS. KARLIN: Good morning. My name is Sarah Karlin, and I am from Livingston, New Jersey. Thank you for the opportunity to testify. I am here today because I am concerned about the devastating impact global warming will have on this country and the entire world if we continue to stand by and casually ignore this impending crisis.

When I was younger, my parents would read to my brothers and me every night. One of our favorite books was the Little Engine That Could. Many of you probably remember this famous tale of a small engine whose hope and courage enabled him to pull a large train over a steep mountain.

Other larger engines refused, but this engine's famous motivating words, I think I can, I think I can, carried him over the hump.

Climate change is happening now, and if we don't respond quickly, global warming will continue to disrupt our environment, our economy, and our very ability to survive. We must act now to reduce our carbon emissions.

The science has made it clear that in order to avoid the worst effects of global warming, we must achieve an 80 percent reduction in greenhouse gases by 2050. At first glance, this may seem like a daunting task, but if we start now, and if like the Little Engine That Could, we believe we can, the U.S. can achieve the necessary emission cuts to prevent the most tragic impacts of climate change.

Yet NHTSA's draft environmental impact statement fails to analyze the benefits of greenhouse gas emission reductions from various fuel economy standards in the proper context.

Not surprisingly, when NHTSA tried to determine the difference in global ocean temperature rise in 2100, resulting from a 31.6 miles per gallon in 2015 standards, versus a 35 mile per gallon in 2015 standards, statistically there is none.

But this does not mean that raising fuel economy standards faster will not have a significant impact in our struggle to reduce global warming pollution. Emissions from the transportation sector in the United States account for roughly 20 percent of our country's greenhouse gas pollution, and as any projected decreases in greenhouse gas emission arising from increased fuel economy standards can never be greater than this, those reductions should be considered as a proportion of the 20 percent, not as a proportion of the entire planet's combined carbon emission. The latter simply overwhelms any measurable progress.

Adequate fuel economy standards can help the U.S. make a significant dent in our overall carbon emissions by 2050. Sure, other measures will need to be taken to meet the 80 percent reduction by 2050. But the transportation sector must play its part.

Imagine what the world would be like if every time history's great innovators faced a daunting task they simply gave up. We'd likely be living in a very different world. Where would the airplanes be, the computer, the internet. The list goes on and on.

Luckily the inventors of these technologies were not deterred by critics or nay sayers. Those with the power to solve global warming must follow in their footsteps.

The transportation sector won't fix all of our climate problem, but it does have a moral obligation to be part of the solution. NHTSA cannot afford to sit back and do nothing. Solving the world's climate crisis is possible if only we truly think we can. Thank you.

MR. KRATZKE: Thank you, Ms. Karlin. At this time, if there are no other speakers from the first 35, we will take our break for lunch. At the beginning I announced we were going to take lunch from 12:30 to 1:30, but since we're giving you extra time, if you could, we'd appreciate it if you'd be back at 1:00. That's about an hour and 15 minutes from now. Thank you, and we're looking forward to the rest of the witnesses. Thanks.

(Whereupon, at 11:44 a.m., a luncheon recess was taken.)

AFTERNOON SESSION

MR. KRATZKE: All right. Thank you. We are going to start our afternoon list of speakers. If I could, I'd like to ask the following group to come up to the tables at the front of the room. Jim Pierobon, Allison Forbes, Ron Halber, Rita Rodgers, James Keck, Rabbi Fred Dobb, Fred Teal, Alina Fortson, Matt Kirby, Jaafar Rizvi, Ben Schreiber, and Sarah Alderfer.

And I suppose with this I'd like to ask Mr. Jim Pierobon if he would like to start us in the afternoon session. Please, at the podium. Thanks. And just to remind folks, if you will, please state by stating your name so that our court reporter will have that clearly in the record. Thank you.

MR. PIEROBON: Thanks, Administrator Kratzke. My name is Jim Pierobon. I'm from nearby Silver Spring, Maryland, and I use, as I almost always do when I get to downtown, public transportation, the Ride-On bus system, and our wonderful subway system.

But not only do I take public transportation to get another car off the road, but it's another way of perhaps dealing with my personal frustration at the serious lack that I think we have in choices for very fuel efficient automobiles.

And I've worked as an energy writer for the Houston

Chronicle and a freelancer for the New York Times on a variety of energy issues going back to the 1980's. So, you know, I've had a lot of personal heart in this. And it's a privilege to come and speak to you here today.

And since then, I've been advocating for anything that can lead to a cleaner and significantly more energy efficient energy future of ours. But personally I'm appalled at how it seems to this layperson, with a fair amount of knowledge about energy markets and energy policy, how disconnected, if you will, the CAFE rulemaking seem to be, and the environmental benefits of significantly higher gas mileage standards.

You know, where possible, I'm a strong advocate for market oriented solutions. And you know, I would love to look to Detroit to be able to recognize the demand for more fuel efficient vehicles, especially as we've seen gasoline prices go up. But in this case, you know, with the growing challenges to our environment, it should compel, I think, you folks to put a much stronger value on higher mileage standards.

So I urge you, just to quickly conclude here, to use more realistic assumptions about how high future gasoline prices could go. And looking back on how high they've been this year. And I hope you'll recognize how fuel efficient hybrids, as one dramatic example, are becoming more valuable and how quickly and efficiently they can deeply penetrate, especially the consumer automobile market. Thanks for your time.

MR. KRATZKE: Thank you, Mr. Pierobon. I'd like to call Allison Forbes.

MS. FORBES: Hi, my name is Allison Forbes. I work with the Sierra Club in the D.C. area and just want to offer my personal comments today.

I have a friend with a Mercedes that's old enough to actually have this gadget on the dashboard that measures the mileage that she's getting, and it's not a new hybrid or anything like that. It's an old car that tells here, you know, how much she's getting for her money and her gas in the tank. And I know we've lost the consciousness of some of these solutions like increased fuel economy. We're not in a crisis.

I think we have an enormous opportunity here today to really change that and look at the long term and really invest in technologies and the vehicles that will increase fuel economy and save us money driving our cars. I think it's been an enormous loss for the U.S. that we haven't taken the opportunity in so long to really increase the fuel economy of our vehicles.

And I'm definitely going to be in the market for a new car in the next several years. I hope I have the opportunity to spend some extra money that will also save me money in the long run, because I know that's an investment, that investing in those new technologies will also reduce costs for consumers, and they'll save money at the gas pump in the long run.

I hope that this hearing and this rule will contribute to ambitious new innovations that America can lead the way in putting cars on the street that are saving consumers money; and also helping solve global warming, bring down emissions. [Sic]

That brings me to the enormous cost of global warming that I want to address, to note that we need to make an impact to reduce our emissions in the next several years. It's apparent that we need to make enormous contributions to this with solutions that have economic benefits as well as environmental benefits. And this is the way to do it. I hope you will be very ambitious in this rulemaking.

And consider the effects on the near term, in terms of reducing U.S. emissions in the near term to consider how important it is to make early investments in technology, so that they are available sooner rather than later, you know, you need to get ahead of the game in solving global warming, as well as being a leader in international markets and in international debate on global warming.

In addition to that, in addressing the need to have economic and environmental solutions, we need to, you know, [sic] America is clamoring for solutions to high gas prices and to our oil dependence. And so I think it's necessary that we invest heavily in the solutions that, you know, benefit us, and also benefit our country, and help us continue to protect lands that are special and pristine.

I also just want to add that the figure you're considering right now for cost of gas is offensive to consumers. And I'm sure you know that, but we definitely need to be considering the higher cost of gas in our analysis. I paid $4.15 a gallon over the weekend driving around, and it's not easy. So please consider that in your rulemaking. Thank you.

MR. KRATZKE: Thank you, Ms. Forbes. We now have Deborah Linick speaking for Ron Halber.

MS. LINICK: Yes. Thank you very much. I'm Debbie Linick. I'm the assistant director of the Jewish Community Relations Council of Greater Washington. Our Jewish Community's national umbrella organizations, the Jewish Council of Public Affairs and the Coalition on the Environment and Jewish Life could not be here today, and so I'm delighted to testify here at their request.

The JCRC is the local chapter of JCPA, representing 210 Jewish synagogues and agencies in and around the nation's capital area. Clearly our Jewish community joins those of many faiths who urge careful stewardship of creation.

We believe that the best environmental initiatives must be economically just, not disproportionately burdening the poor. They must be sustainable over time, and grounded in sound science. The best policy should encourage participation by government, industry, institutions and individuals alike.

Urging strong CAFE standards meets each of these important goals. Increasing gas mileage of our vehicles is the best way to simultaneously save Americans billions of dollars in transportation costs, and cut down on the emissions that exacerbate global warming.

Furthermore, reducing dependence on oil, especially foreign oil, improves our economy and our national energy security interests.

For all of these reasons, we urge you to set strong standards, but achievable standards, and to do so in a transparent way that explains to the American people how stronger standards help protect the environment.

Americans are already paying more than $4 a gallon for gasoline in this country, all around this country. We must regulate fuel economy based on realistic assumptions about the likely future cost of fuel, and with an eye toward encouraging cleaner vehicles, and the pursuit of renewable and alternate sources of energy.

Thank you for inviting our testimony today. We look forward to strong standards deriving from an open and deliberative process. Thank you for allowing us to be part of that.

MR. KRATZKE: Thank you, Ms. Linick. I'd like to ask Rita Rodgers to speak, please.

MS. RODGERS: As I, let me introduce myself. I am Rita Rodgers, R-O-D-G-E-R-S. I was invited by the Union of Concerned Scientists. I do not represent them. I represent myself. I couldn't afford to join them.

As I talked with some of the younger people and listened to them, the first thing that came to mind was, when I drove an English Ford Angler with four cylinders I bought 25 cents worth of gas, and went 30 miles a gallon. That's a long time ago.

We are now at $4.15 a gallon. I think it spiked at $4 -- I don't remember, my 1993 Honda Civic EX gets about 35 to 40. My point is, I have a historical perspective here.

I recall that in the 1970's we had, "an energy crisis." We -- and the government responded, I thought, appropriately. They set standards. Nothing happened, because after that energy crisis passed, we didn't look down the road to see another energy crisis coming.

So here I go. Here's my background. I'd like to first thank the NHTSA for the privilege of speaking about our current energy crisis. My background as a scientist includes the following, a degree in experimental psychology, work equivalent to a BS in chemistry, and graduate work in both areas. University classes include years, two years of engineering calculus, physical and organic chemistry, ecology, et cetera, et cetera, et cetera.

As a scientist, I am not politically correct, which is why I'm unemployed now. I do not value the dollar over life on our planet. As every scientist knows, there is a reaction for every action.

For example, where does the energy go from underground nuclear tests? What effect have manmade disasters, and I have to add a little bit of politics in this, such as September 11, 2001, and wars had on our atmosphere in the form of particulate matter circulating the planet?

If we show the same disregard for clean air that we have shown for clean water resources, what happens to nature's capacity to recycle carbon monoxide. Carbon dioxide creates clean air. I suffer from asthma. And I can recommend as a chemist coffee. It's in the same family as Xanthese. It can give you a heart attack if you are not used to the drugs. Just an aside.

Deforestation and our prolific use of fossil fuels has had a disastrous affect on nature's ability to provide clean air. All this so those [sic] with enormous economic resources can drive the latest and largest SUV's and feel safer, from I don't know what, a terrorist attack.

From my knowledge of nuclear physics, and I didn't go into that field, believe me, I can tell you at ground zero and you're very lucky because you're vaporized. If a hardwood forest is clear cut and left to regrow, it takes 150 to 200 years for it to go through the successive stages to return to being a hardwood forest providing us with clean air. A hardwood forest is preferable to a soft wood or pine forest because the leaves of hardwood forest provide a larger surface area than pine needles for oxygen recycling.

It is my understanding that if we do not, if we continue business as usual, the planet might cease to exist within a century. That's not a joke. The way it would cease to exist, it would implode. It might implode from the destruction of the earth's crust.

For example, drilling. I give you the permafrost in Alaska as an example. Concrete, tar, nuclear tests. These are all assaults man has brought to the earth, to the planet. We don't have a lot of time here. It's time to get serious.

I hope Congress and the federal agencies responsible for the decisions about automotive efficiency will take [sic] these concerns into consideration for the sake of future generations. Thank you.

MR. KRATZKE: Thank you, Ms. Rodgers. Mr. James Keck, please.

DR. KECK: Good afternoon. My name is Dr. James Keck. I'm a preventive medicine resident at the Johns Hopkins Medical Center speaking today on behalf of the Environmental Defense Fund, or EDF, a national nonprofit organization dedicated to finding practical solutions to the most serious environmental problems.

EDF, while supporting the inclusion of climate change health impacts within the EIS is deeply concerned by the assertion that the agency and its consultants were unable to determine the magnitude of these impacts across the proposed CAFE alternatives, not only on the basis of climate change, but also regarding conventional pollutant health impacts.

We believe that NHTSA has failed to comply with the Ninth Circuit's previous mandate to quote, provide the necessary contextual information about the cumulative and incremental environmental impacts of the final rule in light of other CAFE rulemakings and other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions.

We are also concerned that even though EDFCA requires NHTSA to select the maximum technically feasible fuel economy that is economically practicable, the administration has deviated from this mandate and instead selected the standard that supposedly maximizes economic benefits. This so called optimized standard falls below alternative standards that convey less net economic benefits, but are still economically practicable and better meet the other recognized statutory considerations of energy conservation, environmental, and human health protection.

In its decision, the Ninth Circuit quotes from CJ Wall's dissenting opinion in City of Los Angeles versus NHTSA stating, we cannot afford to ignore even modest contributions to global warming. If global warming is the result of the cumulative contribution of myriad sources, anyone modest in itself, is there not a danger of losing the forest by closing our eyes to the felling of the individual trees?

And yet this is precisely what this EIS does. By presenting only the isolated impact of this one set of U.S. regulations upon the entirety of global climate change, and then asserting that health and other impacts are too uncertain to distinguish among the range of alternatives, NHTSA is certainly closing its eyes to the context of this regulation as well as the full set of cumulative impacts relevant to this EIS.

The EIS draws heavily upon the most recent IPCC report in describing the causes of climate change and its

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impacts on the environment and human welfare. However, the EIS ignores the IPCC's description of targets for avoiding the most drastic of these impacts. For example, the IPCC states that avoiding a temperature increase of more than 2.6 degrees centigrade from pre-industrial times reduces the risk of key environmental and health vulnerabilities, and to do this, greenhouse gas emissions must peak within 10 years, and atmospheric carbon dioxide levels stabilize at less than 440 parts per million.

The absence of this critical context within the EIS leaves the public and policy makers unclear whether the preferred CAFE alternative will support a cumulative strategy to avoid the most serious climate change impacts.

Although the IPCC report provides a clear context and benchmark by which NHTSA can assess the alternatives, the EIS has failed to do so.

Let me next address the failure of the EIS to distinguish between CAFE alternatives and the basis of health impacts of conventional air pollutants. EDF and four other organizations called for a transparent quantification of health costs and scoping comments preceding this EIS.

The EIS notes that health costs are included within the Volpe model, used to select optimized alternative, but it fails to include estimates of adverse health events in its statement. And while the EIS provides the future relative reductions in tons of air pollutants across the different CAFE alternatives, it does not link these air pollutant reductions to health in a transparent and meaningful way.

To demonstrate that such a linkage is possible, we used a simple methodology to estimate the changes in meaningful health outcomes associated with a [sic] different CAFE alternatives.

Although I do not have the time to relay all of the specific details of our findings, the health protection resulting from, for example, the pollutant reductions in the cost equals benefits alternative versus the optimized CAFE alternative is measured in thousands of avoided deaths, and thousands of avoided asthma visits to the emergency department per year by the year 2020. We will include the full details of our analysis in our written comments.

In summary, this draft EIS fails in at least three key ways to fulfill its NEPA and EPCA mandates. First, the EIS does not provide an appropriate context to evaluate fuel efficiency in light of the IPCC consensus on the mitigation measures necessary to avoid serious climate, change health and environment impacts.

Second, NHTSA has not provided sufficient transparency to explain why it has departed from more stringent alternatives to better meet the energy conservation goal of EPCA.

And finally, the health impact assessment of conventional air pollutants lacks transparency and utility in that it does not provide meaningful information to policy makers and the public about the health benefits of more stringent CAFE standards. I thank you for your attention.

MR. KRATZKE: Thank you, Dr. Keck. Could I call Rabbi Fred Dobb, please.

MR. DOBB: Thank you. I'm Fred Scherlinder Dobb, a local public rabbi, and the Coalition on the Environment and Jewish Life is here. I'm on its board, as well as the Greater Washington Interfaith Power and Light, the Shalom Center, and Religious Witness for the Earth. And I'm here to urge you to prioritize the climate impacts of fuel standards, and to choose the path of conservation over convenience.

You must be overwhelmed by voices and perspectives today, along side your own proclivities. I hope and pray that you and all who make this decision are able to really maintain an open mind at heart, and be truly open to the evidence and ideas here.

That said, though I'm a man of the cloth, I'm not here to talk theology. I will cite ethical and moral standards. I happen to derive them from the biblical tradition, principals which compel our accuracy, our courage, and our alacrity in turning around this scourge of climate change.

Credentialed folks have already said what the American people get, [sic] anthropogenic climate change is real. Its early effects are seen now, worse lies ahead. A robust scientific consensus takes it very seriously. We bear disproportionate, historical, quantitative, and moral responsibility for it. And everything we do as individuals or national safety committees makes an incremental difference, a real one.

Fuel economy is a global concern, a concern of our nation. In my world it's a Jewish issue, too. Back in the Talmud, the law of not wasting, Baal Tasshchit, specified how you should properly burn the right kind of fuel of naphtha versus oil to get the right result. We had that consciousness 1700 years ago.

Our Jewish community today, through COJL offers a friend of the Court brief on California's clean air challenge to the EPA's non-waiver. We see urgency in curbing our oil addiction, our dependance, and in protecting all that we can.

And like many others here, I'm particularly concerned about calculations for the likely cost of gas in the future. Spiritually and ethically, we cannot reduce endangered species, flood and famine refugees, or the integrity of recreation to pennies in an equation, not that the draft EIS even accounts for them at all.

We cannot stand idly by while our country proposes to ignore the lion's share of logic and evidence, lowball the estimated price of gas a decade hence, lower fuel economy, and send aloft hundreds of millions of tons of carbon that could have been avoided.

It was Mark Twain or Benjamin Israeli who coined lies, damned lies, and statistics. Stats can be accurate. They need to be attempted. They can be harnessed for good, but sometimes they go the other way.

How we best guess the price of gas going forward, using current numbers, current numbers in Europe, which are twice our $4 a gallon, figuring futures markets, there are so many approaches we can take.

I'm no statistician, but as a citizen and clergy person it seems that whatever method yielded $2.25 or even $2.60 as an estimate for a decade out is an outlier at best, and a statistic beyond damn lies at worst.

This Yom Kippur I'll be speaking on responsibility to the other, the subtlety and impact of our personal choices. And I will address driving, the miles and hydrocarbons we take for granted.

I'll ask Adat Shalomers how to explain our profligacy in a conversation with a Bangladeshe or a New Orleanean, or other resident of low lying areas suffering ever more damaging impacts of rising sea level and stronger storms. And I ask you the same, as if not so much in hearing room as a confessional booth, a place of epiphany and reckoning, a day of atonement, when you will look back on your personal, like how and how much to drive, and your national choices, how efficient, ethical, and conservative to make our entire fleet. Looking back, did you do what was expedient or what was right?

Deuteronomy 30:19, I've set before you this day life and death, blessing and curse. You choose life, that you and your descendants may live. Our choices, with free will, have a real life and death implication for our great grandchildren. Please, let your and my great grandkids enjoy a slightly less denuded world. Please use reasonable numbers in your calculations.

As Rabbi Tarfone wrote 1900 years ago, it's not upon you to complete the task, but neither are you free to desist from it. A couple more mpg's won't solve climate change, but it's one of many manageable, meaningful steps that we all can and must take.

You're not supposed to solve this alone, but you must do your part as each of us must do ours. Please do yours with special emphasis on the least among us, the integrity of creation, and our descendants. Thank you.

MR. KRATZKE: Thank you, Rabbi Dobb. I'd like to call Fred Teal, Junior, please.

MR. TEAL: My name is Fred Teal, Junior, and I've come here today from Brookville, Maryland, just a bit north of the city, about 10 miles. I thank you for having me here.

Brookville is a very small town, and in that town I have my home with my wife and a 17 year old son. And I am here today because I'm very concerned about NHTSA's reluctance to upgrade corporate average fuel economy standards above minimum required levels.

I believe there is clear evidence that our air and our water temperatures are increasing steadily with serious consequences for our planet. Sea levels are rising, glaciers and polar ice caps are being reduced. Storms are gaining intensity. And rainfall is extreme in some places and nonexistent in others.

These changes are the result of the increasing levels of greenhouse gases that we now have in our atmosphere.

I understand that today's concentrations of CO_2 are higher than they've been in 600,000 years. Every extra gallon of fuel that we burn spews about 20 pounds of carbon dioxide into the atmosphere. We need to do everything possible to stop this.

My town recently decided to form an energy advisory committee and asked us to figure out what our carbon footprint was. We measured our electricity, our fuel oil, our propane, because we don't have natural gas, and other sources of emissions. And from that we learned that about 42 percent of our emissions came from our vehicles.

In my situation, I have a Prius and a Toyota Sienna. The Sienna is a 1998 model with 170,000 miles on it, and I'm kind of embarrassed to be driving it because it only gets 17 miles per gallon. For about the last four years I've been looking for a substitute.

I have three elderly parents and parents-in-law, and together there are six of us, with my wife and my son and myself. We need to take little trips together. I'm looking for something that's fuel efficient. I'd like to have something that would get 35 to 40 miles per gallon. You know there is no such vehicle on sale in this country today. There is no minivan that gets that kind of mileage. There are several SUV's that will seat five, but none that will seat six.

Do you know that since 2002 in Japan they've had the Toyota Estema, which is a small minivan that's a hybrid, and it gets about 45 miles per gallon. There is also a Mazda 5 which is sold here, but not with a diesel engine which gets around 40 miles per gallon with a diesel engine, but about 27 with a gasoline engine. But it's not being sold here.

It seems to me it's clear that the reason these vehicles are not being sold here that could meet my needs and help reduce global warming is because CAFE standards are not high enough to encourage vehicle manufacturers to bring these high mile per gallon vehicles in as part of their fleets. We need to make a change in that.

T. Boone Pickens, who is a long time republican supporter, and a very successful oil man is mounting a major effort to encourage us to switch to wind and solar and geothermal energy for power generation. He's also said, perhaps we could use a little natural gas to power our vehicles.

His main message is, "I've been an oil man all my life, but this is one emergency we can't drill our way out of." He's investing in a substantial amount of solar energy in a place called Pampa, Texas, in the middle of the state. This is going to create many new American jobs, with a great deal of new technology.

It should be very helpful if we begin to look at some of these technologies in terms of American jobs, and American development.

In summary, I wish to say that I disagree strongly with the arbitrarily low future gasoline prices contained in NHTSA's calculations. It's just incredible that you would use mileage figures for gas costs per gallon for gasoline that would be that low. It's just so impractical, considering our current situation.

I also disagree with your belief that we're not going to have any substantial amount of hybrid vehicles introduced until 2014. They've been around for years, and Ford and General Motors, Honda, Toyota, are making them and selling them today in large quantity.

I disagree with your assumption that the rate of adoption of hybrids is going to be as low as you say it is. I finally say, we stand at a fork in the road, and we can continue to consume fossil fuels and complain about high prices and make only incremental change [sic] in our energy policies, or, on the other hand, we can shift our sights to renewable energy sources and accept the investment and the other costs that that may entail.

I don't think it's a question of whether we're going to do this. Forces are going to push us into doing it because of the high cost of fuel, and because of the high demand coming from other countries. One thing is certain, the sooner we start our journey, the faster we'll reach our destination. Thank you.

MR. KRATZKE: Thank you, Mr. Teal. Is Alina Fortson here?

MS. FORTSON: Hi. My name is Alina Fortson, and I live and go to school in Berkeley, California. Thank you for the opportunity to comment today.

I am here because I think that addressing global climate change is one of the most important issues for this generation. I know that we currently have solutions that reduce greenhouse gas emissions in addition to improving our economy. If we don't act fast, we're going to lose the opportunity to make a difference.

Sutter Creek, the town where I went to high school, is in a rural area in Northern California. Public transportation is lacking, and many families live at least 30 minutes from basic necessities, such as supermarkets and schools, and close to two hours from Sacramento, the closest metropolitan city.

As you can truly imagine, the price and efficiency of fuel has a significant impact on this community. It is critical that we address both the economic and the environmental impact of our oil dependence, and take steps to curb them both.

In order to address climate change, scientists are stressing the importance of achieving an 80 percent reduction in greenhouse gas emissions by the year 2050. This means making small reductions in all of our emission areas, including transportation.

The United States transportation sector amounts to approximately 20 percent of our total greenhouse gas emissions. Therefore, measuring our progress requires considering reductions as a portion of that 20 percent, not as part of the global emissions. In this light, every small improvement does make a difference.

If we are to take advantage of our best, and most feasible technology, we would be in a position to reduce our oil use, in addition to lessening the impact that the price of gasoline has on families like mine.

NHTSA's current proposal hinders this potential. Your analysis uses assumptions for future gas prices that are simply unrealistic. Today, Americans are paying nearly $4 per gallon and there's currently no reason to expect prices to drop as low as $2.25.

Basing decisions on these faulty analyses is irresponsible and disregards NHTSA's duty to impose feasible fuel economy standards. I urge NHTSA to consider how this rulemaking increases the strain on the average family and to reevaluate your position on this issue and on climate change at large. Thank you.

MR. KRATZKE: Thank you, Ms. Fortson. Matt Kirby, please.

MR. KIRBY: Hello. I'm Matt Kirby. I want to thank you for this opportunity to have this hearing. I'm here for two reasons, and that's gas prices and global warming. And these are two crises that are currently facing our country. And they are two crises that NHTSA and the five of you sitting in front of me have the ability to severely help.

I'm from Wisconsin originally. It's a big state, it's a big agricultural base, and it's hurting. And both my parents, they aren't farmers, but they both commute two hours per day. They are strapped.

My dad teaches at a local community college. And several of his students have come forward with these really heartbreaking stories of how they have to cut food out of their food budget to pay to go to his class and to pay to go to work. And it shouldn't be happening in this country. It's criminal. And something has to be done about gas prices.

The only solution that's been presented so far is a stalemate in Congress because Republicans want to drill offshore which everyone knows, Bush' own administration has admitted, it's an insignificant drop in gas prices.

More importantly is facing the reality that this, the way our society is structured, this addiction to gasoline, which Bush has admitted, is fundamentally the cause of also global warming.

So we have two problems wrapped in one. And basically, there is one way to tackle both problems at once. Tackle the economic and the environmental, the gas prices and the global warming, and that's through fuel efficiency. And that's the power that you people hold in your hands and really need to grasp hold of.

The debate over climate change is done. We know this. I actually just finished a really great book a couple months ago that I was long overdue to read called, the End of Nature by Bill McKibben. It was the first major book written on global warming, and it was written in 1989, almost 20 years ago. And everything he says in that book has come to pass. The science was there 20 years ago, and no one has acted.

And in those, in the past two decades, the science has not only confirmed what he wrote, but actually the destruction is accelerating much quicker, much quicker than anyone actually imagined.

So now the science says we need 80 percent reductions by 2050, as several people have said. And one of the most significant being the cars and light trucks, the 20 percent, the 20 percent of emissions in this country, which emits 25 percent of global emissions. Twenty percent of 25 global emissions. That's the power you have. And that's what you can change and significantly alter the course of global warming.

As far as the environmental impact statement goes, we know we need to look at this proportionally to our domestic emissions, to our 20 percent of our domestic emissions, and not as part of the global outreach to get a better idea of how to evaluate it.

Also, NHTSA has picked 2100 as a time line for measuring success, which seems a little ridiculous, considering we have until 2050 to avert catastrophic climate change. So I would urge you to actually set a much closer goal, 2020-25 when you actually are going to begin measuring the success.

And it's setting the 35 miles per gallon by 2020, but actually to extrapolate this through 2100, to not say that 35 miles per gallon is the be all, end all fuel efficient standard, because it shouldn't be. That's an arbitrary number in and of itself, based on the unrealistic gas price of $2.25 assumption which is, frankly, an insult to my parents and an insult to the students who can't afford to eat.

Your own analysis shows that between 2011 and 2015 significantly higher standards can be achieved if you only up the presumed gas price at $3.14. So the use of these below cost energy estimates, it violates your own charter to impose mandatory maximum feasible fuel economy standards on a review of economic and technological feasibility. Thank you very much.

MR. KRATZKE: Thank you, Mr. Kirby. Jaafar Rizvi.

MR. RIZVI: Good afternoon. My name is Jaafar Rizvi. I'm a student. I grew up in Vermont. I go to school at Wesleyan University in Connecticut. I'm in D.C. this summer working.

I would like to thank you guys for having this hearing at a time where, you know, I've kind of lost a little faith in the government. It's nice to see the democratic process at work.

But I am here because I am concerned for several reasons that the fuel economy standards that you all have proposed are not strong enough.

According to the DEIS, fuel economy standards should be set at the maximum feasible average that the Secretary of Transportation decides the manufacturers can achieve in that model year, while simultaneously considering technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need for the U.S. to conserve energy.

And I agree with those guidelines. I think they're good. But I fear that NHTSA didn't properly analyze each of those specifically. For example, when considering economic practicability, the report doesn't really go into all of the economic benefits of lowering emissions, as well as the moral issues, which I won't talk about right now.

Emissions relate to global warming which cause or intensify natural disasters. And consider that $90 billion worth of damage was done by hurricane Katrina. That's $90 billion that can't be spent on something else. It can't be spent on helping our economy or investing in clean energy. Some would argue that those are the same things.

Now, of course, these disasters aren't entirely preventable, but it's within our power to lessen the severity of them.

The DEIS report states that 4 percent of the world's global warming emissions come from American transportation. And if we can lower these emissions by 25 percent, we're lowering the global emissions by 1 percent.

If a decrease in 1 percent could decrease, you know, the severity of the next Katrina by 1 percent, you're talking about saving thousands of lives, and you're talking about saving a billion dollars.

Moreover, we can expect to have more than one large disaster every year. We have been having tons all over the world. Katrina was the last huge one in the U.S. But the International Federation of the Red Cross showed in its 2007 world disaster report that there has been an increase in natural disasters of over 115 percent since 2004, totaling 541 individual disasters. It states that this increase has been due entirely to weather related disasters.

And this trend will continue unless a change is made, as there are more and more natural disasters, the amount of money and lives that are disappearing will only skyrocket.

For this reason [sic] I urge and I hope that NHTSA raises emission standards to a level that will consider long term economic and practical affects of global warming, and to reconsider in a more holistic view on economic practicability.

While the DEIS report shows very detailed calculations and extensive research, the claims of NHTSA just don't coincide with the claims of other incredibly credible scientific institutions. Like so many people have said, there's a call for 80 percent reductions by 2050, and this report doesn't seem to acknowledge that.

And that's fine, of course, but since, you know, research was done, but there's no description of where the divergence is coming from. And I've heard environmental scientists talk about why they disagree with this report. And I haven't heard any argument about why they are wrong. So basically, I'm left with the position where I feel like something isn't right with the research that's been done here.

And that makes me skeptical about analysis on two of the other categories that were mentioned before, the need for the U.S. to conserve energy and technological feasibility.

As it stands in the EIS report, optimal fuel economy standards will lower the increase in relative sea level rise from 37.9 inches to 37.8 inches. The decrease in the surface contour of the earth from .789 degrees to .788 by 2030, and that's just so minuscule.

I urge you to increase the standards to 35 miles per gallon by 2015. And I would urge you to consider that this won't cause undue stress on American car manufacturers. In fact, I have tremendous faith in the ingenuity and the ability of the American people, specifically those in Detroit, not only to successfully meet the high standard, but to prosper and thrive and become leaders.

So please give us the push that we all need, and in doing so America will become a leader in tackling the environmental crisis, one of the most important problems of our generation. Thank you.

MR. KRATZKE: Thank you, Mr. Rizvi. I'd like to call Ben Schreiber, please.

MR. SCHREIBER: Hi. Thank you for having this hearing, giving us a chance to talk about this important subject. My name is Ben Schreiber. I'm the energy advocate for Environment America.

Environment America is a federation of 26 state-based environmental organizations. It's also the new home for U.S. PIRG's environmental work, so we have split off and are our own organization now.

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As the energy advocate here in Washington, D.C., I often get asked, what can we do about gasoline prices. And the solution that I'm coming up with, you know, the solution that I have in the short term is tire pressure and tune-ups. That's the best that I can come up with.

The truth is that after 30 years of failed energy policy, where we have the same CAFE standards that we did in 1975, all I can offer for consumers who are hurting right now is tune-ups and tire pressure.

We really need to do something about our fuel economy to offset the consumer's pain at the pump. And we're hearing a lot of talk about drilling. We're hearing a lot of talk about alternative energy. We're hearing a lot of talk about, you know, how what we need to do is increase supply. All of the talk that we're hearing about has incredible environmental impacts.

Increasing drilling off our coasts leaves us open to potentially having catastrophic oil spills, to infrastructure for drilling, to ruining our special and pristine wild places. And these are places that we need to protect. There's no reason that we should be drilling off of our coast, just because we can't get fuel economy right.

There's no reason that we should be subjecting the caribou and other endangered species in the Arctic National Wildlife Refuge to the riggers of oil production to the, you know, the roads and the drilling, and all of the other side effects that come along with it, just because we decide that we can't do fuel economy.

We've been saying since 2005 that we should be able to get to 40 miles per gallon with 10 years. The National Academy of Sciences said that we should be able to get to 37 miles per gallon within 10 years. And we just haven't acted. And this is without taking into consideration things like hybrid technologies, which are available today.

You know, we're using a price of gasoline of $2.30 to justify doing the bare minimum on fuel economy standards, and yet at the same time the price of $4 is being justified to open up our very last protected wild spaces to more and more oil and gas exploration. And it's unacceptable.

There are, you know, a couple of other serious concerns with the transportation sector and the fuel economy. You know, most Americans don't have choices about where to go when oil prices get high. They, we have very few public transportation options, and Americans are tied to their cars. So in the short term, there's very little that they can do to do that. [Sic]

So we are now feeling the effects of 30 years of inaction on CAFE. We don't want to be in that position, you know, 10-15 years from now. So we need to be taking the steps now so that we can be increasing fuel economy so that we can set the framework so that 10 or 15 years from now when these standards actually kick in and we're getting the new vehicles into the fleet, we're seeing reductions in fuel economy -- I'm sorry, in prices so that Americans can save money at the pump, and so we don't have to drill in our last wild protected spaces, and so we don't have to be dependent on foreign nations for our oil and energy needs. So thank you very much.

MR. KRATZKE: Thank you, Mr. Schreiber. Is Sarah Alderfer here? No. All right. Thank you for this panel. At this point we are going to call the last listed group that we have.

I'd like to invite Ami Greener, Robert Dawes, Catherine Easton, Elizabeth McGurk, Lala Shamerzan, Natia Hess, Brian Fleming, Sean Calvo, Chad Dougherty, Marsha Rucker, and Charles Yoder up to the table, please. Well, Ami Greener is first.

MS. GREENER: Thank you for the opportunity to speak before you. My name is Ami Greener, and I'm the energy policy specialist and legislative assistant for the American Jewish Committee, which I'm representing here today.

We're the nation's oldest human relations organization with over 175,000 members and supporters represented by 31 regional chapters in the U.S. and eight overseas.

AJC is a long time advocate of the need to develop energy policy that will reduce our nation's dependence on foreign energy sources as well as protect the environment. More than 30 years ago, prompted by the then recent Arab oil embargo, AJC first adopted a policy statement on energy.

Over the succeeding years, as the nation coped with energy supply shock in the seventies, coupled with concerns about the environment, safety and tanker dependency, agency adopted and acted on several additional statements that reflected the agency's concern that our nation address an increasing dependence on imported oil, and its impact in a fashion consistent with protection of the environment, and attention to policy impacts on the disadvantaged.

The 911 attacks underscored another crucial consideration, that our national security and our position as world leader are seriously undermined by our dependence on foreign nations.

All too often dollars used to purchase important oil end up supporting regimes such as the governments of Iran and Venezuela whose values run counter to those of America, and in some instances present a strategic threat with potential to disrupt oil supplies world wide, adversely affecting the world and U.S. economies with resulting loss of jobs, a decreased quality of living, and harsher conditions for low income families.

Further, the great transfer of wealth abroad created by our reliance on foreign oil sources, whether to hostile regimes or otherwise, diverse resources that if invested at home could help create good jobs and fund much needed investments in education, social initiatives, and physical infrastructure.

As we've experienced in the past, energy prices have decreased for periods of time, and with such fluctuations, Americans have become less sensitive to the need for this type of policy. Today, they've seen record prices at the pump.

We feel that the need for further action on energy security is more urgent than ever, both by assuring safe and sustainable energy sources, and through renewed attention to issues of conservation and efficiency.

While the U.S. comprises less than 5 percent of the world's population, it consumes approximately 25 percent of the world's oil. Two-thirds of all oil consumed nationwide in the U.S. goes for transportation. A drop in domestic oil production, coupled with increased consumption, has created a scenario by which the U.S. is more reliant on foreign oil sources than ever before.

Moreover, climate change, which the weight of scientific opinion holds is accelerated by greenhouse gas emissions from the use of fossil fuel, has the potential to disrupt our way of life, permanently damage the natural environment, create humanitarian crises, and provoke political and strategic conflicts worldwide.

Investment in a clean, renewable energy grid would both reduce greenhouse gas emissions and restore America's technological leadership, helping to build a sustainable economy to again create jobs and wealth at home.

The weight of the evidence demands that we devise policies directed at stemming climate change, was well as adapting to reality. In urging these policies we act in accordance with the Jewish tradition which commits us to the protection of life, stewardship of the earth and its inhabitants and the well being of future generations.

Last year a historic step was taken when President Bush signed into law the Energy Independence and Security Act that included among other provisions a strengthening of CAFE standards for the first time in more than two decades. We think the strengthening of the CAFE standards is one of the most crucial components of a multi-faceted approach to drastically reduce our dependence on foreign oil, reduce global warming emissions, save money at the gas pump, and help secure America's energy future.

These standards, for example, would save the U.S. 1.1 million barrels of oil per day by 2020, approximately 40 percent of what we import today from the Gulf, the Persian

Gulf, I mean.

In proposing a combined average of 31.6 miles per gallon for model year 2015, NHTSA is failing to acknowledge the current technology that could safely and cost effectively make all vehicles reach state-wide fuel economy average of at least 35 miles per gallon by that year.

Further, the current proposal relies on fanciful gas price assumptions, which result in insufficient fuel economy levels. The proposal assumes future gasoline prices of $2.25 per gallon, when American consumers are already paying prices nearly double that today.

The use of the low cost energy estimates violates the agency's charter to impose mandatory maximum feasible standards based upon a review of economic and technological feasibility. NHTSA must reconsider the proposed standards and use its authority to meet the urgent need of the U.S. to conserve oil and meet the growing demand of American consumers for vehicles that go farther on a gallon of gas.

NHTSA should not conclude in its analyses that fuel economy gains are presumed to stop at 2020 levels, but further grow by means of using existing technologies. We see the use of alternative and renewable fuels, new lightweight materials, and electric vehicles taking up a bigger percentage of miles driven in the U.S. in the near future.

Last statement. We cannot overestimate the importance of moving towards tougher fuel economy standards this time. Even if we -- we shouldn't underestimate the challenges this and other actions addressing energy security will entail. But we see no alternative if we are to put the United States in a more sustainable energy path, essential to both our nation's security and environmental health. Thank you.

MR. KRATZKE: Thank you, Mr. Greener. Is Robert Dawes here?

MR. DAWES: Good afternoon. My name is Robert John Dawes, and I am from (indiscernible) County, Pennsylvania. First and foremost, I greatly appreciate the opportunity to testify before NHTSA today. I come from and represent a small rural farming community located about three miles from Lancaster County, one of the most productive non-irrigated areas of farmland in our nation.

These farmers, who primarily run small dairy and beef operations are the epitome of hard working Americans, are the model for what this country was founded on. Unfortunately, they are now victims of global warming, as well as record high gas prices.

For the past four summers, Pennsylvania has undergone the worst droughts in decades, thus making it virtually impossible for farmers to grow corn, and various feed stocks for their animals. Global warming, coupled with outrageously high fuel prices, has forced many honest, hard working Pennsylvania farms from their homes.

I speak from personal experience, because on my Angus beef farm, the corn crop which we have used to feed our herd or years has required us to consider the use of irrigation for the first time due to low crop yield. Furthermore, the amount of money spent on diesel fuel for one truck as well as one tractor has matched some farmers yearly revenue.

It is gut wrenching to watch my neighbors and fellow farmers sell homesteads that have been in the family for years because of global warming, as well as high gas prices.

Despite these bleak circumstances, I remain hopeful and optimistic. I am optimistic that with the help of NHTSA we can start making manageable emission reductions. For each carbon emitting sector of our economy, each reduction will be part of a larger long term emission reduction plan. As much as I would like there to be a band aid or a short term fix for the farmers of Pennsylvania, there isn't, and all of my peers involved in agriculture know and accept this.

With the increase of global warming emissions and growing oil dependence, our country, not just Pennsylvania farmers, are put at risk. Americans are spending billions of dollars at the fuel pump and yet impacts of global warming are still affecting our nation at an exponential rate.

I hope that NHTSA understands the dire necessity of putting existing fuel saving technology to work by increasing achievable standards for vehicles produced in future years. By doing this alone, these standards would save $54 billion dollars of gasoline over the five years addressed in rulemaking.

Furthermore, by setting standards to 35 miles per gallon in 2015, an additional $22 billion dollars in gasoline would be saved. This translates to 280 million metric tons of CO_2 out of the atmosphere.

Pennsylvania farmers are one part of America that is being hit the hardest by the impacts of high fuel prices and global warming. I'm confident that NHTSA will do everything in their power to stop this quintessential part of American identity from being lost. Global warming is a long term problem in need of immediate action and cooperative long term solutions, thus ensuring a secure energy future for all Americans, as well as the farmers of Pennsylvania. Thank you.

MR. KRATZKE: Thank you, Mr. Dawes. Is Catherine Easton here?

MS. EASTON: Hello. My name is Catherine Easton. And I'm very thankful for this opportunity to testify today. I feel very strongly about this issue, both as a citizen concerned about global warming, and as a consumer dealing with high gas prices.

Global warming is happening right now, and reducing greenhouse gas emissions by 80 percent by 2050 will save us from the worst effects of global warming. But unfortunately, as I think we've all noticed, 80 percent is a lot and increasing CAFE standards will not achieve this.

In fact, no individual sector could reach such a dramatic decrease. And this is why we must strive for smaller achievable decreases in all sectors. These small decreases combined could make a substantial difference.

There is no point doing nothing, giving up, and ruining the planet for future generations, for my generation and my generation's children, simply because increasing CAFE standards alone won't make the required difference.

So this is a simple step, and let us prove that the United States does have the technology to do this. Let us set a good example for other nations. We worry about China and India developing, and the added pollution that will cause. Let us pave the way towards a solution.

Fuel economy standards are already higher in Europe than in the U.S., so the technology is available to the auto industry, but the industry feels threatened by the changing of the status quo, and opposes these higher fuel economy standards, just like the industry opposed seat belts, and just like the industry opposed air bags.

But seat belts and air bags did not hurt the auto industry, and neither will increased CAFE standards. In fact, with the price of gas over $4 a gallon, consumers are looking for fuel efficient vehicles.

If saving the environment isn't an important enough reason, if having a safe nonhazardous planet for future generations to live on isn't enough motivation, then increase CAFE standards to save our wallets.

Higher gas prices increase the price of going to work, so people need to pay exorbitant amounts of money just to make money. Senator McCulsky from Maryland said that when President Bush took office, the average family spent a little over $3,000 a year on gas. Now that average family spends $5,000 a year on gas, and pays more for food, too, because of higher transportation costs.

$2,000 sends a kid to a community college for a year, and $2,000 can alter a family's lifestyle. We pay too much for gas, but more drilling is not the solution. People have been warning for years that there is a finite supply of oil.

Even if we grant oil companies new leases for drilling, it will be 10 years before oil from those leases will be pumped into our cars. Even if we drill more, we will still not produce enough to satisfy U.S. demand. We will still depend on foreign nations for oil, and we will still risk our national security for oil.

Even if we drill more now, there will still come a time then the world's supply of oil runs out. We must fight our addiction to oil, reduce our oil consumption, so that when that day comes, the United States economy will not crash.

Agriculture, industry, transportation and services will continue by using alternative energy sources. This is not a transition that can happen overnight. We cannot wait for the world to run out of oil to begin looking for alternatives. This must be a gradual transition. So why not start by improving CAFE standards. Thank you.

MR. KRATZKE: Thank you, Ms. Easton. Elizabeth McGurk.

MS. McGURK: Hello, and thank you for this opportunity. My name is Elizabeth McGurk, and I am here because as a person of faith, an employee of the National Counsel of Churches and Christ, I recognize that we all have a responsibility to be stewards of God's world, and to care for one another.

Achieving higher fuel economy standards for U.S. cars and trucks is one of the most important actions we can take to reduce our greenhouse gas emissions which are causing global warming and impacting both God's people and God's planet.

Increasing CAFE standards is a critical step that must be taken to reduce pollution and curb greenhouse gas emissions that cause global warming, while protecting those who already suffer from high gas prices.

Improved CAFE standards would mean more vital discretionary income for low income working families to spend on necessities like food, health care, and housing. Significantly improving CAFE standards will also reduce U.S. dependence on oil, and decrease the need to open sensitive wilderness areas, including the outer continental shelf to oil and gas exploration.

As a native Floridian, I know too well that our communities are already beginning to feel the effects of global climate change. During my freshman year at Eckert College in St. Petersburg, Florida, in 2004, we were evacuated four times in one month for four different hurricanes.

I am worried about the ways in which global climate change and our country's dependence on extractive nonrenewable resources will affect my home state, and my friends and family members living there. I know that the costs, both tangible and intangible of doing nothing will far exceed the cost of taking action now.

I urge you to strengthen the current proposed standards by setting a new standard of at least 35 miles per gallon by 2015.

Genesis 2:15 calls us to till and tend the garden. Toward that end, we have a moral obligation to choose the safest, cleanest, and most sustainable sources of energy to protect and preserve God's creation. God calls on us to be wise caretakers of the earth's gifts, protecting air and water quality, as well as ecosystems and human community. Good stewardship includes reducing to the greatest extent possible the human generated carbon dioxide emissions that are causing global warming. Thank you.

MR. KRATZKE: Thank you, Ms. McGurk. I can run down this list of names, but I think you're Ms. Spear, and before you go, sir, would you like to -- yes. I think you're the last one. Or I can read off Layla Shamarisian, Mataya Sess, Brian Fleming, Sean Calvo, Chad Dougherty, Marsha Rucker, Charles Yoder. Very good. Mr. Yoder.

MR. YODER: My name is Charles Yoder. I'm from Baltimore. For identification purposes, I retired about two and a half years ago from a 35-year federal career that included 12 years on the staff of the Senate Committee on Veterans Affairs, and most recently four years as counselor to the Secretary of Veterans Affairs.

Now, I hasten to add that I am speaking for myself and not any government department or member of Congress. I have been retired for over two years.

And I think we can stipulate the importance of climate change. CAFE standards are one step that the Congress has taken to address that challenge. And I think we can say, and I want to emphasize that climate change is not abstract. It's real. The words that you write are not an abstract environmental analysis. They're not a sterile exercise in rulemaking. They'll affect the planet. They'll affect everybody that lives on this planet.

But your charge right now is an EIS. I've noticed that your EIS puts your actions, proposed actions and alternatives in the context of the world. That was addressed by someone as I came into the hall earlier, in the context of the entire planet, not just in terms of the U.S.

If you choose to do that, then I think we need to look at the implications of our national addiction to oil in a world context, in a world wide context.

Our country invests enormous treasure and enormous numbers of lives ensuring our access to oil. In my career I veterans affairs I've talked with surviving spouses, with orphans of young men and women who have died protecting our access to oil. I've talked with young men and women who were maimed for life protecting our access to oil, and it is those conversations that drag me down here from Baltimore.

Now, you will correctly note that you are writing an environmental impact statement, not a human impact statement, and this is not the forum to discuss whether or not that's an artificial discussion. But if the U.S. is going to continue our addiction to oil, then we need to address the impacts on a worldwide basis, and the environmental costs of any standard other than the strictest possible standard are enormous simply because there are powerful nations, not just the U.S., there are many powerful nations seeking access to a limited supply of a resource that overwhelmingly is located in an unstable part of the world.

And I think it's only reasonable to assume that there will be additional conflicts over the next generation, and that those conflicts will have enormous environmental impacts.

So if you're going to consider things in a world context, you need to consider the environmental impact of future wars, and those impacts must weight on the balance as you make your decision of the alternatives available to you in this rulemaking process. Thank you.

MR. KRATZKE: Thank you, Mr. Yoder. Ms. Spear.

MS. SPEAR: Hello. My name is Emily Spear, and I thank you for allowing me to speak today. I am here to voice my concern about the imminent impacts of global warming and the effects of our strong dependence on oil.

Growing up in Southwest Florida, I spent much time exploring beaches, fishing, and learning about coastal marine and wildlife. I love going to Sandibel Island and Captiva to enjoy the outdoors, bike riding, picnicking, walking around town.

Unfortunately, these beach communities and islands are now threatened by global warming. I'm concerned that my grandchildren may not have the same opportunity to enjoy this area and to see the same beauties which I have been so lucky to see.

At the rate we're going, pieces of Sandibel and Captiva may be gone before my grandchildren or my great grandchildren are old enough to visit these treasures, or smaller Southwest Florida barrier islands in their entirety may be lost forever.

Increasing fuel economy standards would be one step in curbing global warming. Scientific reports have concluded that in order to avoid catastrophic effects of global warming, we must reduce our greenhouse gas emissions by 80 percent by 2050, 2050.

This issue is staring us in the face, but I believe that NHTSA can do its part by requiring vehicles to be more fuel efficient. We know that carbon emissions from transportation mechanisms are great at 20 percent, which contribute directly to global warming. However, it concerns me when NHTSA's draft environmental impact statement analyzed the resulting benefits of greenhouse gas emissions from higher fuel economy standards in an improper context, which makes the greenhouse savings appear insignificant, though increasing fuel economy standards to 35 miles per gallon by 2015 would save 280 million metric tons of carbon dioxide.

The transportation sector has the power to help decrease the amount of carbon emitted into the environment by increasing the fuel efficiency standard.

My second main concern is about America's dependence on oil, as it is a national security issue. Our country feeds off of foreign oil, which causes us to be in the pockets of many nondemocratic governments. Increasing our fuel economy standard to 35 miles per gallon by 2015 would save us 300,000 gallons of oil per day by 2020.

Taking this simple and achievable action would help us decrease our dependence on oil, would allow us to take back control, and would help stabilize some issues with security.

Increasing the fuel economy standard would be one step, one great step toward the path that many other sectors could also, and should also follow. This is a community effort. We can do this. The transportation sector has the ability to add their contribution by increasing fuel economy standards, if we know that currently America has the capacity to increase standards to 35 miles per gallon by 2015, what's stopping us?

We have the ability to lead the world by setting an example. We have the ability to make our country more independent. We have the ability to save future generations. We need to make the choice to increase fuel economy standards. Thank you.

MR. KRATZKE: Thank you, Ms. Spear. At this point, we have run through the list of speakers who were registered. Is there anyone here who would like to speak who hasn't already done so?

If not, I would like to sincerely thank each of you for your comments on the analysis and our Draft Environmental Impact Statement. I am sure that I'm speaking for the entire panel when I say that it's different and it's more immediate when you hear and see a person, as opposed to just reading their thoughts.

You've given us a lot to think about. We want you to know that your views, your thoughts are very important to NHTSA on this subject. Please make sure that you submit comments to our docket. It's open. It closes in two weeks.

If you could give us something in writing in addition to this, we have taken a transcript. It will be in the docket. So we will consider this. But if you have other things you've thought of or smaller points that didn't fit into five minutes, it would really be helpful to us if you would submit that to our docket which closes on August 18th.

Thank you for taking the time to come here, and that's it for us today. Thanks again.

(Whereupon, at 2:51 p.m., the hearing was concluded.)

C E R T I F I C A T E

DEPOSITION SERVICES, INC., hereby certifies that the attached pages represent an accurate transcript of the electronic sound recording of the proceedings before the National Highway Traffic Safety Administration in the matter of:

PUBLIC FORUM

Corporate Average Fuel Economy

Draft Environmental Impact Statement

By:______________________________ Date:__________________

Teresa S. Hinds, Transcriber 8/08/08

Acc. No. 0530

Dale W Olson
1079 130th Street
Amery, WI, 54001

I find it truly amazing that in the past when environmental rules were promulgated EPA justifies them with health risks and estimates of deaths. In the case of fuel economy you are disregarding this very concern. To achieve high fuel economy standards vehicles will be made of lighter less strong materials which will make the vehicles less safe and significantly increase highway fatalities. I find it disingenuous that in this case human health can be discounted. This rule is being promulgated to address climate change. Over 32,000 scientists have signed the "Oregon petition" stating they see no convincing scientific evidence that humans are causing catastrophic climate change. They have been joined by the American Physical Society, which recently announced that it was reassessing its prior position - that evidence for global warming was "incontrovertible" - because mony of its 50,000 physicist members disagree strongly with climate chaos claims. Rules should be promulgated based on reality and science not politics especially in this case because people will die.

Acc. No. 0531 – *Federal Register Notice of Availability* can be viewed on the docket: http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0532

DEPT. OF TRANSPORTATION
DOCKETS

2008 JUL 29 P 4: 07

From: Deborah Weinischke [fancifulfun@yahoo.com]
Sent: Saturday, July 26, 2008 5:42 PM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA
Follow Up Flag: Follow up

I know we have had for years the technology to run more efficient vehicles on alternative fuels. I know that the greed of Big Oil has been suppressing this knowledge. It is time to get realistic and start operating out of concern for our environment rather than caving into the pressure of unscrupulous industry.

Acc. No. 0533

DEPT. OF TRANSPORTATION
DOCKETS

2008 JUL 29 P 4: 07

From: Robert Burchard [bobburchard@yahoo.com]
Sent: Monday, July 28, 2008 11:15 AM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08
Follow Up Flag: Follow up

Dear NHSTA:

Even the President now recognizes the reality of anthropogenic global warming. This threat to the biosphere combined with increasing acidity of the earth's oceans caused by increasing atmospheric CO2 necessitates the need for early implementation of rigorous fuel economy standards independent of "paying-for-itself" considerations. America's auto industry needs to have its feet held to the fire and quickly. If Japanese manufacturers can do it, why can't "Detroit"?

Thank you for your action. Robert Burchard, Ph.D.

Acc. No. 0534

From: peggygilges@mac.com on behalf of Peggy Gilges [peggygilges@mac.com]
Sent: Friday, July 25, 2008 12:20 PM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08

Follow Up Flag: Follow up

DEPT. OF TRANSPORTATION
DOCKETS

2008 JUL 29 P 4: 07

I am severely disappointed in the national response to both reducing our desperate need for foreign oil and addressing the myriad environmental damages that heat-trapping gases are causing.

I think it is hugely embarrassing that the United States of America has failed to adopt much higher fuel efficiency standards for all vehicles here. As a hybrid driver, I know that my own vehicle regularly achieves 47-52 mpg in normal driving conditions in town and on the highway, so I am disgusted and saddened by our once- innovative, once-strong American car companies "reaching" for marginal improvements in fuel economy. American government has enabled the current state of affairs.

Please do the right thing by our great nation and mother earth now-- insist on MUCH higher-- already implementable -- standards that dramatically increase fuel efficiency of U.S. vehicles in the near term.

Thank you for your consideration of my comments.

Acc. No. 0535

DEPT. OF TRANSPORTATION DOCKETS

2008 JUL 29 P 4: 08

From: James Farrelly [famesjarrelly@hotmail.com]
Sent: Thursday, July 24, 2008 5:37 PM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08
Follow Up Flag: Follow up

Dear Congressmen--

How can you expect to lead the change needed for a sensible energy policy when you disguise the math? Methinks your math teachers in high school would keep you after school.

As of today the average price per gallon of gas is 4.07 -- not 2.25 or 2.60 a gallon. That was what maybe 2006? So auto manufacturers don't feel the need to change fuel efficiency standards when these sorts of numbers are given as what is paid at the pump by Joe Bagadonutz of Anywhere USA.

You need to wake up and get real. Maybe listen to an oil man like T Boone Pickens if that helps. We are not going to drill ourselves out of this problem esp since we keep on allowing drunks and uncertified drivers to dump oil into our sacred waterways.

Wake up!

James Farrelly

Acc. No. 0536

DEPT. OF TRANSPORTATION
DOCKETS

2008 JUL 29 P 4: 08

From: Ceribon@aol.com

Sent: Thursday, July 24, 2008 11:46 AM

To: NEPA, NHTSA <NHTSA>

Subject: NHTSA Public Hearing8/4/08

Follow Up Flag: Follow up

I BELIEVE THAT ALL EFFORTS SHOULD BE MADE TO PRODUCE AN AMERICAN CAR AND IMPORTED CAR WITH THE HIGHEST MPG POSSIBLE, I DON'T MEAN 25, I MEAN WHAT THE PRIUS IS TOUTING 45MPG.

IT IS ALSO POSSIBLE TO INCLUDE TECHNOLOGIES WHICH CAN INCREASE THIS FURTHER. I ALSO BELIEVE THAT SOMETHING SHOULD BE DONE TO PROVIDE ENERGY EFFICIENT MASS TRANSPORTATION TO REDUCE THE WASTE THAT HAPPENS WHEN TRAFFIC BACKS UP AT RUSH HOUR WITH PEOPLE IDLING AT 0 TO 10 MILES PER HOUR FOR THE 3 HOURS OF RUCH HOUR WHICH HAPPEN IN THE MORNING AND THE EVENING. I ALSO THINK THAT BUSINESSES AND GOVERNMENT BE GIVEN THE INCENTIVES TO PROVIDE WORK FACILITIES IN THE SATELLITE SUBURBS WHICH EMPTY AT 4:00 AM EVERY DAY. MAYBE A SCHEULING OF WORK TIMES FOR LARGE COMPANIES WHO EMPTY A RUSH HOUR, MAYBE THIS COULD BE STAGGERED. ALL THIS WOULD TAKE A STRAIN OFF THE INFRASTRUCTURE WHICH CAN NOT BE REBUILT EVERY TEN YEARS TO ACCOMODATE THE GLUT.

Acc. No. 0537

From: Melissa Briese [purrrlicious@yahoo.com]
Sent: Wednesday, July 23, 2008 9:46 PM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08
Follow Up Flag: Follow up

DEPT. OF TRANSPORTATION DOCKETS

2008 JUL 29 P 4: 08

There are strong enough reasons to switch from a gasoline-fuel based economy to a more progressive, cleaner alternative.

1) Crude oil is dirty. Even if one is debating that greenhouse emissions have no effect on our weather patterns, it is still dirty. It can bring life to a machine but it destroys so many other things (animals caught in oil slicks, the process of extraction from the earth, smoke going into our lungs...)

2) Dependency on oil is bringing too much greedy politics into our lives. These oil companies have too much influence on our banks and policies. They are only concerned with their profits and will push us to the brink financially to get more money and power for themselves. The domino effect of greed is misery that only darken our human existence.

3) Foreign oil keeps locked into a bloody war that taints our humanity. It is time to stop doing business with those who have been rivaling for thousands of years, let them figure out their own affairs, and let us focus on taking care of ourselves first. And that means switching to a new system of fuel. NOW.

4) We are able now more than ever to change our relationship to life; Proactively reaching for technologies that benefit everybody and living as a unified community all sharing this planet. We do so because we are evolving by choice. Darwin observed that the species who thrives the most is the one who thinks of the survival of the whole. It is a point that has been ignored for rugged individualism, an error which needs to be corrected.

If history repeats itself, then it's time to re-write our story and begin the creative journey toward new technologies worthy of our hopeful future.

Thank you,

Melissa Briese

Acc. No. 0538

DEPT. OF TRANSPORTATION
DOCKETS

2008 JUL 29 P 4: 08

From: david levin [cdwfriedmann@cavtel.net]
Sent: Wednesday, July 23, 2008 10:52 PM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08
Follow Up Flag: Follow up

cleaner is better for all

Acc. No. 0539

From: John Schieber [fernoph@verizon.net]
Sent: Wednesday, July 23, 2008 10:57 PM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08

Follow Up Flag: Follow up

DEPT. OF TRANSPORTATION DOCKETS

2008 JUL 29 P 4: 08

Greetings:
I write since I cannot attend your public hearing on fuel economy standards on Aug.4.

The need for an aggressive reduction in fuel usage is not only about an attempt to keep the cost down -- it's about the need to drastically conserve what remains for future generations. Please get with it.

Sincerely
John R. Schieber
1621 Chinquapin Rd
Holland, PA 18966

Acc. No. 0540

DEPT. OF TRANSPORTATION
DOCKETS

2008 JUL 29 P 4: 08

From: Fred Krohn [maliktos@yahoo.com]
Sent: Thursday, July 24, 2008 8:58 AM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08
Follow Up Flag: Follow up

While I will not be available for the DC meeting, I do wish to state my disgust with the current state of petroleum pricing and economy factors.

I have already discontinued use of motor vehicles due to the excesses in gasoline price gouging, automobile misregulation and resultant overpricing, and the state of insurance scams. I use a bicycle, which only uses minuscule amounts of lubricant and occasional tyres and innertubes vice guzzling drastically overpriced fuel. I do not value a gallon of gasoline over 75¢, a 200 liter barrel of oil over $15, nor place any value on the current 'standard features' forced into cars that have driven the new vehicle prices way over reasonable levels.

We had it once, back near the middle of last century. The Fish carburetter, the Baker Electric Car Company, the Moller Company, and others are signs of the stolen promises of a future lost to political scams, greed, and fraud. We should have had a working toroidal or impulse fusion reactor design already, not be penny-pinching research while our supposed leaders skim off the funds.

Honest pols may be able to cushion the fall of this part of the nation, though I doubt even that would save it. The petrochemical scam has already lost me. I can only hope that the current failures don't explode on impact...

Acc. No. 0541

Document Acc. No. 41 is not included because of a numbering mistake in the docket.

Acc. No. 0542

DEPT. OF TRANSPORTATION
DOCKETS

2008 JUL 29 P 4:08

From: James Prescott [jprescott34@comcast.net]
Sent: Wednesday, July 23, 2008 5:20 PM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08
Follow Up Flag: Follow up

24 July 2008

Dear Sir,

The U.S. public understands that strong fuel economy standards are a primary path toward addressing high energy prices and global warming pollution from autos. An excess profit tax is mandatory, if this objective is to be achieved and raise the funds necessary to support the research necessary to become free from fossil fuels for the world's increasing energy needs.

James W. Prescott, Ph.D.
1140-17 Savannah Road
Lewes, DE 19958
302.645.7436
jprescott34@comcast.net
http://www.violence.de
http://www.ttfuture.org/Prescott
http://www.montagunocircpetition.org

Acc. No. 0543

DEPT. OF TRANSPORTATION DOCKETS

2008 JUL 29 P 4: 08

From: Micheal Wadas [mwadas93@yahoo.com]
Sent: Wednesday, July 23, 2008 6:45 PM
To: NEPA, NHTSA <NHTSA>
Cc: mwadas93@yahoo.com
Subject: NHTSA Public Hearing8/4/08

Follow Up Flag: Follow up

Not only do we have to find alternative fuels to regain our independence from other countries. We also must increase fuel economy/energy efficiency, to better stimulate our economy, and reduce our carbon footprint. We have taken small steps towards solutions, when we should be taking broad leaps, and bounds. Our future depends on energy alternatives, and we should not depend on petroleum to guide us through life. If we don't start acting on behalf of the greater good of America, and on behalf of the American people, we will create a self-inflicting decline in our National security, and not only become more dependent on other countries, but we will be owned by them.

Our time is now!

In Liberty,

Your friend in peace,

Mike Wadas

Acc. No. 0544

From: makirchner1@netzero.net
Sent: Wednesday, July 23, 2008 8:57 PM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA

Follow Up Flag: Follow up

DEPT. OF TRANSPORTATION DOCKETS

2008 JUL 29 P 4:08

Sirs,
I support REAL WORLD fuel economy standards, and whole heartily support increasing these standards toward the goal of 100mpg. The cost of fuel is driving our economy into a depression and will soon bankrupt our country.
For to long the government supported an easy way out for the auto manufactures. It is time for real progress.

Michael A. Kirchner
5959 Jacobs Avenue
Harrisburg, PA 17112

Acc. No. 0545

From: Mary Hamilton [aquhamilton@yahoo.com]
Sent: Wednesday, July 23, 2008 9:45 PM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08
Follow Up Flag: Follow up

The sensible way to go in this global climate crisis is to INCREASE miles per gallon.

Acc. No. 0546

From: Robert Keiter [rkeiter@yahoo.com]
Sent: Thursday, July 24, 2008 9:56 AM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08
Follow Up Flag: Follow up

A Gov't for the People by the people? Yeah Right! Stop protecting the automakers and do your job for once to help citizens that pay your checks.

Acc. No. 0547

From: Fred Marshall [fmarshall@quantumlearninginc.com]
Sent: Thursday, July 24, 2008 10:54 AM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08

Follow Up Flag: Follow up

DEPT. OF TRANSPORTATION DOCKETS

2008 JUL 29 P 4: 08

We need to raise cafe standards not erode them. It is insane to drill in environmentally sensitive areas when we can directly reduce demand for oil by mandating that all passenger cars get at least 40 mpg by
2012. It is so clear, double the mpg and you double the fuel supply.
Our cars are vastly overpowered and we can and should put smaller engines into our cars and then work to make them more aerodynamic.
Too many American cars use plastic bling grills for looks that create terrible aerodynamics. Instead, we should use that plastic to make cars lighter and more fuel efficient.

Fred Marshall
100 north state street
Newtown, PA 18940
215-579-0540

Acc. No. 0548

DEPT. OF TRANSPORTATION
DOCKETS

2008 JUL 29 P 4: 09

From: Carl Henne [carlhenne@cox.net]
Sent: Thursday, July 24, 2008 11:07 AM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08
Follow Up Flag: Follow up

We urgently need to promote more efficiency and cleaner vehicles and this also goes for trucks,ships and boats, rail locomotives and aircraft.

The CFTA requirement should be at least 50mpg for all cars and light trucks by 2018 and an equal proportional improvement for all trucks and busses.

Sincerely.

Carl Henne
1803 Genther Lane
Fredericksburg VA 22401

email: carlhenne@cox.net

Acc. No. 0549

DEPT. OF TRANSPORTATION
DOCKETS

2008 JUL 29 P 4:08

From: Nancy Miller [solacel@gmail.com]
Sent: Wednesday, July 23, 2008 4:29 PM
To: NEPA, NHTSA <NHTSA>
Subject: NHTSA Public Hearing8/4/08
Follow Up Flag: Follow up

I am writing to protest the ridiculous assertion that we will be paying between $2.25 to $2.60 per gallon for gas through 2020. DOT is calling for fuel economy improvements only if they pay for themselves through fuel savings—the money saved from the gas the cars wouldn't use.
This gas price fantasy allows automakers to shave three to four miles per gallon off of the historic new fuel economy requirements that became law in 2007. If accurate gas prices are used, the new requirements would further reduce global warming pollution equivalent to taking about 10 million cars off the road.

Obviously, strong fuel economy standards are a primary path toward addressing high energy prices and global warming pollution from autos. I must express my outrage over this gas price ruse!

Cleaner cars are an absolute necessity in the effort to ameliorate the effects and perils of rampant global warming.

Sincerely,
Nancy Miller, RN

--

Sarah E Larsen
FL, 33928

My name is Sarah Larsen and I am an Environmental Engineering student at Florida Gulf Coast University in Fort Myers, Florida. As a Florida resident, I am incredibly concerned about the impacts of global warming on my state. I am here because I think NHTSA has a responsibility to put into place the strongest fuel efficiency standards possible to help reduce our global warming emissions from vehicles.

Global warming presents Florida with serious challenges that threaten human health, economic prosperity, and treasured natural areas. Over several decades, changes in sea level, average temperature, and weather will affect coastal property and beaches, water resources, agriculture, and ecosystems. Global warming has the potential to affect everything that defines Florida.

Scientists have already observed changes in Florida that are consistent with the effects of global warming. These changes include retreating and eroding shorelines, dying coral reefs, salt water intrusion into the freshwater aquifer, increasing numbers of forest fires, and warmer air and sea surface temperatures. In coming years, these effects may become more common, and increasingly severe.

Florida’s land, water and reefs support thousands of animals and plants, including five species of sea turtles, and nearly 120 endangered, threatened or species of special concern such as the American crocodile, wood stork and West Indian manatee. The state also is home to the world’s third largest coral barrier reef. It shelters more than 18 million full-time residents, and attracts millions of seasonal visitors annually. With nearly 1,200 miles of coastline and 95 percent of its population living within 35 miles of the coast, Florida is uniquely vulnerable to climate change. It is not just the environment that will be affected. Three key economic sectors in Florida are directly tied to the health, productivity and beauty of the natural world’s agriculture, tourism and fishing. Florida’s economy, as well as its communities and native habitats, will likely sustain heavy damage as the planet’s temperatures and oceans rise in response to human-induced global climate change.

Florida needs NHTSA to put in place the strongest fuel efficiency standards possible to help reduce our global warming emissions from vehicles.

I feel the most disappointing thing about the Draft Environmental Impact Statement is that it fails to analyze the benefits of greenhouse gas emission reductions in the proper context. When NHTSA tries to determine the difference in global ocean temperature rise in the year 2100 resulting from a 31.6 mpg standard vs. a 35 mpg standard, statistically, there is none; however, this does not mean that raising fuel economy standards faster will not have a significant impact in our struggle to reduce global warming pollution.

In the United States, emissions from the transportation sector account for roughly 20% of our country’s greenhouse gas pollution; therefore, any projected decreases in greenhouse gas emissions arising from increased fuel economy standards can never be greater than 20%. For that reason, reductions should be considered as a proportion of the 20% - not as a proportion of the entire planet's combined carbon emissions.

In addition, NHTSA takes a presumed 35-mpg fleet in 2020, assumes that fuel economy stops increasing, and then measures the cumulative CO2 savings through the year 2100. I believe NHTSA should only be measuring reductions at the 35-mpg fleet level for the life of these vehicles. Fuel economy should not be presumed to stop at 2020 levels. If NHTSA wants to evaluate carbon savings through the year 2100, then they should do so by assuming fuel economy standards continue to increase to the year 2100 at the same rate of increase as between 2011-2015. Furthermore, considering that relevant science is talking about reductions needed by 2050, it again seems out of context for NHTSA to have randomly picked the year 2100 as timeline for measuring success of today's carbon reductions from vehicles. I believe success and progress should be measured by how close these fuel economy improvements get us to reducing the transportation sector's carbon emissions by 80% in time for the 2050 deadline. To do otherwise fails to realistically evaluate vehicle emission reductions as a key part of the strategy to curb global climate change.

Although there is no magic antidote to get us to an 80% reduction in CO2 emissions by 2050, one of the single biggest step we can take in this country to reduce our global warming emissions is to make our cars and trucks go further on a gallon of gasoline. The technology exists today to safely and cost-effectively make all passenger cars and light trucks reach a fleet wide fuel economy average of at least 35 miles per gallon by 2015. Taking this step will achieve the goals of the new fuel economy law and as is most pertinent to this hearing will greatly reduce the global warming emissions from the transportation sector.

NHTSA has proposed standards for both cars and light trucks in response to the Energy Independence and Security Act's mandate to achieve a fleet wide fuel economy average of at least 35 mpg by 2020. NHTSA proposes to raise the fuel economy of cars and light trucks to a combined average of 31.6 mpg for Model Year 2015. While this increase is more than half of what is required to meet the mandate of 35 mpg by 2020, I believe NHTSA fails to take full advantage of available fuel saving technologies, and fails to fully and fairly evaluate the benefits of greenhouse gas emission reductions.

As a college student and Florida resident, I urge NHTSA to reconsider the proposed standards and use its statutory authority to mandate a fleet wide fuel economy average of 35 mpg by 2015.

Acc. No. 0551

From: Derzon, James H [DerzonJ@BATTELLE.ORG]

Sent: Wednesday, July 30, 2008 1:24 PM

To: NEPA, NHTSA <NHTSA>

Subject: NHTSA Public Hearing8/4/08

I think it unlikely that gas will be below $3.00 per gallon again in my lifetime, so get busy and strengthen fuel economy standards. Current standards are criminal.

Jim Derzon, PhD
Senior Evaluation Specialist,
Centers for Public Health Research and Evaluation, Battelle
2101 Wilson Blvd. #800
Arlington, VA, 22201-3008
v. 703.248.1640, f. 703.527.5640, c. 240.505.7488
derzonj@battelle.org

Acc. No. 0552

PUBLIC SUBMISSION

As of: August 12, 2008
Received date: Not specified
Status: Posted
Posted: August 08, 2008
Tracking No. 806b5496
Comments Due: January 01, 0001
Late comments are accepted
Submission Type: Web

Docket: NHTSA-2008-0060
Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards

Comment On: NHTSA-2008-0060-0531
U.S. DOT/NHTSA - EPA - Notice of Availability of Draft EIS

Document: NHTSA-2008-0060-0552
Alina Fortson - Comments

Submitter Information

Name: Alina Fortson
Address:
Berkeley, CA,

General Comment

My name is Alina Fortson and I live in Berkeley, CA. Thank you for the opportunity to comment today.

I am here because I think that addressing global climate change is one of the most important issues for this generation. I know that we currently have solutions that reduce greenhouse gas emissions in addition to improving our economy. If we don?????????t act fast we are going to lose the opportunity to make a difference.

Sutter Creek, the town where I went to high school, is in a rural area of northern California. Public transportation is lacking and many families live at least 30 minutes from basic necessities such as supermarkets and schools and close to two hours from Sacramento?????????the closest metropolitan city. As you can imagine, the price and efficiency of fuel has a significant impact on this community. It is critical that we address both the economic and environmental effects of our oil dependence and take the steps to curb them both.

In order to address climate change, scientists have stressed the importance of achieving an 80% reduction in green house gas emissions by the year 2050. This means making small reductions in all of our emission areas, including transportation. United States????????? transportation sector amounts to approximately 20% of our total green house gas emissions. Therefore, properly measuring our progress requires considering reductions as a portion of that 20%, not as part of global emissions. In this light, every small improvement makes a difference.

If we were to take advantage of our best and most feasible technology, we would be in a position to reduce our oil use in addition to lessening the impact that the price of gasoline has on families like mine. NHTSA?????????s current proposal hinders this potential. Your analysis uses assumptions for future gas prices that are simply unrealistic. Today Americans are paying nearly $4 per gallon, and there is currently no reason to expect prices to drop as low as $2.25. Basing decisions on faulty analysis is irresponsible and disregards NHTSA?????????s duty to impose feasible fuel economy standards.

I urge NHTSA to consider how this rulemaking increases the strain on the average family and to reevaluate their position on this issue and on climate change at large.

Comments to the U.S. Department of Transportation
National Highway Traffic Safety Administration
at the Public Hearing on the Draft Environmental Impact Statement for New Corporate
Average Fuel Economy Standards,
Passenger Cars and Light Truck, MY 2011-2015

Submitted by Tara C. Morrow
August 4, 2008

Good morning. Thank you for the opportunity to speak today on this DEIS. My name is Tara Morrow and I am the Communications Director for Greater Washington Interfaith Power and Light. We are one of twenty-eight Interfaith Power and Light organizations across the U.S., a growing movement of people of faith responding to global warming.

When religious people talk about responsible stewardship of our resources or care of the earth, it is toward abundant life for future generations that they measure the costs to their own lives. As you set standards to meet the Energy Independence and Security Act's mandate to achieve a fleet wide fuel economy average of at least 35 mpg by 2020, may you remember that 35 mpg is a minimum and future generations will applaud us for our boldness in implementing what is technologically feasible or wonder how we lacked the creativity and will to respond to global warming and the challenges of energy security.

I did study physics in college, which helps me get through the statistics and tables of the DEIS, but I am here today as a person of faith, in particular greatly concerned about the impact energy policies and activities resulting in increased global warming emissions have upon the poor and vulnerable. As was demonstrated during the aftermath of Hurricane Katrina and around the world in recent months with increased food prices, quantifying the impacts of global climate change is not simple and will only increase in value as we more fully grasp its consequences. The debate about whether climate change is real, or caused by human activity, is over and as I witnessed from first-hand accounts during a recent trip to the Philippines, the effects are already taking a toll upon our world. While I was glad to see that the DEIS does assign a dollar value, greater than zero, to CO_2 reductions, I ask you to take another look at the value range and price carbon more accurately given the most recent analysis. The costs of global warming exacted on us, or more accurately on our children and grandchildren and generations to come, if we take only token action now is sure to be steeper than any costs incurred now.

Another matter for closer examination is the estimate of the price of gasoline used to determine what is then cost-effective. An assumption of $2.25 per gallon in 2016, in 2006 dollars, seems unrealistic given current realities – at least given what I paid yesterday on my way back from a family reunion in Pennsylvania. When higher projections of gas prices are used, then significantly higher standards are technologically feasible and economically practical.

Given the recent soaring gas prices, we are seeing a change in the market by consumer demand for vehicles with greater fuel economy. However I think the American people are ready for bold action – at least my generation is - and moving forward will take more than responding to market research. It takes full measure of the costs to us if we do not take action or take only very modest action, costs which the DEIS begins to address but I hope will be more fully incorporated when the final fuel economy standards are issued for passenger cars and light trucks for 2011-2015.

DEPT. OF TRANSPORTATION DOCKETS

Acc. No. 0554

2008 AUG 11 P 1:39

James Adcock

5005 155th PL SE

Bellevue WA 98006

August 6, 2008

Comments on the Draft Environmental Impact Statement for New Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, MY 2011-2015

National Highway Traffic Safety Administration

Docket No. NHTSA-2008-0060

I respectfully submit the following comments on NHTSA's DEIS for "Average Fuel Economy Standards for Cars and Light Trucks – Model Years 2011-2015"

I submit these comments as representing the interests of my two under-aged children. My comments relate primarily to the issue of GHG and the issue of climate "tipping point" raising the potential of premature death of my children, the possible extreme degradation of the planet they live on, and the possibility of such "tipping point" issues reducing the choices they have to bear their own children (who would be my grandchildren) and raise those children to have a happy, complete, secure life. My comments relate to reasons why NHTSA has set GHG CO2 emissions standards too high and how and why NHTSA should fix these regulatory errors.

*EIA Estimates of future gas prices are not rational estimates given the recent run-up in gas prices. The EIA estimates can be compared to the estimate of future gas prices implied in the short-term and long-term NYMEX oil and gas futures. If the EIA Estimates were correct estimates, and the NYMEX futures greatly differ [which they do] then that difference represents an arbitrage opportunity that traders can exploit, which in turn would drive NYMEX prices back to EIA Estimates. (Modern Arbitrage Theory) This hasn't happened. The conclusion is that EIA Estimates cannot be current rational estimates. See attached graph. Based on NYMEX future estimates of gas prices during the regulatory time frame I suggest that NHTSA adopt its "HOP – High Oil Price" scenario rather than its current "MOP – Moderate Oil Price" scenario. Or use NYMEX futures values directly rather than outdated EIA estimates.

*Truck CAFÉ curves cross Car CAFÉ curves. See attached graph. For several years at medium values of footprint NHTSA compliance curves set lower values for Cars than for Trucks. Since the MPG values for trucks have historically been set lower than cars because of the unique challenges and abilities trucks have, including greater hauling capacity and greater towing capacity, inverting this relationship never makes sense. This problem is part of a larger problem that NHTSA have largely designed the curves for cars and trucks independently when instead NHTSA needs to recognize that both consumers and manufacturers have the choice of car vs. truck. Thus the curves for cars and trucks need to be designed in a consistent and rational manner to work together. For example the great disparity between car and truck curves for small footprints should encourage manufacturers to design "AMC Eagle" style small "trucks" which have car-like characteristics except for being high and needlessly unstable, leading to unnecessary rollover fatalities. NHTSA's choice of design curves for cars vs. trucks works directly against NHTSA's charter of Highway Safety while resulting in greater GHG.

*CAA Preemption. NHTSA assertion of preemption is not rational for several reasons. First, NHTSA's proposed standards do not actually regulate GHG tailpipe emissions. Rather NHTSA sets relationships between tailpipe emissions and footprint. NHTSA does not know how much GHG will be emitted because it will depend on the actual mix of car, trucks, and their footprints. States might set rules that tend to affect this mix or limit GHG which would not stop NHTSA for setting whatever GHG/footprint, car vs. truck relationships NHTSA want. Secondly, Congress specifically prevents NHTSA from consideration of alternative fuels, which states might use in their regulations to limit overall GHG net emissions. For example California might set regulations designed to make 10% of their autos electric powered by green electricity, thereby reducing GHG emissions by 10% compared to federal regulations.

*Kahane: NHTSA continues to misinterpret the results of Kahane exactly backwards. Kahane's studies illuminate nothing about how manufacturers might actually design new vehicles to achieve higher fuel economy. For hypothetical example a vehicle redesigned to have a carbon fiber body with the same stiffness but lower weight might have higher fuel economy AND greater safety. We don't know. Nothing in the Kahane studies comes close to addressing these kinds of engineering design tradeoffs. But on the contrary, Kahane *does* well-model the scenario where in the face of high gas prices consumers are on average forced within an existing market mix of vehicles to purchase slightly smaller vehicles in order to achieve affordable fuel economy when facing a market where NHTSA and Manufacturers have failed to provide vehicles with fuel economy matching market gas prices. NHTSA then, should be looking to Kahane to illuminate the excess deaths caused to consumers when NHTSA sets fuel economy standards too weak in the face of high gas prices. Such a failure to regulate, and the excess deaths that result, represent a direct failure of NHTSA to meet its primary mandate of Highway Safety. Weak Fuel Economy Standards Equals Excess Traffic Deaths. Not the other way around. Consumers need to be able to buy the fuel economy they need in the vehicle size they want without being forced to downsize due to NHTSA setting fuel economy standards that are too weak. Continuing to read Kahane "backwards" results in setting GHG emissions standards too high.

*Fuel Economy Advertisements: Manufacturers are widely misrepresenting EPA Fuel Economy values on TV by quoting highway mileage values as-if they are combined mileage values. NHTSA need to act to correct these deliberately distorting practices. These advertisements are in turn representative of the fact NHTSA has been setting fuel economy standards too low, forcing manufacturers to misrepresent to the public how they have chosen to implemented those standards. Allowing these advertising deceptions results in higher GHG.

*Bias in the High Threshold transition point of the truck curves. NHTSA has lowered the high point threshold in the truck curves without a rational basis for doing so. Having incomplete information on the subject means choosing a best estimate, not biasing that estimate. Biasing this threshold results in greater GHG, and reduces most consumers ability to choose a rationally size vehicle to meet their family's needs without fear of death in collisions with those large trucks that the biased high threshold encourages, which again increases GHG.

*"Divide and Conquer" NHTSA's analysis of GHG emission from cars and trucks which only looks at US cars and trucks, only looks at the regulatory delta of those cars and trucks, and only looks at the US part of the SCC value of those cars and trucks is a case of "Divide and Conquer" where each regulatory agency of the government claims its actions are small enough to be considered "negligible" in the global context, whereas the reality is that GHG pollution from cars and trucks worldwide represents a large fraction of the entire GHG problem. On the contrary, NHTSA should be considering vehicle GHG emissions as being part of an overall scheme necessary to reduce total GHG emissions in the US and around the world. For example, if GHG is reduced by 10% by NHTSA's regulations, consider if this was part of scheme to reduce total GHG emissions by 10% in the US, and around the world.

*"Cowboy Diplomacy" NHTSA's analysis of GHG emissions assumes implicitly these regulatory changes only affect the behavior of vehicles in the United States. However most manufacturers are world-wide and can be expected to apply developed technology world-wide. Further, if the US reduces GHG emissions from vehicles that should be expected to engender at least some amount of goodwill "diplomatic synergy" with other nations, particularly with Europe. If the US reduces vehicle GHG Europe can also be expected to reduce vehicle GHG. If a 10% reduction in US vehicle GHG resulted in a 10% reduction in European vehicle GHG one would have 100% diplomatic synergy between the regions. NHTSA is currently assuming implicitly 0% diplomatic synergy, IE "Cowboy Diplomacy" where the US acts alone without any other nation following suit. Since both major candidates for the presidency during the years of these regulations have pledged better cooperation with other nations NHTSA should be assuming something more than 0% diplomatic synergy. Further, US GHG reductions from vehicles can be a starting point for cooperation in reducing GHG in other areas, increasing even more the "diplomatic synergy." NHTSA implicitly is assuming a value of 0% for all these synergies when NHTSA rationally should be expecting a higher value.

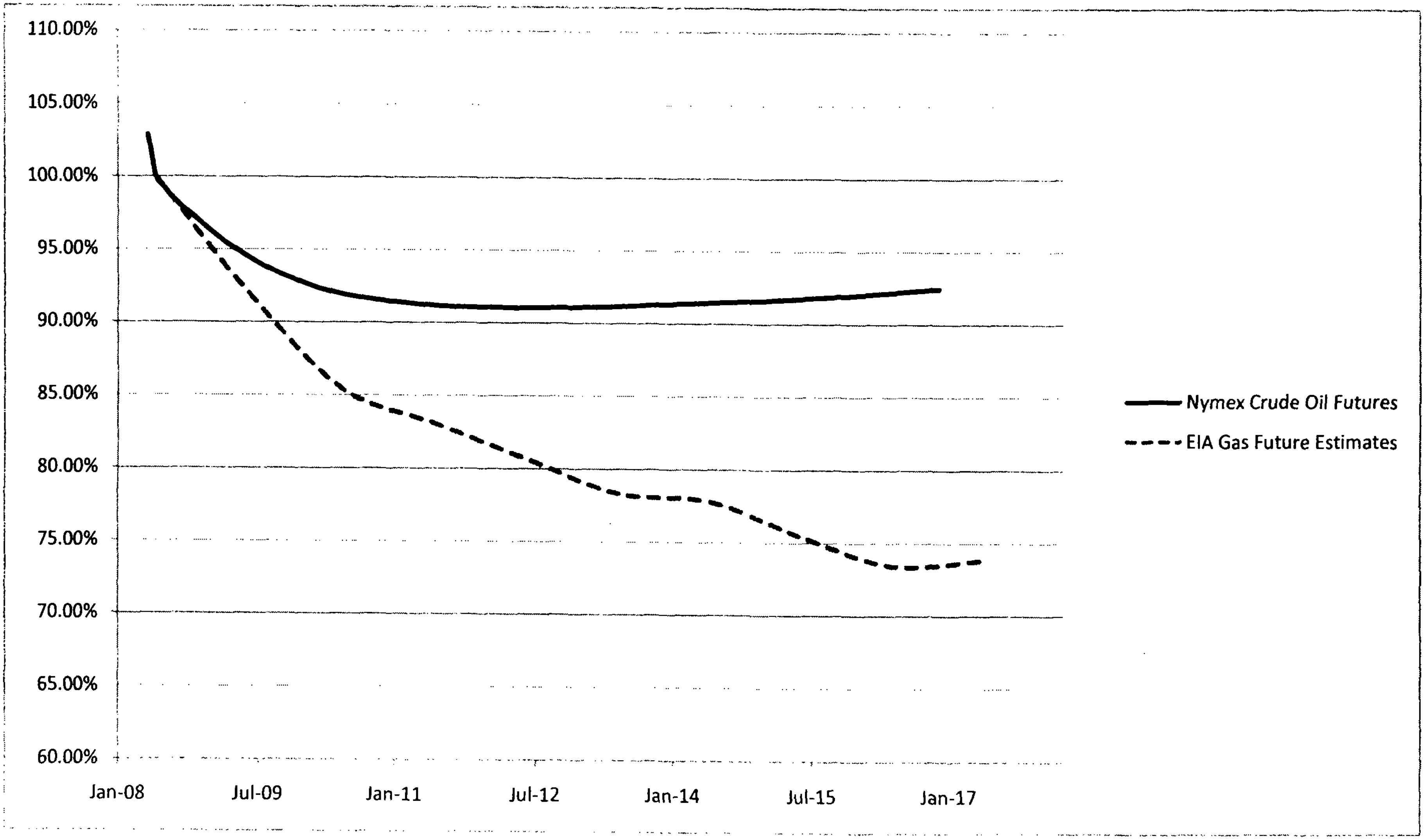
*Plug-in hybrids. Given GM commitment to delivering a plug-in hybrid (Chevy Volt) in this time frame, NHTSA's assumption that plug-in technology will not exist during the regulatory period is troubling, and will lead to higher GHG.

*Start/stop mild hybrid on small cars. NHTSA's assumption that this technology is not available for small cars is troubling given that it has already been implemented in Europe (Smart Fortwo mhd.) This assumption results in higher GHG.

*Uncertainty in future gas prices and GHG understanding. Given the uncertainty in future gas prices, as evidenced by the disparity between the EIA values NHTSA has used vs. recent gas prices, and recent large decreases in the estimated GHG concentrations necessary to reach tipping point [http://www.columbia.edu/~jeh1] NHTSA should reduce the numbers of years its proposed regulations extend forward. The farther one projects into the future, the greater the error in these projections. Given the rapid changes in our understanding of Global Warming and GHG, and the rapid changes in gas prices, it would be rational to extend the regulations forward for fewer years, allowing NHTSA to respond more appropriately once better understanding of these issues have been reached.

Waiting Your Response,

James L. Adcock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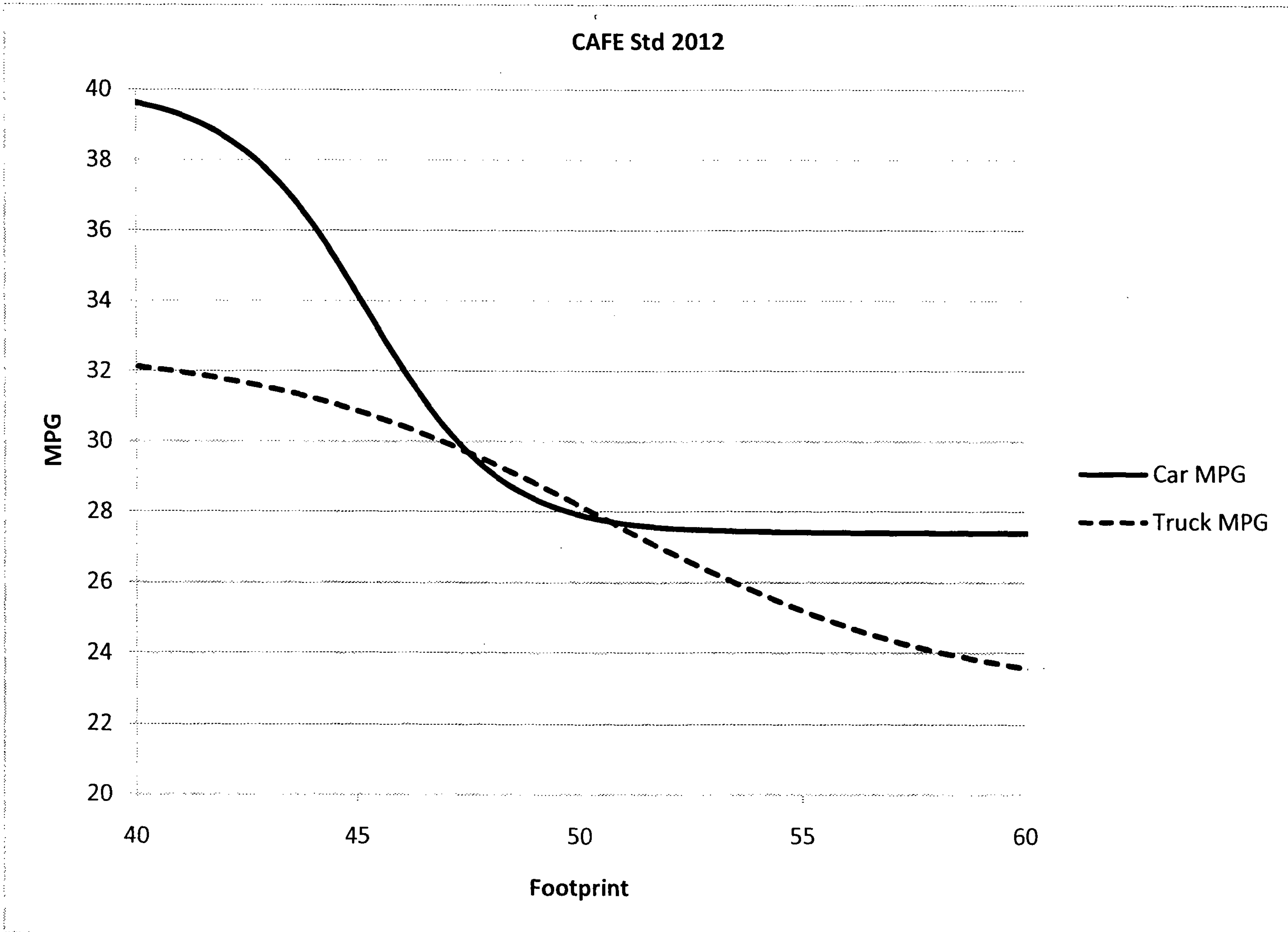
Nymex Crude Oil Futures
EIA Gas Future Estimates


CAFE Std 2012
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60
Footprint
Car MPG
Truck MPG

Acc. No. 0555

Public Submission: NHTSA-2008-0060-0555 **Bookmark:** Learn more Public Subr

Docket	NHTSA-2008-0060
Docket Title	Notice of Intent to Prepare an Environmental Impact Statement for New Corp Economy Standards
Docket Type	Rulemaking
Document	NHTSA-2008-0060-0531
Document Title	U.S. DOT/NHTSA - EPA - Notice of Availability of Draft EIS
Public Submission	NHTSA-2008-0060-0555
Public Submission Title	National Council of Churches Eco-Justice Program - Comments
Views	
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Title	National Council of Churches Eco-Justice Program - Comments
Abstract	
Document Type	PUBLIC SUBMISSIONS
Document Sub-Type	Comment(s)
CFR Citation	
Author / Document Date	08/15/2008
Answer Date	
Media Location	
Media Type	
Page Count	1
Start End Page	
Order Number	
Old Submitter Rep	
Old Submitter	
Effective Date	
OMB / PRA Approval Number	
Received / Filing Date	08/15/2008
Legacy ID	
Federal Reg Citation	
Federal Register Number	
Date Posted	08/15/2008
Comment Start Date	03/28/2008
Comment Due / Reply Date	
Implementation / Service Date	

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Organization / Org Unit	National Council of Churches Eco-Justice Program
Submitter's Representative	

Representative's Address
Rep's City, State & Zip
Government Agency Type
Government Agency

General Comment

Comment My name is Elizabeth McGurk. I am here because as a person of faith and an employee of the National Council of Churches in Christ, I recognize that we al have a
responsibility to be stewards of God's world and to care for one another. Achieving
higher fuel economy standards for U.S. cars and trucks is one of the most important
actions we can take to reduce our greenhouse gas emissions which are causir global
warming and impacting both God's people and God's planet. Increasing Corpc Average Fuel Economy (CAFÉ) standards is a critical step that must be taken reduce pollution and curb greenhouse gas emissions that cause global warmir while
protecting those who already suffer from high gas prices. Improved CAFÉ standards
would mean more vital discretionary income for low-income working families spend
on necessities like food, health care, and housing. Significantly improving CAF standards will also reduce U.S. dependence on oil and decrease the need to o sensitive wilderness areas including the outer continental shelf to oil and gas exploration.

As a native Floridian, I know too well that our communities are already begin to feel
the effects of global climate change. During my freshman year at Eckerd Colle in
St. Petersburg in 2004, we were evacuated four times in one month for four different
hurricanes. I am worried about the ways in which global climate change and c country's dependence on extractive non renewable resources will affect my h state
and my friends and family members living there. I know that the costs both tangible and
intangible of doing nothing will far exceed the cost of taking preventive action Your environmental impact statement should take into consideration the environmental
benefits of increasing CAFÉ standards in their entirety. For this reason, I urge to
strengthen the current proposed standards by setting a new standard of at le 35mph
by 2015.

Genesis 2:15 calls us to "till and to tend the garden." Toward that end, we ha moral
obligation to choose the safest, cleanest, and most sustainable sources of ene to
protect and preserve God's creation. God calls on us to be wise caretakers of Earth's gifts—protecting air and water quality, as well as ecosystems and hum communities. Good stewardship includes reducing, to the greatest extent possible, the
human-generated carbon dioxide emissions that are causing global warming.

Thank you.

Elizabeth McGurk

Attachments

NHTSA-2008-0060-0555.1 **National Council of Churches Eco-Justice Program - Comment**

Acc. No. 0555.1

July 18, 2007

Dear Representative:

As people of faith, we are called to "till and to tend the garden" (Gen 2:15). Toward that end, we have a moral obligation to choose the safest, cleanest, and most sustainable sources of energy to protect and preserve God's creation. Thus, on behalf of the religious organizations we represent, we urge you to increase the Corporate Fuel Economy (CAFE) standards of America's vehicles and increase the percentage of renewable energy used in the United States.

God calls on us to be good caretakers of the Earth's gifts—protecting air and water quality, as well as ecosystems and human communities. Good stewardship includes making timely investments in renewable energy technologies, increasing the percentage of renewable energy used in the United States, and increasing fuel efficiency.

By reducing our use of carbon-based electricity through the use of renewable energy, we can also reduce our carbon dioxide emissions. In the U.S., the largest source of carbon dioxide emissions that cause global warming is the electric power industry, accounting for about 40 percent of all U.S. emissions. More than 80 percent of these emissions come from older, dirtier coal-fired facilities. Additionally, these power plants are a source of nitrogen oxide and sulfur dioxide, which cause smog, asthma and other breathing-related illnesses, and mercury exposure which causes birth defects.

Increasing CAFE standards is another critical step that must be taken to reduce pollution and curb greenhouse gas emissions that cause global warming. Improving CAFE standards will also decrease U.S. dependence on oil and decrease the need to open sensitive wilderness areas to oil and gas exploration. Higher fuel economy standards would also benefit our families and our communities by reducing the burden of high gas prices. This would mean more vital discretionary income for low-income working families to spend on necessities like food, health care, and housing.

As people of faith, we have long recognized our responsibility to be stewards of God's creation. As individuals, congregations, and communities, we are committed to pursuing God's vision of a restored creation. To do so requires a change in current patterns of behavior and a reordering of our priorities as a nation. As representatives of the faith community, we urge you to adopt a national energy policy based upon the values of justice and sustainability. Any renewable energy standard must rely on energy options such as wind, solar, geothermal and biomass – resources that are clean and sustainable while moving our country away from coal and other fossil fuels.

We urge you to support a renewable energy standard and higher CAFE standards that will protect human health, increase our energy security, and curb the warming of the earth which threatens all of God's creation. Taking such action is a way to act upon the faith-filled call to love, preserve, and protect the integrity of God's creation.

Sincerely,

Columban Justice, Peace and Integrity of Creation Office (USA)
The Episcopal Church
Evangelical Lutheran Church in America
Friends Committee on National Legislation
Maryknoll Office of Global Concerns
National Council of Churches USA
Presbyterian Church (USA) Washington Office
United Church of Christ Justice and Witness Ministries
The United Methodist Church General Board of Church and Society
Union for Reform Judaism

Please contact:
Tyler Edgar
Associate Director, Climate and Energy Campaign
National Council of Churches
202-544-2375
tedgar@ncccusa.org

Acc. No. 0556

Public Submission: NHTSA-2008-0060-0556 **Bookmark:** Learn more Public Subr

Docket	NHTSA-2008-0060
Docket Title	Notice of Intent to Prepare an Environmental Impact Statement for New Corp Economy Standards
Docket Type	Rulemaking
Document	NHTSA-2008-0060-0001
Document Title	Notice of Intent to Prepare an Environmental Impact Statement for New Corp Economy Standards
Public Submission	NHTSA-2008-0060-0556
Public Submission Title	Catherine Easton - Comments
Views	
Add Comments	
How To Comment	

Title	Catherine Easton - Comments
Abstract	
Document Type	PUBLIC SUBMISSIONS
Document Sub-Type	Comment(s)
CFR Citation	
Author / Document Date	08/14/2008
Answer Date	
Media Location	
Media Type	
Page Count	1
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Effective Date	
OMB / PRA Approval Number	
Received / Filing Date	08/14/2008
Legacy ID	
Federal Reg Citation	
Federal Register Number	
Date Posted	08/15/2008
Comment Start Date	03/28/2008
Comment Due / Reply Date	
Implementation / Service Date	

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Phone Number	
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Organization / Org Unit	

D-192

Submitter's Representative
Representative's Address
Rep's City, State & Zip
Government Agency Type
Government Agency

General Comment

Comment August 14, 2008

NHTSA

Dear NHTSA,

I feel very strongly about this issue both as a citizen concerned about global warming, and as a consumer dealing with high gas prices.

Global Warming is happening Right Now. Reducing green house gas emission by 2050 will save us from the worst effects of global warming. Unfortunately, we've all noticed 80% is a lot.
Increasing CAFÉ standards will not achieve this. In fact, no individual sector could reach such a dramatic decrease. This is why we must strive for smaller, achievable decreases in all sectors. These small decreases combined could ma substantial difference.

There is no point doing nothing, giving up, and ruining the planet for future generations – for my generation and our children - simply because increasing CAFÉ standards alone won't make the required difference.

This is a simple step. Let us prove that the United States does have the technology to do this. Let us set a good example for other nations. We worry about China and India developing and the added pollution that will cause. Let pave the way towards a solution.

Fuel economy standards are already higher in Europe than in the U.S. So, the technology is available. The industry feels threatened by the changing of the status quo, and opposes these higher fuel economy standards. Just like the industry opposed seatbelts. Just like the industry opposed airbags. But seatbelts and airbags did not hurt the auto industry, and neither will increase CAFÉ standards. In fact, with the price of gas over $4 a gallon, consumers are looking for fuel efficient vehicles.

If saving the environment isn't an important enough reason, if having a safe, non-hazardous planet for future generations to live on isn't enough motivatio increase CAFÉ standards to save our wallets.

Higher gas prices increase the price of going to work. People need to pay exorbitant amounts of money just to make money.
People pay more for food that needed to be transported.

Sen. Mikulski from Maryland said that when Bush took office, the average fan spent a little over $3000 a year on gas. Now, that average family spends $50 and pays more for food too. $2000 sends a kid to a community college for a y $2000 can alter a family's lifestyle.

We pay too much for gas and more drilling is not the solution. People have be warning for years that there is a finite supply of oil. Even if we grant oil companies new leases for drilling, it will be 10 years before oil from those leases will be pumped into your car.
Even if we drill more, we will still not produce enough to satisfy U.S. demand. We will still depend on foreign nations for oil. We will still risk our national security for oil.
Even if we drill more now, there will still come a time when the world's supply of oil runs out.

We must fight our addiction to oil. Reduce our oil consumption so that when t day comes, the United States' economy will not crash. Agriculture, industry, transportation and services will continue using alternative energy sources. Th is not a transition that can happen over night. We cannot wait for the world to run out of oil to begin looking for alternatives. This must be a gradual transition.

So, why not start by improving CAFÉ standards?

Thank you for your time.

Sincerely,

Catherine Easton

COMMENTS ON:
Draft Environmental Impact Statement
Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011—2015

Department of Transportation,
National Highway Traffic Safety Administration
Docket No. NHTSA—2008—0060

Submitted by
Luke Tonachel, Vehicles Analyst
Brian Siu, Policy Analyst
for the
Natural Resources Defense Council (NRDC)
on
August 14, 2008

The Natural Resources Defense Council (NRDC) is pleased to provide comments to the National Highway Traffic Administration's (NHTSA) Draft Environmental Impact Statement (DEIS) for Corporate Average Fuel Economy Standards for Passenger Cars and Light Trucks, Model Years 2011—2015.

NRDC respectfully disagrees with the NHTSA's characterization that the environmental impacts of the evaluated alternatives are small and difficult to distinguish. When considered in the context of multiple strategies to cut global warming pollution and avoid dangerous climate change, a standard of at least 35 miles per gallon (mpg) for model year 2015 results in very significant benefits over the NHTSA's proposed standard of 31.6 mpg. The time for strong action on global warming is now and more aggressive fuel economy standards must be part of that action to ensure that passenger vehicles remain on a reasonable trajectory to the much higher levels of fuel economy that will be needed to meet 2050 climate stabilization targets.

The DEIS is further deficient because it evaluates invalid CAFE alternatives. The alternatives are derived from a NHTSA's CAFE rule that proposes unlawful fuel economy levels because they fail to meet the test of maximum feasible. As explained in

NRDC's comments to the Notice of Proposed Rulemaking (NPRM), Docket 2008-0089, NHTSA used faulty methodology and assumptions that resulted in an unlawfully weak CAFE standard. To provide the impact of new fuel economy standards, the DEIS must evaluate valid CAFE alternatives.

Our comments are provided in more detail in the following sections.

NHTSA Should Evaluate the Impact of CAFE Alternatives in the Context of the Multiple Strategies to Cut Global Warming Pollution

In the DEIS, NHTSA characterizes the differences in the environmental impacts between the proposed standard and the other evaluated alternatives as small and difficult to distinguish. The fuel economy level proposed by NHTSA in the CAFE rule, referred to as the "Optimized" alternative in the DEIS, reaches a fleetwide fuel economy level of 31.6 mpg in for model year (MY) 2015. Other alternatives reach higher levels; for example the Total Cost Equals Total Benefits (TC=TB) alternative reaches 37.5 mpg for MY 2015. The DEIS concludes that there is almost no difference between the proposed standard and the TC=TB alternative, noting that the two alternatives differ by only 0.2 percent in terms of global warming emissions reductions in 2100. Our analysis of similar alternatives shows that NHSTA's characterization is misleading. In reality, more aggressive alternatives to the proposed rule can have very significant environmental benefits over the proposal. For example, a standard that reaches 35 mpg with MY 2015 instead of MY 2020 could save more than a billion barrels of oil and cut greenhouse gas (GHG) emissions by more than 510 million metric tons of CO_2-equivalent (MMTCO_2e) by 2020. A 35 mpg standard for MY 2015 would also pave the way for future fuel economy increases beyond 2015; these increases would put the U.S. on a path to achieve at least 40 mpg by 2020 and provide further oil and GHG savings not envisioned by the current DEIS.

The inability to differentiate the impacts among alternatives is the result of NHTSA's failure to consider light-duty fuel economy increases in the context of other measures designed to reduce global warming pollution. Fuel economy standards must be evaluated in the context of a comprehensive package of emission reduction measures needed to meet GHG emission reduction targets necessary to solve global warming. To draw an analogy, when a state must clean up its air to meet national ambient air quality standards, a State Implementation Plan, or SIP, must be submitted to EPA describing how pollution reductions will be achieved from a package of regulations on vehicles, fuels and consumer products. To solve global warming, GHG emission reductions are needed beyond the transportation from other energy-intensive sectors of the economy including power generation, industrial, commercial and residential sectors. When considered alongside measures in other sectors, it is clear that fuel economy standards play a critical, substantial role in avoiding dangerous climate change and more stringent standards are critical for achieving the necessary global warming pollution reductions in the transportation sector.

The weak passenger vehicle standard proposed by NHTSA for MY2011-MY2015 does not ensure that vehicle fuel economy levels will be on a continuous, smooth trajectory to meet the longer term fuel economy necessary to achieve 2050 GHG emission reduction targets. This introduces serious risk because the necessary trajectory gets steeper and steeper the longer we wait.

Reducing global warming pollution 80 percent by mid-century will require the United States to substantially transform its energy economy. NRDC examined multiple strategies to reduce global warming pollution on both the demand (energy consuming) side and the supply (energy producing) side of the equation and pinpointed six major groups of energy sector opportunities that will put America on the path to significantly reducing the pace and magnitude of global warming.[1] In this context, fuel economy standards are a very significant strategy for reducing U.S. emissions. As shown in Figure 1, when combined with smart growth measures, improved vehicle efficiency can contribute 13% of total reductions needed.[2]

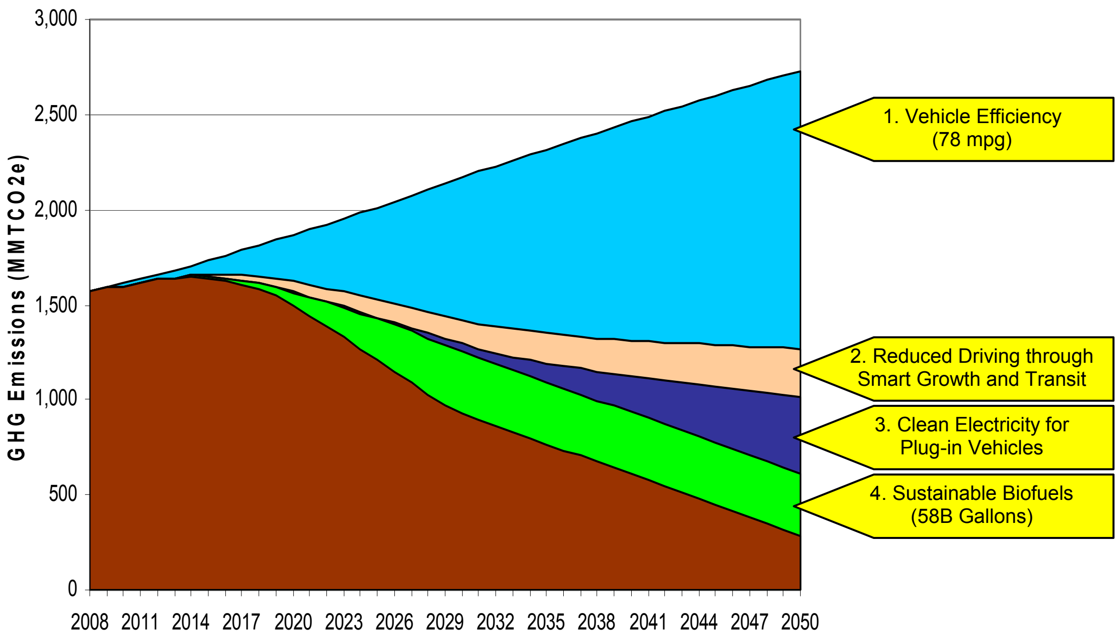
Figure 1: Six Opportunities for Reducing U.S. Fossil Fuel Emissions

		Carbon Pollution Avoided by 2050	Percent of Total Needed by 2050
1	Building efficiency to reduce heating and electricity needs.	1.7 billion tons	16%
2	Vehicle efficiency and smart growth communities to help cars go farther on less fuel and reduce vehicle travel.	1.4 billion tons	13%
3	Industrial efficiency such as combined heat and power to reduce industrial energy use.	1.2 billion tons	11%
4	Renewable electricity from sources such as wind, geothermal, and solar power, which have the potential to supply 40 percent of our energy needs.	1.4 billion tons	13%
5	Low-carbon transportation fuels such as biofuels made from crop waste and switchgrass to replace imported oil.	1.1 billion tons	10%
6	Carbon capture and storage of CO_2 emissions from coal-fired power plants in geologic structures deep in the earth, where it is gradually absorbed.	1.1 billion tons	10%
		TOTAL: 7.9 billion tons of carbon pollution avoided	**TOTAL: 73% of total emissions reductions needed**

[1] These measures achieve three-quarters of the reductions needed by 2050. The remainder would come from non-CO2 gases, forestry measures, and innovations to address thousands of smaller sources.
[2] Chart from NRDC Issue Paper, "The New Energy Economy: Putting America on the Path to Solving Global Warming," June 2008. Available at http://www.nrdc.org/globalWarming/energy/contents.asp.

In terms of the transportation sector alone, fuel economy improvements comprise an even larger share of the GHG reductions. NRDC estimates that improved efficiency can contribute nearly 60 percent of the cumulative GHG reductions needed from the passenger vehicle sector. As shown in Figure 2, achieving 80% reductions from current emissions in the light-duty vehicle fleet requires a combination of improved fuel economy, smart growth, increased transit investments and a transition to low carbon alternative fuels such as electricity and biofuels. Without significant and early GHG reductions from greater vehicle efficiency, achieving the 80 percent reduction target becomes extremely challenging, if not impossible.

Figure 2: Four Key Strategies for Achieving 2050 80 Percent Reduction Climate Stabilization Target for Light-Duty Vehicles



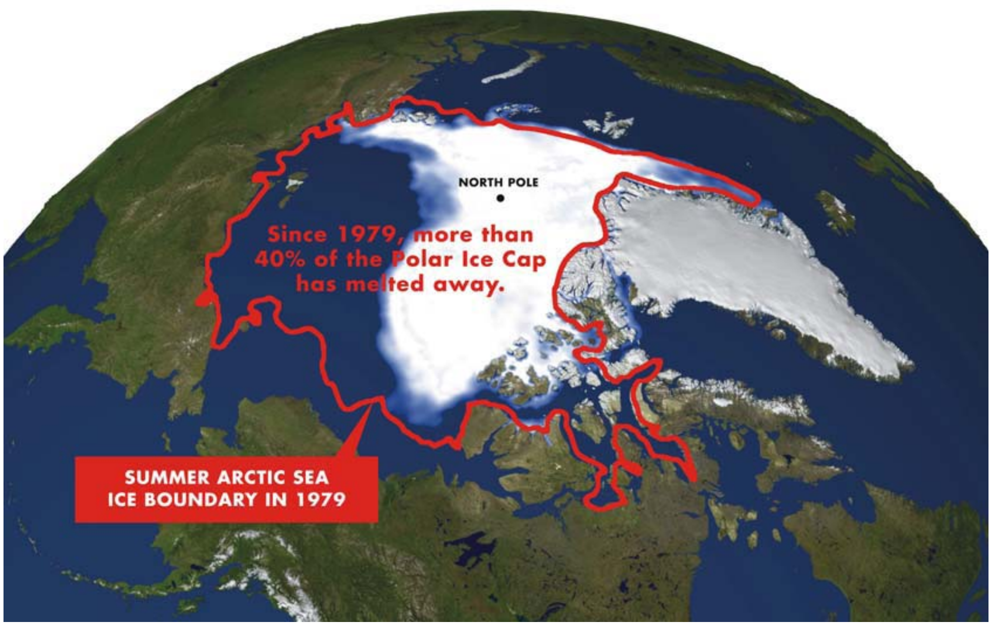
To Avoid Dangerous Climate Change, the U.S. Must Act Today to Implement All Cost-Effective Technologies that Reduce Global Warming Pollution

More stringent alternatives to NHTSA's proposed fuel economy levels result in larger GHG reductions sooner. Furthermore, earlier action provides greater certainty that the US will reach its mid-century GHG reduction target and avoid dangerous climate change. Early action relies on the use of existing cost-effective technologies and allows for a more gradual transition from today's energy infrastructure to low carbon resources. Because of the cumulative build-up of global warming pollution in the atmosphere, a slow introduction of technologies designed to reduce pollution makes avoiding climate change much more challenging.

Recent Congressional testimony by Michael Goo, NRDC's Climate Legislative Director, clearly describes the urgent need for aggressive action on global warming today. The testimony excerpted below was presented to the Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, United States House of Representatives hearing on legislative proposals to reduce greenhouse gas emissions, June 19, 2008:[3]

> The time for action on global warming has already been delayed too long. Every day we learn more about the ways in which global warming is already affecting our planet. Recent satellite pictures show that summertime arctic ice has declined by 40 percent since 1979 (Figure [3]). The UN Intergovernmental Panel on Climate Change (IPCC) found that 11 of the past 12 years are among the 12 hottest years on record. The Greenland and West Antarctic ice sheets are losing mass at accelerating rates. Rising sea surface temperatures correlate strongly with increases in the number of Category 4 and 5 hurricanes. Increases in wildfires, floods and droughts are predicted to occur as global warming continues unabated. Our oceans are warming and becoming more acidic. Everywhere one looks, the impacts of a disrupted climate are confronting us.

Figure [3]: ARCTIC MELTDOWN - Arctic summer sea ice extent in 1979 and 2007.
Source: NASA.



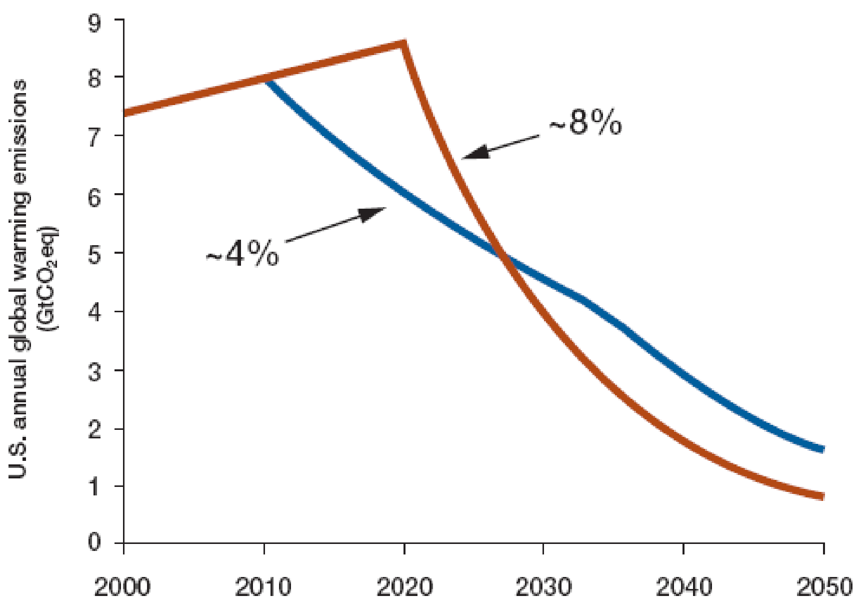
> Climate scientists warn us that we must act now to begin making serious emission reductions if we are to avoid truly dangerous global warming pollution concentrations. Because carbon dioxide and some other global warming pollutants can remain in the atmosphere for many decades, centuries, or even longer, the climate change impacts from pollution released today will continue throughout the 21st century and beyond. Failure to pursue significant reductions in global warming pollution now will make the job much harder in the future—both the job of stabilizing atmospheric pollution concentrations and the job of avoiding the worst impacts of a climate gone haywire.

[3] Full testimony available at http://docs.nrdc.org/globalWarming/default.xdl.

Since the start of the industrial revolution, carbon dioxide concentrations have risen from about 280 parts per million (ppm) to more than 380 ppm today, and global average temperatures have risen by more than one degree Fahrenheit over the last century. A growing body of scientific opinion has formed that we face extreme dangers if global average temperatures are allowed to increase by more than 2 degrees Fahrenheit from today's levels. We may be able to stay within this envelope if atmospheric concentrations of CO_2 and other global warming gases are kept from exceeding 450 ppm CO_2-equivalent and then rapidly reduced. However, this will require us to halt U.S. emissions growth within the next few years and then cut emissions by approximately 80 percent over the next 50 years.

This goal is ambitious, but achievable. It can be done through an annual rate of emissions reductions that ramps up to about a 4 percent reduction per year (see Figure [4]). But if we delay and emissions continue to grow at or near the business-as-usual trajectory for another 10 years, the job will become much harder. In such a case, the annual emission reduction rate needed to stay on the 450 ppm path would double to 8 percent per year. In short, a slow start means a crash finish, with steeper and more disruptive cuts in emissions required for each year of delay.

Figure [4]: SLOW START… CRASH (OR BURN) FINISH
Source: Union of Concerned Scientists.



To avoid the crash finish, the United States should act today to aggressively implement existing, cost-effective technologies to global warming pollution from all sectors. The NHTSA CAFE DEIS should distinguish how more aggressive alternatives to the proposed standard put the U.S. on a more certain path for solving global warming.

The Environmental Impact Assessment Should Evaluate a Valid CAFE Proposal and Alternatives; Faulty Methodology in the NHTSA Proposed Rule Means that the DEIS Findings Are Based on an Unlawful Proposed Rule

The Draft Environmental Impact Statement is inaccurate because evaluates an unlawful NHTSA CAFE proposal. As explained in NRDC's comments to the proposed rule, NHTSA failed to meet its statutory directive to set the maximum feasible fuel economy levels.[4] In calculating the required fuel economy level, NHTSA used erroneous assumptions for key input parameters and NHTSA set arbitrary limits on the availability of key vehicle technologies that could significantly improve fuel economy. These assumptions inaccurately characterized technologically feasible and economically practicable fuel economy in NHTSA's NPRM for both the proposed rule and the alternatives and therefore similarly skew the findings in the DEIS. Specifically, there are four main incorrect assumptions the agency makes: too low fuel prices, undervalued economic value of climate change oil externalities, too high of a discount rate, and undervaluation of economic values for military oil externalities. The agency also arbitrarily underestimated the availability of technology to improve vehicle fuel economy. In summary:

- NHTSA relies on the Energy Information Administration's Reference Case forecast for fuel prices. However, both the Reference and High Case forecasts have consistently underestimated fuel prices and NHTSA fails to use a reasonable forecast consistent with likely price trajectories.

- The social cost of carbon used by NHTSA is based on an arbitrary range of values and incorrectly relies on a central estimate of $7 per metric ton of CO_2. Unmitigated, costs of dangerous climate change are very likely much higher than estimates in standard literature, and NHTSA must use a reasonable risk premium in its calculations.

- NHTSA fails to adhere to standard economic practice and governmental guidelines when it used a discount rate of 7 percent. The agency should use a discount rate that does not exceed 3 percent and should conduct sensitivity analysis for even lower values.

- The economic value of military security to protect oil supplies should be non-zero and positive. When NHTSA used zero it ignored the U.S. military security-related benefits of reduced oil consumption, such as enhanced flexibility to respond to supply threats and move the country in the direction of oil being a nonstrategic resource.

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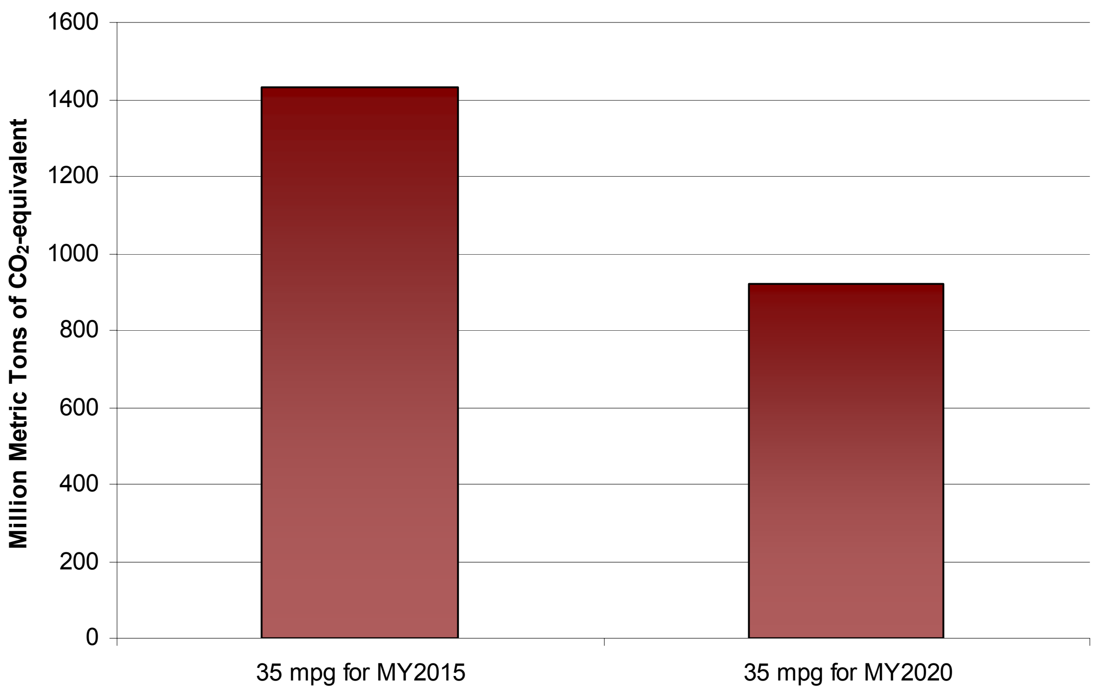
[4] NRDC, "COMMENTS ON: Notice of Proposed Rulemaking, Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011—2015, Department of Transportation, National Highway Traffic Safety Administration, Docket No. NHTSA—2008—0089," submitted July 1, 2008.

- NHTSA set arbitrary limits on technology availability in the Volpe Model, which biased toward setting a weaker fuel economy standard. Two specific examples include an arbitrary constraint on the use of lightweight materials substitution to improve fuel economy and the exclusion of plug-in hybrid electric vehicles from consideration in the Volpe Model.

If NHTSA had used reasonable assumptions for their analysis, the fuel economy levels in the proposed rule and all cost-dependent alternatives would be higher. For example, based on NHTSA's *own* sensitivity analysis presented in the Preliminary Regulatory Impact Assessment, the MY2015 fuel economy standards should be set at least at the level that would result in a combined fleet average of 35 mpg by MY2015 if the fuel savings are more properly valued.

The potential additional public and private benefits of raising the standards to 35 mpg by MY2015 are enormous. Consumer pocketbooks, the nation's energy security, and the environment would all stand to benefit tremendously from a 35 mpg standard. We estimate by 2020, the U.S. would conserve 3 billion barrels of oil, 1.5 times more, if the MY2015 standard was set at a level that resulted in a combined 35 mpg instead of 31.6 mpg. The 35 mpg level in MY2015 also avoids 510 million metric tons of global warming pollution (see Figure 5).

Figure 5: Cumulative Global Warming Pollution Reductions in 2020



NRDC calculation using the Long-range Energy Alternatives Planning (LEAP) system stock model (available at http://www.seib.org/software/leap.html) to estimate on-road fleet fuel economy. Savings for each scenario are in relation to a baseline using vehicle populations and mileage for 2005 to 2030 provided from in EIA's Annual Energy Outlook 2008. Baseline new passenger car and light truck fuel economy are held constant at the 2010 level from 2011 to 2030.

The emissions reduction estimates are conservative, however. Beyond 2015, the fuel economy standards could continue to increase to over 40 mpg in 2020, which would result in even greater pollution reductions.

The Draft EIS must evaluate a lawful proposed rule and compare it against reasonable alternatives. In the case of this DEIS, NHTSA has failed to evaluate a maximum feasible standard and a consistent breadth of alternatives based on reasonable assumptions.

Acc. No. 0558

Public Submission: NHTSA-2008-0060-0558 **Bookmark:** Learn more Public Subr

Docket	NHTSA-2008-0060
Docket Title	Notice of Intent to Prepare an Environmental Impact Statement for New Corp Economy Standards
Docket Type	Rulemaking
Document	NHTSA-2008-0060-0528
Document Title	Notice of Availability of a Draft Environmental Impact Statement (DEIS) for N Average Fuel Economy Standards; Notice of Public Hearing
Public Submission	NHTSA-2008-0060-0558
Public Submission Title	Marissa S. Knodel - Comments
Views	
Add Comments	
How To Comment	

Title	Marissa S. Knodel - Comments
Abstract	
Document Type	PUBLIC SUBMISSIONS
Document Sub-Type	Comment(s)
CFR Citation	
Author / Document Date	08/14/2008
Answer Date	
Media Location	
Media Type	
Page Count	1
Start End Page	
Order Number	
Old Submitter Rep	
Old Submitter	
Effective Date	
OMB / PRA Approval Number	
Received / Filing Date	08/14/2008
Legacy ID	NHTSA-2008-0060-0550(09000064806ac9c4)
Federal Reg Citation	
Federal Register Number	
Date Posted	08/15/2008
Comment Start Date	03/28/2008
Comment Due / Reply Date	
Implementation / Service Date	

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Government Agency Type	
Government Agency	

General Comment

Comment Taking actions that reduce American's dependence on oil and set us on a path a clean energy future are matters of environmental justice and NHTSA has an obligation to increase fuel economy standards to the maximum feasible in ord to save Americans money, eliminate our addiction to oil, and protect the environment.

Attachments

NHTSA-2008-0060-0558.1	**Marissa S. Knodel - Comments**

NESCAUM
www.nescaum.org
The Clean Air Association of the Northeast States
101 Merrimac Street, 10th Floor Boston, MA 02114
Phone 617-259-2000 Fax 617-742-9162
Arthur N. Marin, Executive Director

August 15, 2008

To: Docket ID No. NHTSA-2008-0060 (Electronic Submittal)

RE: Draft Environmental Impact Statement for New Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, MY 2011-2015

NESCAUM (Northeast States for Coordinated Air Use Management) submits the following comments on NHTSA's Draft Environmental Impact Statement (DEIS). NESCAUM is an association of state air pollution control agencies in Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. Please note that NESCAUM recently submitted comments to the docket[1] on the NHTSA's Proposed Rule for Average Fuel Economy Standards. NESCAUM incorporates by reference our previous comments pertaining to the DEIS in that proposed rule.

In our previous comments, we noted that the Proposed Rule was published on May 2, 2008 with a deadline for comments of July 1, 2008, but NHTSA did not release the DEIS until June 24, 2008. Consequently, there was little opportunity to consider the DEIS while reviewing and developing comments on the Proposed Rule. The applicable federal regulations state, "NEPA procedures must insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken."[2] Further, these regulations require federal agencies to "[i]ntegrate the requirements of NEPA with other planning and environmental review procedures…so that all such procedures run concurrently rather than consecutively." In so doing, the effect is to "[e]ncourage and facilitate public involvement in decisions which affect the quality of the human environment." Unfortunately, by separating the review periods for these two actions, the public involvement processes, both for the Proposed Rule and for the DEIS, were not well served.

NESCAUM's primary concern with the DEIS is with how it addresses cumulative effects, defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and *reasonably foreseeable* future actions regardless of what agency (Federal or non-federal) or person undertakes such other actions." (emphasis added)[3]. Noteworthy in this regard is the official NEPA guidance document, <u>Considering the Cumulative Effects under the National Environmental Policy Act</u>,[4] which makes a number of important points, including:

- The analyst's primary goal is to determine the magnitude and significance of the environmental consequences of the proposed action in the context of the cumulative effects of other past, present, and future actions.

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[1] Docket ID No. NHTSA-2008-0089
[2] 40 CFR 1500.1 & 1500.2
[3] 40 CFR § 1508.7
[4] http://www.nepa.gov/nepa/ccenepa/ccenepa.htm

- The effects of a proposed action on a given resource, ecosystem, and human community include the present and future effects added to the effects that have taken place in the past.
- Individual effects from disparate activities may add up to or interact to cause additional effects not apparent when looking at the individual effects one at a time.

The DEIS, inconsistent with the regulations and policy guidance on cumulative effects, evaluates the effects of new CAFE standards without consideration of other important factors. For example, while NHTSA asserts the DEIS fully addresses foreseeable impacts through the year 2100, it errs by incorporating an assumption that technological improvements in fuel economy cease after model year 2020.[5] In reality and in contrast with this approach, technology-forcing requirements historically have spurred technological innovation to meet and even exceed environmental benchmarks. This interrelationship between policy initiatives and technology advancement has been well documented by numerous researchers[6] for more than thirty years and has even been given a name; *induced technological change.* There is little question that policies and legislative initiatives aimed at reducing carbon emissions are in our future, and these programs will create economic disincentives to continued business as usual, relative to consumption of fossil fuels in the transportation sector. Consequently and according to the principles of induced technological change, business and government will respond by engaging in more extensive research and development, including in the fuel economy arena, with a goal of reducing reliance on conventional fuels. As these research and development efforts bear fruit, technological progress will follow.

Given this principle of induced technological change, coupled with the underlying legislative requirement (i.e., the Energy Policy and Conservation Act – EPCA) for NHTSA to take a technology-forcing approach to future fuel economy requirements, further improvements beyond model year 2020 are, in fact, *reasonably foreseeable*. Thus, the approach taken in the DEIS disregards both precedent and the law. It is also important to note that economics by itself will play a future role, inducing technological change to improve fuel economy. The U.S. Energy Information Administration in its 2008 Annual Energy Outlook projects in its “high economic growth–high fuel price” scenario that between 2008 and 2030, energy use in the light duty vehicle sector will grow by 13 percent while at the same time, the price of gasoline will grow by 18 percent. As this scenario unfolds, there will be further incentives for investment into research and development for improving fuel economy. Therefore, NHTSA would do well to incorporate such economic factors into its cumulative effects analysis.

Despite these developments which call for bold policy steps to actively pursue significant improvements in fuel economy, NHTSA has chosen to pursue a very conservative course in setting near-term standards. We made this point in our comments submitted on the Proposed

[5] NHTSA’s apparent rationale is that the Energy Information and Security Act (EISA) mandates a fuel economy target that extends only through model year 2020.
[6] As a prime example, see Goulder, L.H., et al., Induced Technological Change and the Attractiveness of CO_2 Abatement Policies, *Resource and Energy Economics*, 21 (1999) 211-253.

Rule, noting NHTSA's initial consideration of seven different fuel economy stringency scenarios (ranging from no-action to technology exhaustion alternatives), and ultimate choice of an "optimized" alternative that maximized net benefits from an economic standpoint. In settling on this alternative for which there is little to no impetus for forcing technology, NHTSA's actions will have a dampening effect on progress toward long term improvements to fuel economy and by extension to progress addressing the environmental impacts brought about by climate change.

The DEIS, in its assessment of global benefits, also disregards the principle of technology transfer. If U.S. industries develop technology that markedly improves fuel economy, it's very unlikely that the technology will remain confined to the U.S. fleet. Ultimately, fleets worldwide will incorporate the same technologies. According to the World Resources Institute, energy consumption accounts for 61 percent of total GHG emissions and transport accounts for 22 percent of all energy consumption-related GHG emissions. U.S. transportation, according to the Energy Information Administration, accounts for 18 percent of global GHG emissions from petroleum consumption. Clearly, an aggressive program in the U.S. to markedly improve fuel economy, coupled with technology transfer, can be a key strategy for reducing GHG emissions globally.

The DEIS disregards these factors and NHTSA concludes that the standards will have a negligible impact on climate change. Quoting from the DEIS:

…because EISA requires average fuel economy of the passenger car and light truck fleet to reach a combined 35 mpg by 2020, the MY 2016-2020 CAFE standards are a reasonably foreseeable future action. Accordingly, the cumulative impacts analysis assumes the minimum MY 2016-2020 CAFE standards necessary to get to 35 mpg by 2020…Overall, the emission reductions for the MY 2011-2015 CAFE alternatives have a small impact on climate change. The emission reductions and resulting climate impacts for the MY 2011-2020 standards are larger, though they are still relatively small in absolute terms.

NHTSA's approach with the DEIS is unfortunately consistent with EPA's discredited argument in *Massachusetts v. EPA 127 S. Ct. 1438 (2007)* as to why that federal agency should not regulate GHGs emissions from new motor vehicles. EPA's rationale was that such regulations would have an insignificant effect on mitigating climate change. The Supreme Court rejected EPA's argument, pointing out that, "Agencies, like legislatures, do not generally resolve massive problems in one fell regulatory swoop. ('[A] reform may take one step at a time, addressing itself to the phase of the problem which seems most acute to the legislative mind' [internal citation omitted].)… And reducing domestic automobile emissions is hardly a tentative step… [T]he United States transportation sector emits an enormous quantity of carbon dioxide into the atmosphere."

In summary, NHTSA has an obligation to pursue a technology-forcing approach, as envisioned under EPCA, and address all *reasonably foreseeable* cumulative effects. The approach taken by NHTSA provides insufficient information to fully evaluate the fuel economy scenarios in the

DEIS. The DEIS overlooks the environmental harm of the less aggressive technology scenarios (including NHTSA's preferred option) caused by foregoing more technology-forcing alternatives having greater climate benefits. The failure to fully consider the reasonably foreseeable broad dissemination of advanced fuel efficient technologies is an informational lapse that needs to be more fully addressed. If you have any questions, feel free to contact Eric Skelton of my staff at (617) 259-2028 or eskelton@nescaum.org.

Sincerely,

Arthur N. Marin
Executive Director

Cc: NESCAUM Directors

Acc. No. 0560

Public Submission: NHTSA-2008-0060-0560 **Bookmark:** Learn more Public Subr

Docket	NHTSA-2008-0060
Docket Title	Notice of Intent to Prepare an Environmental Impact Statement for New Corp Economy Standards
Docket Type	Rulemaking
Document	NHTSA-2008-0060-0528
Document Title	Notice of Availability of a Draft Environmental Impact Statement (DEIS) for N Average Fuel Economy Standards; Notice of Public Hearing
Public Submission	NHTSA-2008-0060-0560
Public Submission Title	American Jewish Committee - Comments
Views	
Add Comments	
How To Comment	

Title	American Jewish Committee - Comments
Abstract	
Document Type	PUBLIC SUBMISSIONS
Document Sub-Type	Comment(s)
CFR Citation	
Author / Document Date	08/18/2008
Answer Date	
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Page Count	1
Start End Page	
Order Number	
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Effective Date	
OMB / PRA Approval Number	
Received / Filing Date	08/18/2008
Legacy ID	NHTSA-2008-0060-0559.1(09000064806c6867)
Federal Reg Citation	
Federal Register Number	
Date Posted	08/18/2008
Comment Start Date	03/28/2008
Comment Due / Reply Date	
Implementation / Service Date	

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Organization / Org Unit	American Jewish Committee

D-210

Submitter's Representative
Representative's Address
Rep's City, State & Zip
Government Agency Type
Government Agency

General Comment

Comment AJC TESTIMONY FOR AUGUST 4TH 2008
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION (NHTSA) HEARING ON FUEL ECONOMY
ENVIRONMENTAL IMPACT STATEMENT

Thank you for the opportunity to speak before you today. My name is Ami Gr and I am the Energy Policy Specialist and Legislative Assistant for the Americ Jewish Committee which I am representing here today. We are the nation's o human relations organization with over 175,000 members and supporters represented by 31 regional chapters in the U.S., and 8 offices abroad.
AJC is a long-time advocate of the need to develop energy policy that will reduce our nation's dependence on foreign energy sources as well as protect environment. More then thirty years ago, prompted by the then-recent Arab embargo, AJC first adopted a policy statement on energy. Over the succeedin years, as the nation coped with an energy supply shock in the 70's, coupled w concerns about the environment, safety, and tanker dependency raised by th Exxon Valdez oil spill, AJC adopted and acted on several additional statement on energy policy. These statements reflected the agency's concern that our nation address its increasing dependence on imported oil, and the impact of t dependency on our economic health, and strategic and social stability, in a fashion consistent with protection of the environment and attention to policy impacts on the disadvantaged.
The 9-11 attacks against the U.S. underscored another crucial consideration, that our national security and our position as a world leader are seriously undermined by our dependence on foreign nations, many unfriendly or potent unstable, for a primary energy supply. Thus, just as this nation is taking extensive actions at home and abroad to protect the safety of our citizens, it is imperative that we take the steps necessary to enhance our national energ security.
As we have experienced in the past, energy prices have decreased for periods time, and with such fluctuations, Americans have become less sensitive to the need for this type of policy. Today, facing record prices at the pump, we feel that the need for further action on energy security is more urgent then ever, both by assuring safe and sustainable energy sources and through renewed attention to issues of conservation and efficiency.
While the U.S. comprises less then 5 percent of the world's population, it consumes approximately 25 percent of the world's oil. 2/3 of all oil consumed nationwide is for transportation - most of that for motor vehicles. A drop in domestic oil production, coupled with increased consumption, has created a scenario by which the U.S. is more reliant on foreign oil sources than ever before. As this trend continued, the U.S. has become even more reliant on oil from countries that have not traditionally been friendly to U.S. strategic interests and that have the potential to disrupt oil supplies worldwide, adversely affecting the world and U.S. economies with resulting lost jobs, a decreased quality of living, and harsher conditions for low-income families.
Dependence issues aside, climate change has the potential to disrupt our way life, irreversibly harm the natural environment, create ongoing humanitarian crises, and—because these changes may foster instability as societal demand exceed the capacity of governments to cope—undermine our efforts to keep ourselves safe and secure.

A majority of scientists today hold that climate change is attributable in large part to an increase in the volume of atmospheric greenhouse gases and that t gases are primarily a result of human activity, mostly CO_2 (carbon dioxide) fr combustion of fossil fuels.

The weight of the evidence demands, as a matter of prudence, that we devise policies directed at stemming climate change, as well as adapting to its reality. In urging these policies, we act in accordance with Jewish tradition, which commits us to the protection of life, stewardship of the earth and its inhabitants, and the well-being of future generations.

Last year, a historic step was taken when Congress passed, and President Bu signed into law the Energy Independence and Security Act that included, amo other provisions, a strengthening of Corporate Average Fuel Economy (CAFE) standards for the first time in more than two decades. We think that strengthening CAFE standards is one of the most crucial components of a multifaceted approach to drastically reducing our dependence on foreign oil, reduce our global warming emissions, save money at the gas pump and secu America's energy future. These new standards will save the United States. 1. million barrels of oil per day by 2020––approximately 40% of what we import the Persian Gulf.

In proposing a combined average of 31.6 mpg for Model Year 2015, NHTSA is failing to acknowledges the current technology that could safely and cost effectively make all vehicles reach a fleet wide fuel economy average of at least 35 miles per gallon by 2015. Further, the current proposal relies on fanciful gas price assumptions, which result in insufficient fuel economy levels. The proposal assumes future gasoline prices to be only $2.25 per gallo in 2016 (in 2006 dollars), when American consumers are already paying price nearly twice as much today. The use of below-cost energy estimates violates agency's statutory charter to impose mandatory maximum feasible fuel econo standards based upon a review of economic and technological feasibility.

NHTSA must reconsider the proposed standards and use its statutory authorit meet the urgent need of the United States to conserve oil and meet the curre growing demand of American consumers for vehicles that go farther on a gall gas. NHTSA should not conclude in its analyses that fuel economy gains are presumed to stop at 2020 levels, but further grow by means of using existing technologies. Furthermore, we see the use of alternative and renewable fuels new lightweight materials and electric powered vehicles taking up a bigger percentage of vehicle miles driven in the U.S. in the near future, further reducing our dependence on foreign oil and our GHG emissions.

We cannot overstate the importance of moving toward tougher fuel economy standards at this time, even as we should not underestimate the challenges t and other actions addressing energy security will entail. But we see no alternative if we are to put the United States on a more sustainable energy path, one that is essential both to our nation's security and our environmenta health.

- Remarks presented by Ami Greener, Energy Specialist at the Office of Government and International Affairs, American Jewish Committee.

Attachments

NHTSA-2008-0060-0560.1	**American Jewish Committee - Comments**
NHTSA-2008-0060-0560.2	**American Jewish Committee - Comments**

Acc. No. 0561

Public Submission: NHTSA-2008-0060-0561 **Bookmark:** Learn more Public Subr

Docket	NHTSA-2008-0060
Docket Title	Notice of Intent to Prepare an Environmental Impact Statement for New Corp Economy Standards
Docket Type	Rulemaking
Document	NHTSA-2008-0060-0528
Document Title	Notice of Availability of a Draft Environmental Impact Statement (DEIS) for N Average Fuel Economy Standards; Notice of Public Hearing
Public Submission	NHTSA-2008-0060-0561
Public Submission Title	Consumer Federation of America - Comments
Views	
Add Comments	
How To Comment	

Title	Consumer Federation of America - Comments
Abstract	
Document Type	PUBLIC SUBMISSIONS
Document Sub-Type	Comment(s)
CFR Citation	
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Answer Date	
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Effective Date	
OMB / PRA Approval Number	
Received / Filing Date	08/18/2008
Legacy ID	
Federal Reg Citation	
Federal Register Number	
Date Posted	08/18/2008
Comment Start Date	03/28/2008
Comment Due / Reply Date	
Implementation / Service Date	

Submitter Information

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Organization / Org Unit	Consumer Federation of America Dr. Mark Cooper

D-213

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Government Agency Type	
Government Agency	

General Comment

Comment	Please see attachments for comments and addendum.

Attachments

NHTSA-2008-0060-0561.1	**Consumer Federation of America - Comments**
NHTSA-2008-0060-0561.2	**Consumer Federation of America - Comments**

Acc No. 561.1

National Highway Traffic Safety Administration

Notice of Proposed Rulemaking; Docket;	**)**	
Average Fuel Economy Standards, Passenger	**)**	**No. NHTSA 2008-0060,**
Cars and Light Trucks; Model Years 2011-2015	**)**	

COMMENTS ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

of

AkPIRG, Arizona Consumers Council, Arizona PIRG, CALPIRG, Citizens' Utility Board of Oregon, Consumer Action, Consumer Assistance Council of Cape Cod, Consumer Federation of America, Consumer Federation of the Southeast, Consumers for Auto Reliability and Safety, Democratic Processes Center, Empire State Consumer Association, Florida Consumer Action Network, Florida PIRG, Illinois PIRG, Maryland Consumer Rights Coalition, Maryland PIRG, Massachusetts Consumers Council, New Jersey Citizen Action, New Mexico PIRG, NYPIRG, The Consumer Alliance, USPIRG, Utility Consumers Action Network, Victims Committee for Recall of Defective Vehicles, Virginia Citizens Consumer Council, VPIRG, Wisconsin Consumers League

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August 18, 2008

The Consumer Federation of America and 27 of its member groups appreciate the opportunity to file comments in the above captioned docket. The groups filing these comments are from fifteen states and focus on a wide range of public policy issues, but they all recognize the vital importance of fuel economy standards for America's energy future. We believe that raising fuel economy standards must play a critical role in reducing the nation's oil addiction, enhancing national security and protecting the environment. We are deeply disappointed by the failure of the National Highway Traffic Safety Administration (NHTSA) to raise the standards to a level that reflects the severe energy situation and the current auto market reality in the United States. NHTSA has failed to set standards at the maximum feasible level, denying consumers and the nation over 150 billions of gallons of gasoline savings in the next decade. As the attached study prepared by one of the consumer groups shows, NHTSA has completely misjudged the consumer and the auto marketplace and proposed a standard that is far too low. The draft environmental impact statement suffers from the same basic flaws that afflict the proposed rule.

Many of the issues discussed below have been addressed in prior comments filed in this rulemaking, but recent events have made the flaws in NHTSA's analysis and framework so much more obvious that we feel obliged to restate our objections to the proposed rule and incorporate that new evidence into the record. Our recommendations mirror earlier recommendations of consumer advocates in this proceeding. In order to propose a reasonable standard that fulfills the goals of the statute, NHTSA must:

- Raise the proposed standards for 2011 and 2012; and
- Withdraw the proposed standards for 2013 through 2015, so it can fix its faulty analytical framework and economic assumptions.

In light of the new evidence on the swift changes by consumers to embrace more fuel-efficient vehicles, we believe that the standard should be set at the highest level in NHTSA's analysis that was economically practicable.[1] This would raise the standard for 2011 to 30.6 miles per gallon, from the proposed level of 27.8 mpg. The attached report shows that consumers are more than willing to purchase such vehicles and the dramatic changes that the automakers have announced in their product plans indicate they can deliver the vehicles necessary to achieve this level of fuel economy.

THE PROPOSED RULE AND ITS ENVIRONMENTAL IMPACT STATEMENT FAIL TO ACHIEVE THE GOALS OF NEPA AND EPCA

There are two problems in the draft environmental impact statement that render it woefully inadequate to address the public policy goals of the National Energy Policy Act and the Energy Policy Conservation Act.

First, the analysis underlying the proposed rules is so fundamentally flawed that the agency has not considered an appropriate range of policy options, for which the environmental impact should be evaluated. Erroneous assumptions about market fundamentals have led NHTSA to center its analyses on a level of fuel economy that is so low that it sheds little light on what the environmental impact of a reasonable fuel economy standard would be. NHTSA has based the proposed rule on flawed assumptions and data on:

- Consumer behavior and attitudes toward fuel economy;
- Automaker capabilities to incorporate fuel savings technologies; and
- The price and value of energy.

[1] This is the point in the initial analysis where total benefits equal total costs. When NHTSA corrects the many flaws in its approach benefits from this level of fuel economy will far exceed the costs

NHTSA's approach to setting fuel economy standards is to start with automaker product plans, assert that consumers undervalue fuel economy by demanding unrealistic economic returns from fuel saving technologies and assume that automakers are severely constrained in their ability to incorporate new fuel-saving technology into the vehicle fleet. Neither the product plans, nor the assumptions about consumer and automaker behavior relied on in NHTSA's analysis bear any relationship to reality.

- Consumers are looking for higher mileage in the new vehicles today than NHTSA has mandated for seven years from now.
- The product plans on which NHTSA based its rule seven years into the future have already been torn up by the automakers who have belatedly recognized the strong shift in consumer behavior.
- The mix of cars and trucks that NHTSA projects bears no relationship to the vehicles that consumers are buying.
- Not only did NHTSA assume that consumers are unwilling to buy fuel economy beyond a very narrow economic assumption, but it also assumed that higher fuel economy has no value in the marketplace (particularly in resale value), which is contrary to what is happening in the market.

Our market behavior analysis and public opinion polling show that consumers want more fuel-efficient cars than the automakers are offering them. The crucial role of a higher fuel economy standard is to push the automakers to deliver what the public wants and deliver the maximum feasible fuel economy, but NHTSA has failed to do so.

The second problem in the Draft Environmental Impact Statement stems from the fact that NHTSA takes a fundamentally flawed approach to its externality analysis. This was evident in the analysis of the military and strategic externalities in the proposed rule, where NHTSA engaged in reasoning that can, at best, be described as blind incrementalism.

- Rather than see improvements in fuel economy as a part of a broader solution to the national oil addiction, NHTSA argues that because this rule alone cannot solve the problem, it does not deserve to be counted as making a contribution to the solution.

- Implementing a law entitled the Energy Independence and Security Act, NHTSA concluded that oil consumption has no military or strategic value whatsoever.

The analysis of environmental impacts suffers from the same affliction. Because improvements in fuel economy alone do not solve the climate change problem, they are shown to have zero effect on the damage that global warming will do. Yet, every reasonable analysis of the big picture and the global impacts of greenhouse gas emissions recognizes that reductions of emissions in the transportation sector must play a large role in the overall solution to the problem.[2]

- Indeed, because of the nature of the sector, it is vital to get the maximum possible contribution to reductions from this sector to achieve a solution.
- Because no individual policy can solve the problem, this approach will reject every policy measure individually, even though taken together they can actually solve the problem.

Unfortunately, in NHTSA's approach, the whole is not even equal to the sum of its parts. NHTSA's approach embodies a myopic bias against action. NHTSA should start from an estimate of what the value of a solution to the national energy problem would be worth, and then give increases in fuel economy credit for their role in that solution.

The Draft Environmental Impact Statement is essentially meaningless because the underlying analysis is so fundamentally flawed that the agency has not considered an appropriate range of policy options for which the environmental impact should be evaluated, and the environmental impacts are not set in the proper context of the problem that needs to be addressed. The challenge of national security and environmental impact that emanates

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[2] Raymond Kopp and William A. Pizer, *Assessing U.S. Climate Policy Options* (Resources for the Future: November 2007), estimate that the transportation sector is the second largest source of greenhouse gas emissions and "vehicle use alone accounts for roughly 16 percent of total U.S. emissions and that emissions from this sector have been growing fifty percent faster than the economy-wide rate of growth of emissions (pp. 24, 162). Moreover, McKinsey and Company and The Conference Board, *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* (December 2007), shows vehicle fuel economy as one of the lowest costs options for reducing greenhouse gas emissions

from the nation's addiction to oil are global and multifaceted, and the analytic framework must recognize that fuel economy standards are one important part of a broader solution.

NHTSA'S PROPOSED RULE DOES NOT REFLECT THE AUTO MARKET REALITY

The attached study of consumer attitudes and auto market behavior prepared by the Consumer Federation of America has a series of findings that call into question the fundamental approach that NHTSA took to set the standard and compel NHTSA to thoroughly reconfigure its analytic approach before it issues a final rule.

Consumers are deeply concerned about rising gasoline costs and the national security implications of our dependence on foreign oil and are prepared to take actions to remedy these problems. Neither the auto industry in its marketing plans nor NHTSA in its proposed rule has fully comprehended the current state of consumer attitudes toward fuel efficiency and the state of the auto market.

- Eighty-four percent of respondents say they are concerned about rising gasoline prices (70 percent very concerned) and eighty-four percent say this rise in price has placed a financial burden on their household budgets (63 percent say severe).
- Seventy-four percent of respondents say they are concerned about Mid Eastern oil imports (57 percent very concerned).
- Among those who drive and intend to purchase a vehicle, the current average fuel economy of their vehicle is reported at about 24.1 mpg, but they intend to get 32.7 mpg in their next vehicle.
- Thus, the average goal for consumers in the market <u>today</u> is 32.7 mpg above the standard of 31. 6 mpg that NHTSA has set for 2015.
- There is a huge mismatch between consumer demand and models offered by automakers in 2008. Whereas 59 percent of the respondents say they want to get more than 35 mpg in their next vehicle, only 1 percent of the models offered by automakers in the first half of 2008 achieve that mileage.

- About 60 percent of the poll respondents say they are willing to consider major changes to achieve higher fuel economy, including switching to four cylinder engines, small cars and hybrids.

Moreover, as the attached report shows, consumers are not merely considering these measures to achieve higher fuel economy; they are acting on their attitudes.

- Four cylinder engines have increased their market share dramatically.
- Smaller cars are in exceptionally high demand, while trucks and SUVs languish on the lots.
- Hybrids are flying out of the show rooms.

However, in direct contradiction to these market trends, NHTSA's proposed rule restricts the level of the standard because it makes assumptions about consumer behavior or automaker ability to incorporate fuel-saving technology that fail to reflect this market reality. NHTSA refuses to consider vehicle downsizing or different performance characteristics as a means of increasing fuel efficiency. NHTSA's underlying assumptions are so out of touch with reality that they are arbitrary and capricious, resulting in a rule that is unreasonable.

The change in consumer attitudes and purchasing patterns has deeply affected the resale value of vehicles, yet NHTSA's proposed rule does not recognize the impact of fuel economy on the resale value of vehicles. NHTSA erroneously assumes that a gas guzzling SUV has the same resale value (as a percentage of the original purchase price) as a fuel sipping small car.

- Contrary to this assumption, SUVS and pickups are piling up on dealer lots across the country.
- SUVs and trucks, both new and used, have plummeted in value, while small cars have increased sharply.
- The Big 3 U.S. automakers announced plans to discontinue leasing these vehicles precisely because the value at the end of a lease is so much lower than the price they have to pay.

The faulty assumptions on resale value play a critical role in NHTSA's analysis by undervaluing fuel efficiency in its consumer payback analysis and preventing NHTSA from including more fuel savings in the fleet in its evaluation of standards.

The analysis of auto market behavior in the attached report shows that these consumer attitudes and trends were not a sudden development in the early part of 2008. They have been evident and progressing for several years. The auto industry and NHTSA have simply ignored the clear evidence.

- The shift in sales was not sudden, nor is it only the result of a shift from trucks to cars. Consumers have also been demanding greater fuel economy within vehicle categories.
- The structural shift to fuel economy occurred in 2004 for trucks and 2006 for cars.
- The effect has built over time so that by the first half of 2008, the level of fuel economy of a car model accounts for over 40 percent of the variance in the change in sales.
- Simply put, it did not take $4/gallon gas to cause the change in consumer behavior, it started at least three years ago when gas was $2.50 per gallon and has been growing progressively.

The automakers not only missed the shift in consumer behavior, they actually tried to resist it by continuing to pump out gas-guzzlers and trying to bribe consumers to buy them with rebates and low interest. However, the trend has proven too powerful and fundamental to resist. Now that the automakers have recognized that they must change, they are rapidly shifting their operations, retooling plants and adopting new technologies at a pace that is far greater than NHTSA had assumed possible. Thus, NHTSA's auto market model erroneously assumes a slow incorporation of fuel savings technology into the vehicle fleet for several reasons. Not only were the product plans on which NHTSA based its proposed rule thoroughly outdated, but also the ability of automakers to change was vastly underestimated by NHTSA. A rule based on data that is so out of touch with reality is arbitrary and capricious and unreasonable.

THE FLAWS IN THE ANALYTIC FRAMEWORK

The failure of NHTSA's proposed rule to reflect the auto market reality is magnified by an analytic structure and economic assumptions that are equally flawed. As described in earlier comments in this proceeding, **NHTSA has inexplicably undervalued the benefits of increased vehicle fuel economy**. In its economic assumptions, NHTSA has chosen to grossly undervalue gasoline consumption and therefore undervalues the fuel savings that will flow from a higher fuel economy standard. To arrive at the proposed rule, NHTSA:

- Used gasoline prices that are far too low – a price of only $2.45 per gallon for 2015 (in 2008 dollars);
- Discounted the value of fuel savings at an unnecessarily high rate; i.e. after identifying two possible discount rates: 1) a high rate based on the automaker view of capital costs and 2) a low rate based on the consumer view of consumption expenditures. NHTSA failed to choose a rate between the two, instead applying the high "capital" rate.
- Assumed that consumers irrationally burn up their fuel savings on increased driving, rather than using it to buy other goods and services, and applied this excessive "rebound" effect to analyses where it should not play a role.

Combined, these overt flaws in NHTSA's economic assumptions have led the Administration to value gasoline savings at less than half of what would be a reasonable estimate.

NHTSA failed to give the "need to conserve energy" proper consideration in light of the clear, obvious, and painful national energy crisis currently facing all Americans In speaking for the American public, Congress was very clear in its requirement that NHTSA set the fuel economy standard at the "maximum feasible level." In doing so, NHTSA was to take into consideration "the four statutory factors underlying maximum feasibility (technological feasibility, economic practicability, the effect of other standards on fuel economy, and the need of the nation to conserve energy)." NHTSA completely failed to give proper consideration to this last and most fundamental reason for the Act: "the need of the nation to conserve energy."

In its analysis, NHTSA identified two alternatives that bracket the range of possibilities that are economically practicable. One alternative – the "total benefit equals total cost (TB=TC)" alternative would maximize fuel savings at no net cost to society, by including fuel savings technologies until the total cost equals the total benefit. The other economic extreme, which HNTSA called the "optimized" approach, would maximize the economic return of investments in fuel economy by including fuel savings technology only up to the point where marginal benefits equal marginal costs.

- We believe that the TB=TC approach is the proper way to recognize "the need of the nation to conserve energy.
- At a minimum, an approach that would reasonably consider "the need to conserve energy" would balance the economic and conservation concerns and set the standard between the two extremes.
- NHTSA did not do so. It simply chose to set the standard at the lower level with no consideration of the enormous energy conservation cost of that decision.

NHTSA chose to define "feasibility" and "practicability" in a manner that lets the least fuel-efficient automakers drive down the standard. It protects the least capable automakers rather than requiring them to rise up to the level that the industry as a whole could achieve. Ironically, by setting a lower standard, in the face of dramatically rising consumer expectations, the Administration is creating an environment of failure for those companies who are driving down the standard. NHTSA allows the laggards in the industry, who have been trailing farthest behind the shift in consumer behavior, to pull the standard down.

NHTSA SET UNREASONABLY LOW STANDARDS FOR AN UNREASONABLY LONG PERIOD

Throughout its analysis, NHTSA indicates that certain assumptions were made with incomplete data and without critically important information about the auto market. Nevertheless, for no apparent reason, NHTSA set this low standard for the maximum period allowable under the law. NHTSA excuses the failure to obtain complete and accurate data for its assumptions with a claim that it must promulgate a standard for model year 2011 by mid-2009 in order to give automakers proper advanced notice. While that is correct, **there was no need to rush to promulgate standards for later model years, certainly not 2013 through 2015.** With numerous important issues still under study, it was incredibly irresponsible for NHTSA to write rules for years that do not require an expedited process, when additional time would afford a much more informed rulemaking. Critical information missing from NHTSA's analysis includes:

- The effectiveness of available technologies for improving fuel economy;
- The cost of technologies for improving fuel economy;
- Market shares of various models in the vehicle fleet; and
- The value of reduced emissions of greenhouse gases.

Unbelievably, NHTSA fully recognized that it did not have reliable and accurate information in these areas and would obtain that information only after the rule was promulgated. Additional and critical information missing from the Administration's analysis resulted in NHTSA making projections that were way ahead of the data available to them. This is, however, data that could be obtained, which would provide a much firmer basis for developing a rule that applies to 2013 vehicles and beyond. Without this critical data, NHTSA's conclusions:

- Relied on old sales data and projections in a time of rapid change in the industry;
- Failed to consider the impact of vehicle mix on safety;
- Did not incorporate technology adoption strategies ("pull ahead") that speed penetration of fuel-saving technology into the vehicle fleet;
- Ignored recent changes in fuel economy and the practices of automakers in adopting fuel economy technologies; and
- Overlooked changes in vehicle usage patterns across time.

Some underlying data used by NHTSA is suspect and would benefit greatly from even a small amount of further research and disclosure by the automakers, including:

- The production plans of automakers;
- Market share and price data;
- The validity of the speed of adoption of technology (phase-in caps) in light of dramatic changes in auto market behavior; and
- Assumptions about the compliance strategies of auto manufacturers.

There is no question that NHTSA needed to get the rulemaking started for 2011, and perhaps 2012, so it could complete the process eighteen months before the model year, as mandated by the new statute, but going beyond that, in light of the incredible importance of this regulation and the woeful lack of knowledge of critical aspects of the analysis, was irresponsible. NHTSA certainly could have moved forward with this rulemaking in light of these uncertainties by providing the minimum notice necessary, thereby keeping its options open for writing fuel economy standards for later years based on better information.

By rushing ahead with imperfect knowledge, faulty assumptions and a bias against fuel savings, NHTSA's approach denies the critical benefits of reduced gasoline and oil consumption to individual consumers and the nation as a whole. Therefore, it was unreasonable for NHTSA to set standards that run so far ahead of its knowledge. Adopting proposed standards for 2013 to 2015 based on such faulty data is arbitrary and capricious and leads to standards that are unreasonable.

The damage of NHTSA's proposed rule goes beyond the immediate impact of lost savings. By relying on a flawed analytic framework and flawed empirical specifications, this rulemaking undermines future rulemakings in two ways.

- First, procedurally, once this framework is set, it will be difficult to change. Inertia and judicial deference make it difficult to reverse agency decisions.
- Second, setting a low standard makes it far more difficult for the industry to meet higher future standards. Requiring large jumps in improvements is always more expensive than gradual improvements toward a goal, so fixing the mistakes later is harder because the industry is farther behind.

Because of the enormous importance of this particular rulemaking, it is critical for NHTSA to get the fundamental framework correct from the start and to set the standard at a reasonable and achievable level.

RECOMMENDATIONS

Based on our review of the proposed rule, it is clear that NHTSA's analysis is riddled with flaws. The result is a set of proposed fuel economy standards for the period 2011-2015 that is unreasonably low, covers a period that is unreasonably long, and is inadequately documented. NHTSA's proposal meets neither the spirit nor the intent of the Energy Independence and Security Act of 2007. Its flawed analysis and failure to obtain the data necessary to promulgate a reasonable rule violates the Administrative Procedures Act.

Due to the extraordinary urgency needed to respond to the current energy crisis, we recommend the following:

1. NHTSA should explicitly correct the conceptual flaws in its model and establish clear tests and analytic approaches to evaluate standards, independent of the level at which they are set in any given proceeding. NHTSA needs to distinguish more precisely between the "ruler" by which standards will be measured and the "rule," which prescribes the standard at a given moment in time.
2. NHTSA should set the standards for 2011-2012 at a level substantially higher than it has proposed. It should set the standard for 2011 according to the total benefit equals total costs level – 30.6 mpg not 27.8.
3. NHTSA should rescind the standards for 2013-2015, complete the gathering of the critical information that is needed to make an informed recommendation, and develop recommendations based on that information.

These reasonable suggestions, which have been incorporated into detailed comments and submitted to NHTSA on its proposed fuel economy standards, will enable NHTSA to meet its statutory requirements in the short run and do the best possible job of securing America's energy future in the long run. It will also bring NHTSA into compliance with the Energy Independence and Security Act of 2007. This is an extraordinary opportunity to dramatically set our country on the right course toward much needed and long overdue improvements in fuel economy. We trust that the points we have made are compelling and that the Administration will do what is in the country's best interest and adopt our recommendations.

Acc. No. 561.2

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FUEL ECONOMY AND AUTO SALES: AUTOMAKERS AND THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION IGNORE MARKET SIGNALS

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AUGUST 2008

EXECUTIVE SUMMARY

This analysis explores important and fundamental flaws in the underlying economic assumptions made by the National Highway Traffic Safety Administration (NHTSA) in proposing its 2011-2015 fuel economy standards for autos and light trucks that render the draft environmental impact statement (DEIS) insufficient. NHTSA's proposed fleet wide standards that reach a mere 31.7 miles per gallon in 2015 and are grossly inadequate, robbing consumers and the nation of multiple billions of gallons of vital gasoline savings over the next decade. As a result, the DEIS measures the wrong alternatives and reaches the wrong conclusions about environmental impacts.

NHTSA's approach to setting fuel economy standards is

- to start with automaker product plans,
- assert that consumers undervalue fuel economy by demanding unrealistic economic returns from fuel saving technologies and
- assume that automakers are severely constrained in their ability to apply new fuel saving technology.

Neither the product plans nor the assumptions about consumer and automaker behavior relied on in NHTSA's analysis bear any relationship to auto market reality.

- Consumers are looking for higher mileage today than NHTSA has mandated for seven years from now.
- The product plans on which NHTSA based its rule seven years in the future have already been torn up by the automakers, who have belatedly recognized the shift in consumer behavior toward greater fuel economy.
- The mix of cars and trucks that NHTSA projects bears no relationship to the vehicles that consumers are buying.

Relying on auto industry judgment in product plans, which are out of touch with the market reality, NHTSA has proposed fuel economy standards that are far too low. Not only did NHTSA assume that consumers are unwilling to buy fuel economy beyond a very narrow economic assumption, but it also assumed that higher fuel economy has no value in the marketplace (particularly in resale value). Our market behavior analysis and public opinion polling shows that consumers want more fuel-efficient cars than the automakers are offering them. The crucial role of a higher fuel economy standard is to push the automakers to deliver what the public wants, but NHTSA has failed to do so.

CFA made many of these points in its July comments filed in the rulemaking, but recent events have made the flaws in NHTSA's analysis and framework so much more obvious that we feel obliged to restate our objections to the proposed rule and incorporate new evidence into the record. Our earlier recommendations are all the more compelling in light of the mounting evidence that NHTSA has failed to propose a reasonable standard. NHTSA must:

- Raise the standards for 2011 and 2012; and
- Withdraw the proposed standards for 2013 through 2015, so it can fix its analytical framework and economic assumptions before promulgating fuel standards for those distant years.

The anecdotal evidence of the dramatic changes in the auto market is everywhere. In the past month, the Big Three have announced (or leaked) plans to abandon or slash their leasing businesses because the value of their gas-guzzlers at the end of the lease term is so low that the economics of leasing no longer makes sense. Clearly, fuel economy is a key determinant of the resale value, but NHTSA's analysis assumes that fuel economy has no impact on resale value of vehicles whatsoever.

While data on auto sales for the first half of 2008 make it clear that consumers are highly sensitive to fuel economy in their purchase decisions, our analysis shows that this shift in consumer behavior has been evident for three years. In addition, our analysis reveals that it is not just a shift between trucks (SUVs) and cars, but that it is has also been evident within the car and truck categories.

The automakers were slow to recognize this market change. They chose to continue to produce gas-guzzlers, trying to bribe consumers to purchase them with discounts, rebates and low interest financing. It was a fool's game, and the jig is up. In the past month, the big 3 U.S. automakers have declared their intention to dramatically alter its vehicle mix in the next few years, yet NHTSA assumes that automakers cannot make such changes rapidly. Assuming that vehicle manufacturers are unable to make such changes causes NHTSA to severely underestimate the fuel savings technologies that could be included in new vehicles. Pushing automakers to close the gap is precisely the role of fuel economy standards. The technologies exist to achieve almost twice the fuel savings that NHTSA's proposed rule achieve, but NHTSA has incorrectly assumed that consumers lack the desire and automakers lack the ability to get these technologies into the fleet.

Dramatic changes in the marketplace reflect a greater willingness of consumers to buy more fuel-efficient vehicles (new and used). However, at the core of NHTSA's analysis are assumptions that restrict the inclusion fuel saving technologies in new vehicles. NHTSA's base case fuel economy levels and vehicle mix simply do not reflect the reality of the auto market. Our survey evidence analyzed below demonstrates the motivation and willingness of consumers to purchase more fuel-efficient vehicles and reveals a shocking mismatch between what consumers want and what automakers have been offering.

The remainder of this report examines the increasing responsiveness of the auto market to fuel economy, which was not fully reflected in NHTSA's modeling. NHTSA has based its proposed rule on automaker product plans that are completely outdated. It did not have to set standards beyond 2012 in the current rulemaking and the choice to do so, despite clear evidence that the product plans do not reflect reality, violates the letter and spirit of the Energy Policy Conservation Act (EPCA) as recently amended by the Energy Independence and Security Act of 2007. Instead of proposing rules that achieve the maximum feasible increases in fuel economy, as obligated under the EPCA, NHTSA has proposed rules that are much closer to the minimum allowable.

In our initial comments we demonstrated that if NHTSA repaired the analytic framework and corrected its economic assumptions, it could easily go to a much higher standard that would push the fleet average for 2015 from 31.6 mpg to 34.5 mpg. Given the dynamic developments in the marketplace, NHTSA should certainly consider even higher levels for 2013 to 2015. The highest level of fuel economy that NHTSA considered, called the "technology exhaustion" standard, was based on erroneous assumptions about the inability of automakers to improve fuel economy. The technology exhaustion alternative, which would move the fleet to 41.4 mpg by 2015, is certainly technologically feasible and, under realistic assumptions about the value of oil and externalities, would not only save 50 billion gallons more gasoline, but also produce $30 billion more in net total benefits. With so much potential gain for consumers and the nation, NHTSA must adopt a more realistic model of consumer and automaker behavior, adjust the economic assumption and consider much higher levels of fuel economy.

This report is divided into three sections:

- Consumer Attitudes
- Fuel Economy and Year-Over-Year Changes in Auto Sales
- Changes in Consumer Behavior in Gasoline and Auto Markets

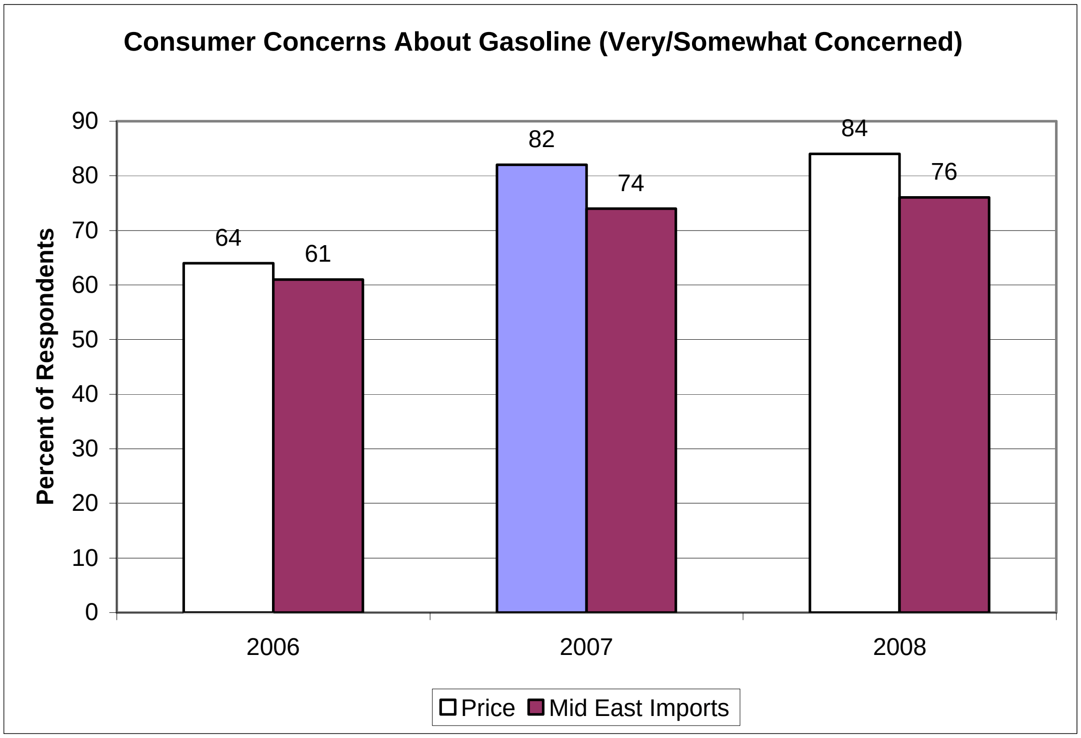
The next section presents a discussion of recent survey evidence on the shift in consumer and market behavior, which must inform NHTSA's analysis. We then analyze year-over-year changes in sales and fuel economy to ascertain when the shift in consumer behavior occurred. Finally, we review long run trends and present an econometric analysis of fuel economy over the past half-decade.

CONSUMER ATTITUDES

Our survey evidence demonstrates the motivation and willingness of consumers to purchase more fuel-efficient vehicles (see Exhibit 1).

- Eighty-four percent of respondents say they are concerned about rising gasoline prices (70 percent very concerned).[1]
- Seventy- six percent of respondents says they are concerned about Mid Eastern oil imports (57 percent very concerned).
- Both of these figures have been rising steadily since we began asking the question about two years ago.

Exhibit 1:



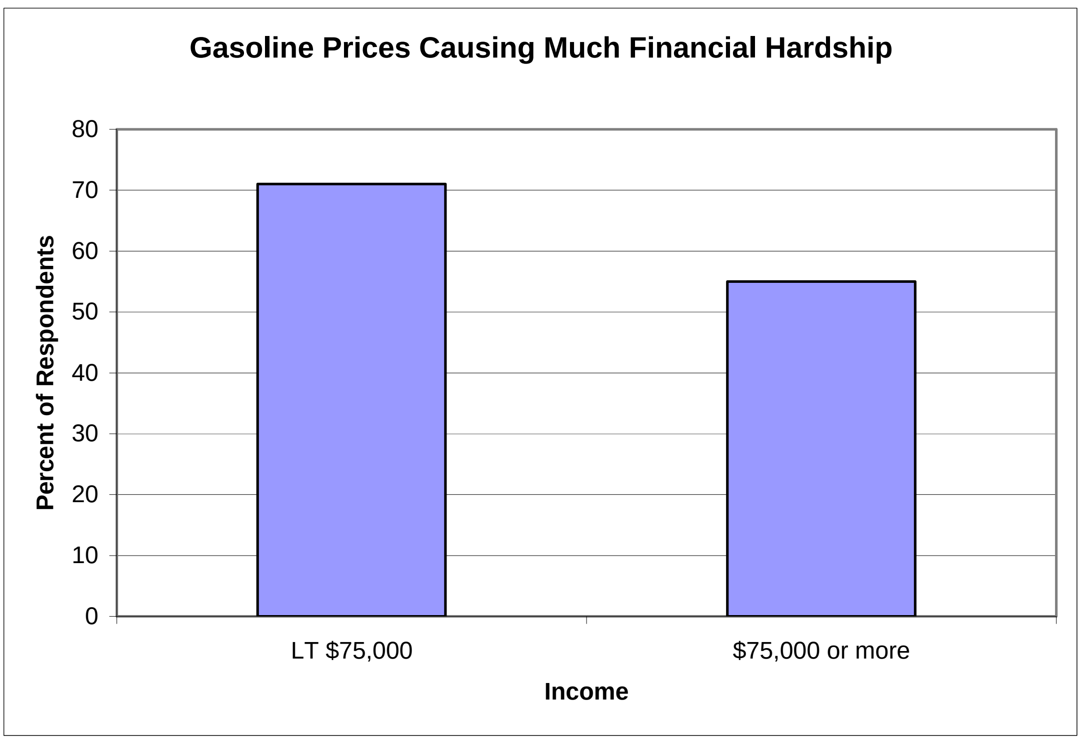
Source: National opinion polls conducted for the Consumer Federation of America by the Opinion Research Corporation. 2008, July 17-20; 2007, see Consumer Federation of America, *No Time to Waste*, available at http://www.consumerfed.org/pdfs/No_Time_To_Waste.pdf 2006 see Consumer Federation of America, *Consumers Still Greatly Concerned About Better Gas Mileage and Oil Imports Despite Falling Gas Prices, available at http://www.consumerfed.org/pdfs/Gas_Mileage_Consumer_Attitudes_Manu_Performance_Press_Release111306.pdf*

[1] "Thinking about the next five years, how concerned personally are you about gasoline prices, U.S. dependency on Mid Eastern oil, and global warming?"

There are no significant differences in these concerns across various demographic categories (age, income, education, gender) with one exception. Households with incomes of $35,000 per year or more are more likely to be concerned about Mid East imports (81 percent) than those with incomes below $35,000 (69 percent).

The concern about gasoline prices reflects the impact that rising gasoline prices are having on the respondents. Eighty-four percent of respondents say that rising gasoline prices have placed a financial burden on their household budgets (63 percent a severe burden). Not surprisingly (see Exhibit 2), households with incomes of $75,000 or more are less likely to say they have suffered much financial hardship (55 percent) than households with incomes below $75,000 (71 percent.) Also, rural households (those living outside of metropolitan areas) are more likely to say they have suffered much financial hardship as a result of gasoline costs (35 percent) compared to those living in urban areas (26 percent).

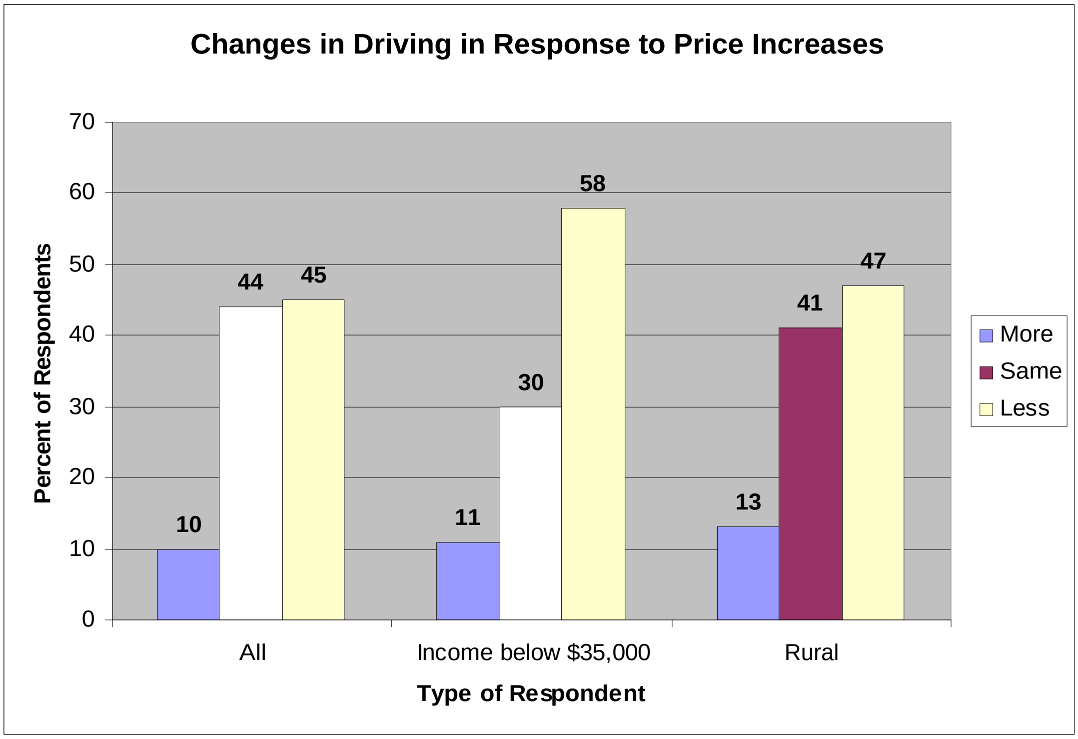
Exhibit 2:



Source: National opinion poll conducted for the Consumer Federation of America by the Opinion Research Corporation. 2008, July 17-20

Our April 2008 survey also helped reveal how Americans are responding to this hardship.[2] When asked (whether they were driving more or less than a year ago, 45 percent of respondents said less, and only 10 percent said more (see Exhibit 3). Lower income households were more likely to say that they were driving less (58 percent compared to 45 percent for all respondents).

Exhibit 3



Source: See Mark Cooper, *Ending America's Oil Addiction* (Washington, D.C.: Consumer Federation of America, April 2008). http://www.consumerfed.org/pdfs/First_Quarterly_Gas_Report_2008.pdf

The most striking result of the most recent survey can be found in responses to questions about the fuel economy of the vehicles consumers currently drive compared to the fuel economy they would like to get in their next vehicles.

- Among those who drive and intend to purchase a new vehicle, the current average fuel economy is reported at about 24.1 miles per gallon.
- These respondents say they want to get 32.7 miles per gallon in the vehicle they purchase.

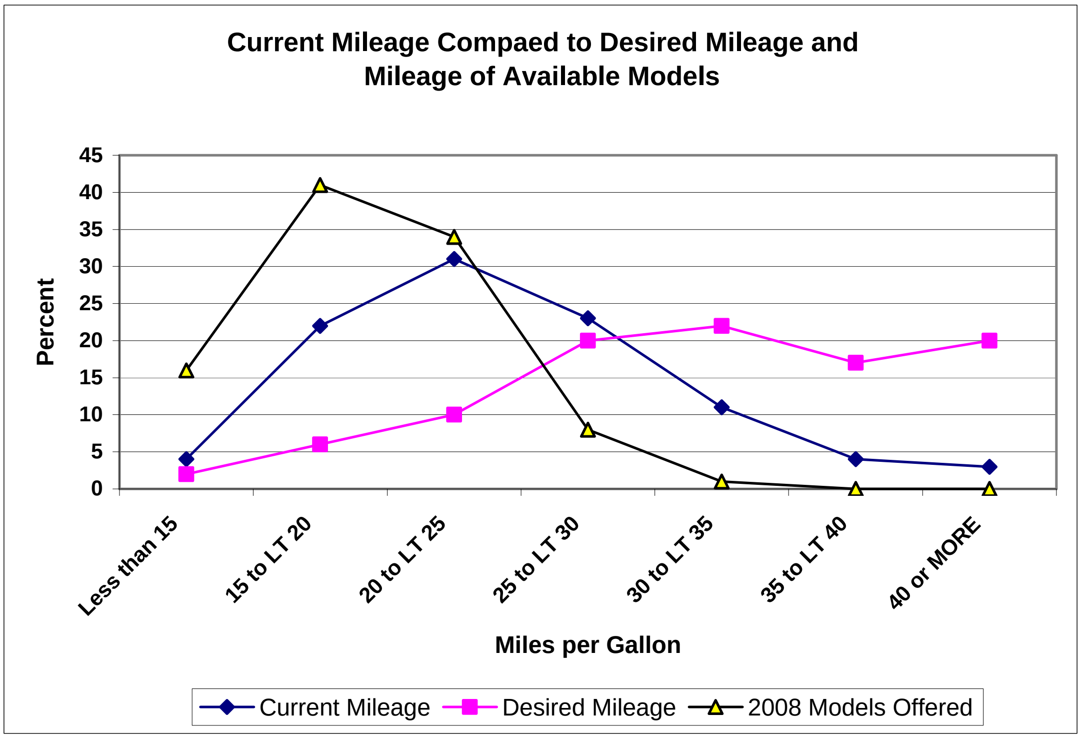
[2] See Mark Cooper, Ending America's Oil Addiction (Washington, D.C.: Consumer Federation of America, April 2008).

http://www.consumerfed.org/pdfs/First_Quarterly_Gas_Report_2008.pdf

There is also a clear mismatch between the desires of consumers and the models that the automakers offered in 2008 (see Exhibit 4).

- Whereas 59 percent of the respondents say they want to get more than 35 miles per gallon in the next vehicle they purchase, only 1 percent of the 2008 models offered by automakers achieve that mileage.
- The average goal for consumers in the market today is 32.7 miles per gallon, well above the standard of 31.6 miles per gallon that NHTSA has set for 2015.

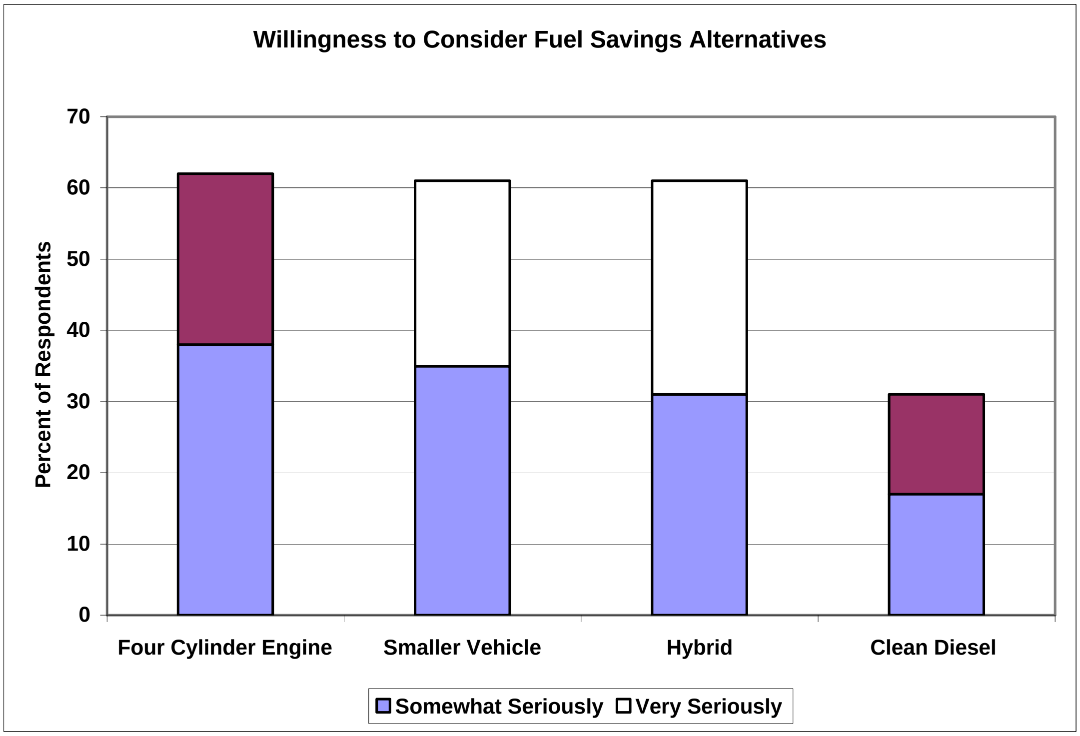
Exhibit 4:



Source: National opinion poll conducted for the Consumer Federation of America by the Opinion Research Corporation. 2008, July 17-20; CFA database on miles per gallon.

Consumers back up their desire to achieve higher fuel economy in their next vehicles with a willingness to consider alternatives that would lower fuel economy (see Exhibit 5.) When asked about four major ways to improve fuel economy, about 60 percent of respondents said they would very or somewhat seriously consider four cylinder engines, hybrids and small vehicles. Clean diesel engines would be considered by about one-third of respondents. There were few differences across demographic categories, with two exceptions. Respondents with incomes above $50,000 were more willing to consider a hybrid (68 percent) than those with incomes below $50,000 (57 percent). Younger (age 18-24) and older respondents (age 65 or more) were less likely (50 percent) to say they would consider a hybrid than respondents with ages between 25 and 65 (70 percent).

Exhibit 5:



Source: National opinion poll conducted for the Consumer Federation of America by the Opinion Research Corporation. 2008, July 17-20;

These attitudes are impacting behavior in the marketplace. Consumers do not just say they are feeling the pinch of rising gasoline prices, or claim to alter their behaviors in reaction to higher gasoline prices, or just express a desire to have more fuel efficient vehicles, the evidence on auto sales suggests that they are taking action. Consumers are switching to smaller vehicles[3] with smaller engines.[4] Large vehicles are piling up on lots and losing value both as new and used vehicles.[5] Automakers are dramatically retooling their production plans in response to consumer behavior.[6]

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[3] David Shephardsom, "U.S. Auto Fleet Hits MPG Record," *Detroit News,* August 13, 2008, " By year's end, when actual car sales are tabulated, the fuel efficiency numbers are expected to be even higher because consumers are responding to high oil and gas prices by buying smaller vehicles, Beth Lowery, General Motor's vice president for the environment said."

[4] Ron Lieber and Tara Siegel Bernard, "Ditch the Gas Guzzler? Well, Maybe Not Just Yet," *New York Times,* August 2, 2008, p. B-4, "Sales of vehicles with four-cylinder engines represented 47.2 percent of all new vehicle sales during June, up from 38.4 percent of all new sales compared to the year-earlier period. "They would be even higher if they were available," said Charlie Vogelheim, vice president of automotive development at J.D. Power and Associates.

[5] Nick Bunkley, "An SUV Traffic Jam," *New York Times,* August 13, 2008, p. C-1.

[6] See University of Michigan Transportation Research Institute, Automotive Analysis Division, "Auto Consumers Restructuring the Auto Industry's Restructuring," *Auto New Service,* Issue 53, for compilation of the announcements and related press.

FUEL ECONOMY AND YEAR-OVER-YEAR CHANGES IN AUTO SALES

While the headlines describing the current woes of the automakers point to a sudden shift in consumer purchasing patterns, a shift from light trucks and large SUVs to more fuel-efficient cars, a close look at the data indicates that:

- There was nothing sudden about the shift.
- It involves much more than a shift from trucks and SUVs to cars (higher fuel economy within vehicle types sells more vehicles).
- Simply put, it did not take $4 gas to cause the change in consumer behavior, it started at least three years ago when gas was $2.50 per gallon and has been growing progressively.

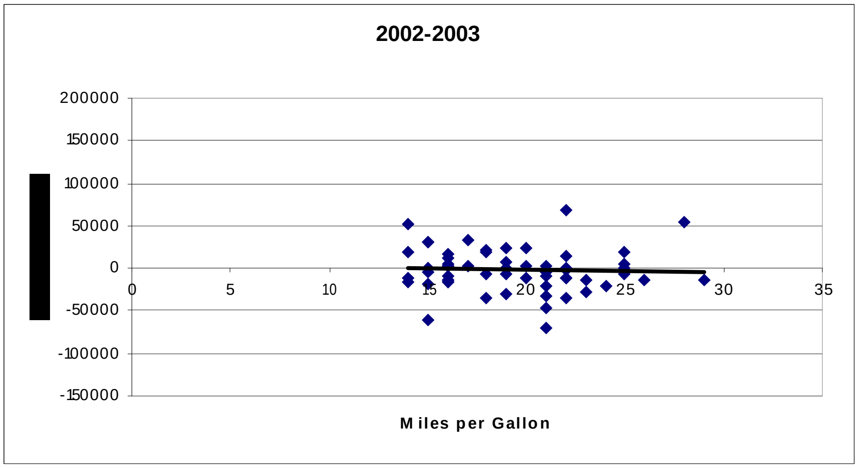
The automakers not only missed the shift in consumer behavior, they actually tried to resist it by continuing to pump out gas-guzzlers and trying to bribe consumers to buy them with rebates and low interest.[7] To examine this issue we compiled a database of the top fifty models in each year and charted their sales (reported by Automotive News) and EPA mileage ratings across time. There is an average of 61 models in each year-to-year comparison (because different models will be included in the top fifty in one year, but not the next). A total of 83 models occurred in the top fifty over this period for which we had sales and mileage data. These models represent an average of approximately two-thirds of all units sold over the period.

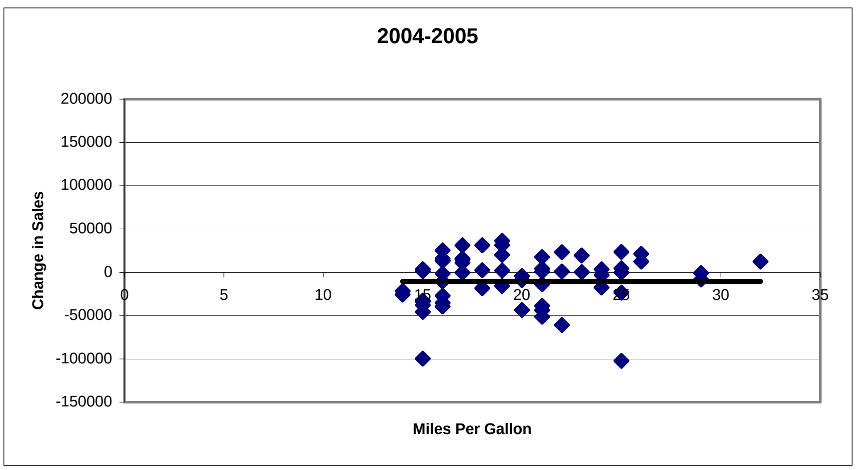
Exhibit 6 shows the sales for the top sixty models, plotting EPA mileage ratings (all based on the new method) against the change in sales. From 2003-2005, there was no relationship between fuel economy and sales; the regression line was flat. Starting with the 2005-2006 comparison, there is a relationship; vehicles that got higher mileage fared better in the marketplace. The relationship persisted in 2006-2007 and through the first half of 2008. While the direction of the relationship remained about the same (i.e. the slope of the line did not change much) the relationship became much stronger (the scatter of the observations around the line became smaller in magnitude). In the first half of 2008, the level of fuel economy of the model accounts for over 40 percent of the variance in the change in sales.

The graphs in Exhibit 5 exclude the Prius, which is the only hybrid to be ranked in the top fifty over this period and has been so popular that there have been delivery delays. (It is an outlier and its "poor" performance in recent years is not the result of a lack of demand but, rather, the result of a lack of supply. This is a circumstance that is radically different than that faced by vehicles with conventional engines).

[7] While the discounting practices are obvious, blasted incessantly across TV screens and in newspaper advertising, rigorous analysis is rare. One early analysis (Walter McManus, "The Link Between Gasoline Prices and Vehicle Sales," *Business Economics,* January 2007) shows that the shift in pricing occurred in early 2005.

Exhibit 6: Fuel Economy Affects Changes in Sales





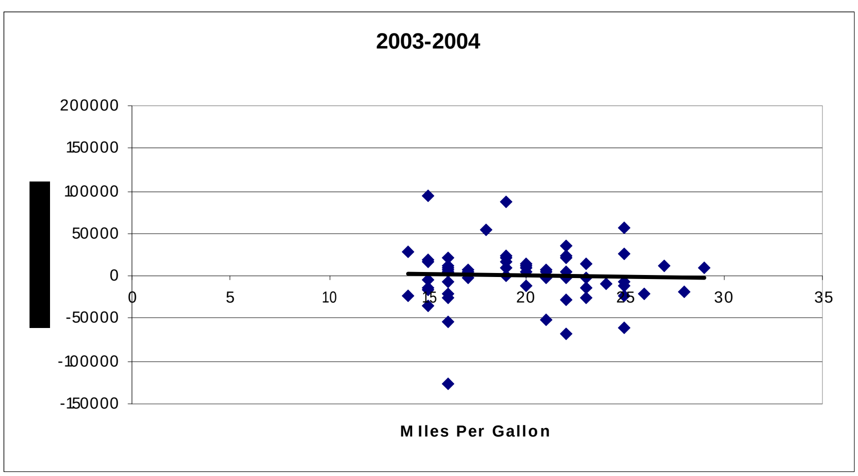
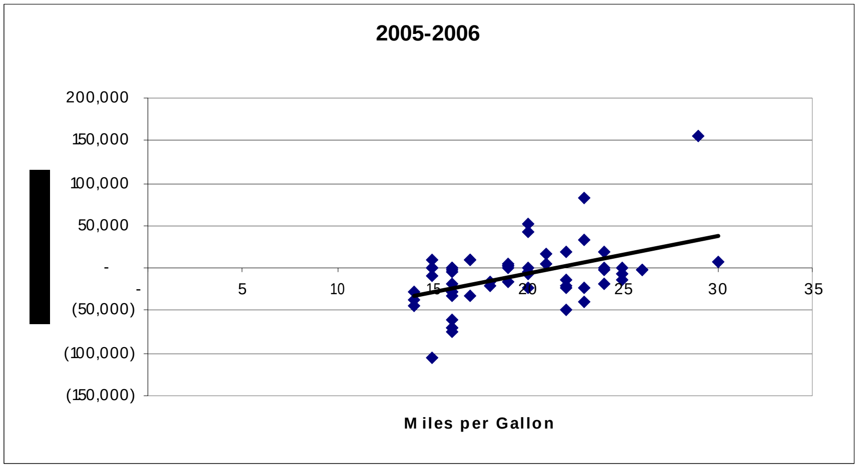
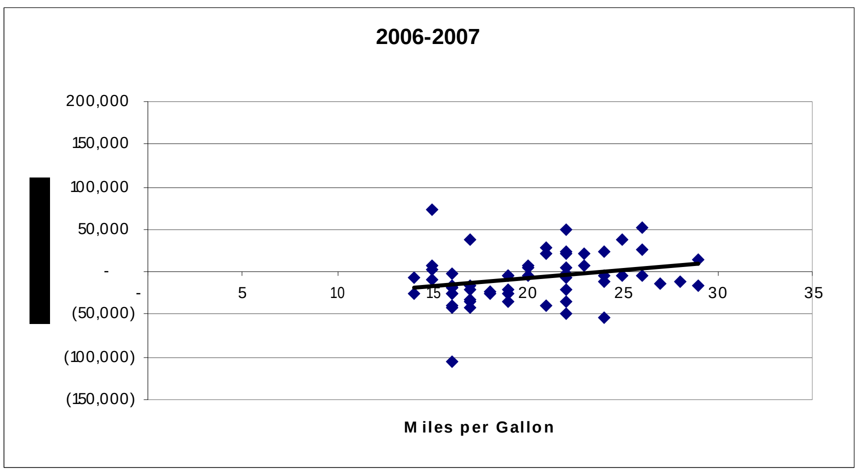
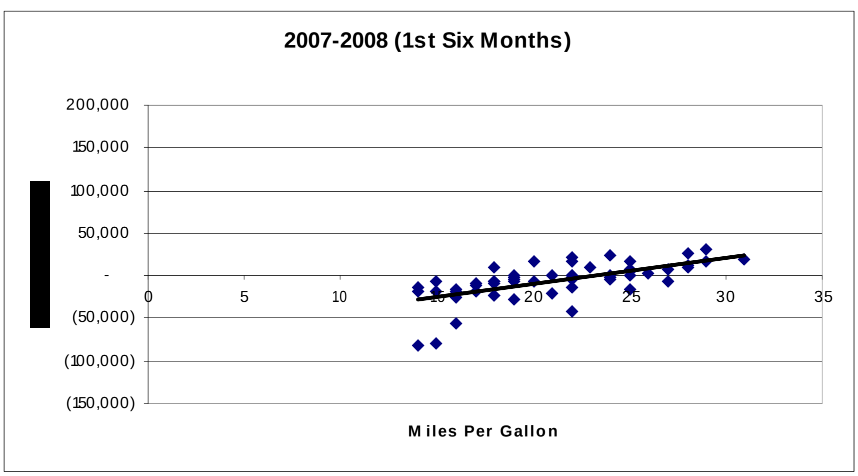


Exhibit 5 (cont'd):



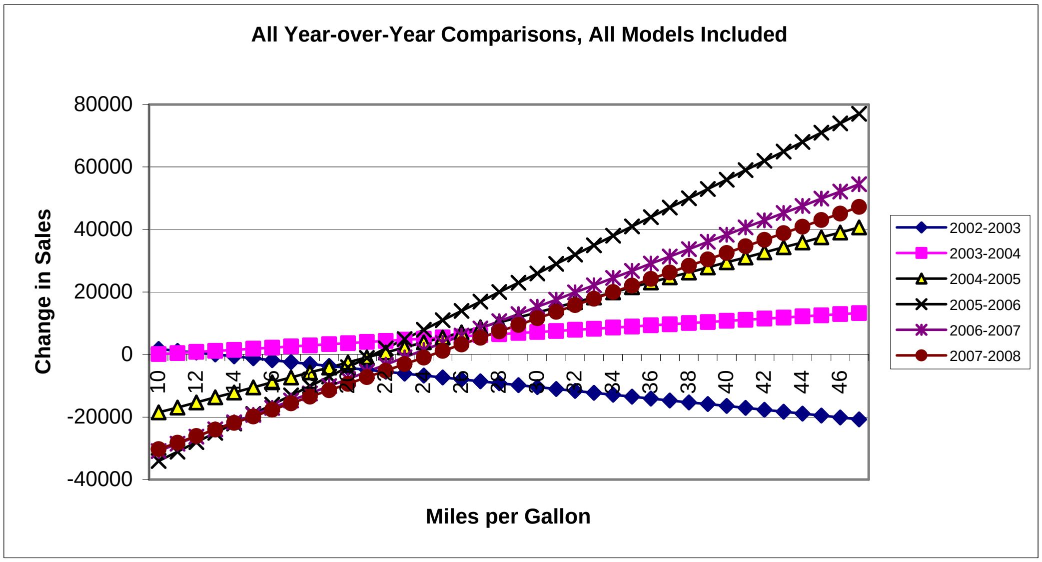


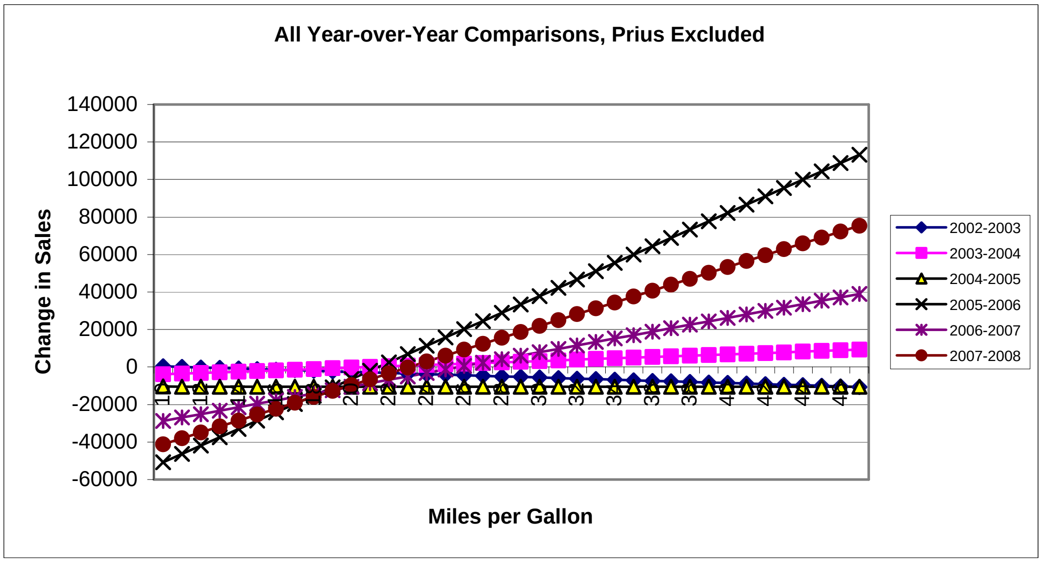


Source: CFA Data Base

Exhibit 7 shows the individual regression lines (without the data points) for all vehicles and vehicles with conventional engines. The graphs show that the shift in the market took place well before the first half of 2008. Including the Prius does not change that conclusion; it merely pushes the data of the market structural change back one year.

Exhibit 7





Source: CFA Data Base

The above analysis concludes that fuel economy played a key part in determining sales in recent years. We explored alternative explanations that might account for the shift in buying patterns. One obvious possibility is a shift in preference away from truck and SUVs. Exhibit 8 shows that the structural shift is not the result of a shift from trucks to cars. We examined this in two ways. In one set of regressions, we introduced trucks as a covariate, to control for the effect of being a truck model as opposed to a car model. Even controlling for the type of vehicle (car v. truck) fuel economy is an important determinant of the change in sales. A second approach is to examine the relationship between fuel economy and sales separately for cars and trucks. Our conclusion that the structural shift occurred well before the first half of 2008 is confirmed and strengthened. The structural shift occurred in 2006 for cars and somewhat earlier (2005) for trucks.

Exhibit 8: Regression Results: Fuel Economy as a Predictor of Sales

Year	All Light Duty Vehicles			All Light Duty Vehicles (Truck Covariate)			Cars Only			Truck Only		
	B	Sig.	R2	B	Sig.	R2	B	Sig.	R2	B	Sig	R2
2002-2003	-297	*	0	1697		3	4511	*	7	-179		0
2003-2004	-354		0	68		0	-624		0	2842		0
2004-2005	-4		0	1036		0	-940		0	4535	**	9
2005-2006	4429	***	21	5463	**	20	3020	*	0	3738		5
2006-2007	1833		2	4487	**	6	4191		6	4878	*	9
2007-2008	3150	***	42	3124	***	41	2752	***	31	3778	**	17

*** $p < .10$, ** $p < .0$,*** $p < .01$**

We also examined the issue of whether the change in mileage for a specific model, year over year, affected change in sales. While all of the coefficients were positive, indicating better mileage was associated with better sales performance, none was statistically significant and all were small. This should not be surprising because the improvement in fuel economy within models was quite small, only 1 mile per gallon, on average, over the five year period from 2002-2005. It is the much larger differences in mileage between models that are having the effect.

CHANGES IN CONSUMER BEHAVIOR IN GASOLINE AND AUTO MARKETS

Thus far we have seen that public opinion and new car sales indicate a clear shift in consumer attitudes toward fuel economy. A recent Congressional Budget Office Study[8] (CBO) explores similar issues and reinforces our findings. What are the effects of high prices on consumption patterns? After four years of rising prices (2002-06), CBO found that when gasoline prices rise significantly, people will:

- Use less gasoline;
- Drive less if they can;
- Drive more slowly;
- Use mass transit where it is available; and
- Buy more fuel-efficient cars, if they can find them.

The formal expression of this relationship in economic analysis is the price elasticity of demand. How much does a particular behavior change in response to a price change? The price elasticity of demand is usually calculated in percentages. A one-percentage point increase in prices that results in a one-percentage decline in the behavior is said to be an elasticity of -1 (-.01/+.01 = -1). CBO studied a variety of behaviors and calculated the elasticity of demand – the percentage change in a particular behavior in response to a change in gasoline prices. As Exhibit 9 shows, there is a small, negative price elasticity. The short-run elasticities are considerably less than -.1. A one percent increase in price leads to a reduction in consumption or changes in behavior that reduce consumption of less than one-tenth of one percent. In the long run, the elasticities are somewhat higher -.2 to -.4, but still quite low compared to other commodities. Moreover, the elasticity of demand has declined over time and is likely to continue to do so.

> For a variety of reasons, consumers are currently only about one-fifth as responsive to short-run changes in gasoline prices as they were several decades ago. That decline in sensitivity has been attributed to growth in real income, which has rendered gasoline a smaller share of consumers' purchases from disposable income. Price sensitivity has also declined because a gallon of gasoline takes a car farther than it did in the past, in part because of fuel economy standards. The development of distant suburbs also has contributed by making consumers more reliant on the automobile. The longer commutes are balanced by lower housing costs.[9]

---

[8] Congressional Budget Office, *Effects of Gasoline Prices on Driving Behavior and Vehicle Markets*, January 2008.
[9] CBO, Effects of Gasoline Prices, pp. x-xi.

Exhibit 9: Price Elasticities of Demand for Various Gasoline Consumption-Related Behaviors Compared to Selected Other Products

Product	Study Trait	Period of Impact Short-terms	Long-term
Gasoline Related[a]			
Consumption	CFA (1997-2005 Expenditures)		-.28
	Recent	-.06	-.40
	1994-2006	-.02 to -.04	
	Higher prices	-.066 to -.074	
	1974-1989	-.05 to -.08	
	Older		-.38 to -.43
Travel Speed	CBO	-.06	
	Recent	-.05	
	Older		-.35
Miles Traveled	CBO	-.035	
	Recent	-.02 to -.03	-.11 to -.15
	Older	-.1 to -.16	-.26 to -.31
New Vehicle Fuel Economy (improvement)	CBO truck-car		
	Switch to cars	.28	
	CFA Implicit mpg	.1	
	CFA	.1	
Other Commodities[b]			
Eggs			- .1
Gasoline			- .2
Shoes			- .9
Foreign Travel			-1.2
Alcoholic Beverages			-1.5
Jewelry			-2.6

a) Congressional Budget Office, Effects of Gasoline Prices on Driving Behavior and Vehicle Markets (Washington, D.C.: January 2008).
b) Jon B. Taylor, *Economics* (Boston: Houghton Mifflin, 1998), *p*. 99.

To track the trends in vehicle fuel economy, the CBO relied on Environmental Protection Agency (EPA) mileage estimates and auto sales from *Automotive News.* CFA compiled a database on fuel economy and sales using NHTSA data.[10] Our analysis includes more recent data than was used by the CBO, allowing us to extend some analyses to 2007 with preliminary sales data. We find similar patterns of shifts to more fuel-efficient vehicles in consumer purchasing behavior, and with these data,

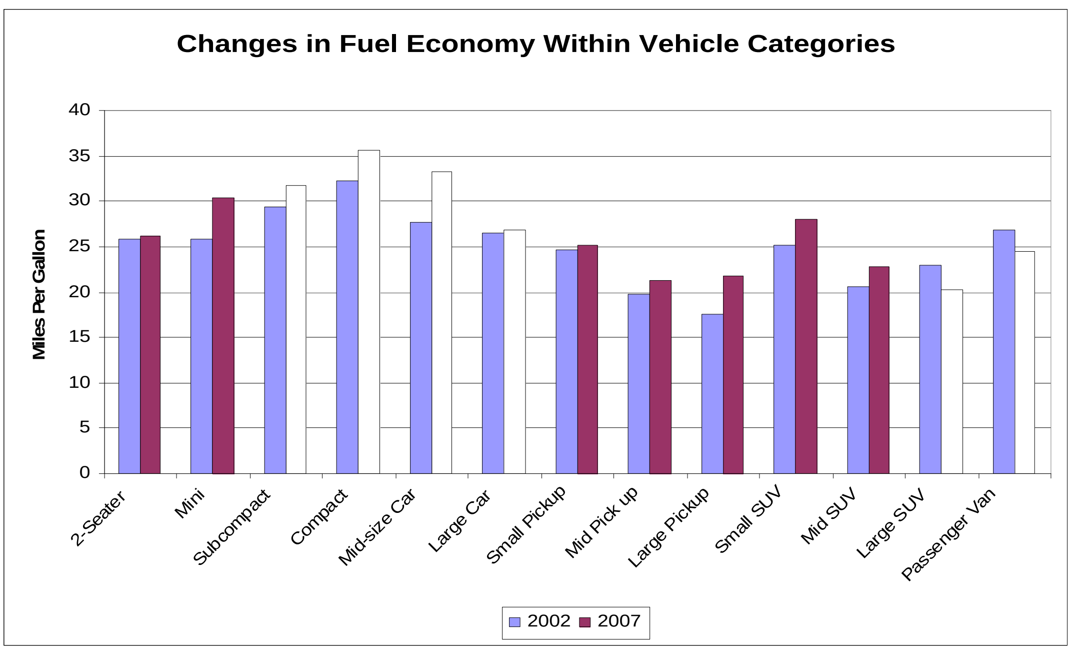
[10] Jack Gillis and Mark Cooper, *Still Stuck in Neutral: America's Continued Failure to Improve Motor Vehicle Fuel Efficiency: 1996:2005*, July, 2007, available at http://www.consumerfed.org/pdfs/Still_Stuck.pdf; Jack Gillis, Stuck *in Neutral: America's Failure to Improve Motor Vehicle Fuel Efficiency: 1996-2005*, November 2006; available at http://www.consumerfed.org/pdfs/Stuck_in_Neutral.pdf.

we can explore some important aspects of the automotive market in greater detail.

As gasoline prices rise, people switch from less fuel-efficient trucks to cars. As the CBO noted, "Price spikes in the spring of 2005, in October 2005 (after Hurricane Katrina), and in the spring of 2006 all coincided with sharp increases in the new-car market share. Market shares for leading categories of light trucks – especially SUVs – went the opposite way, dipping as gasoline prices rose."[11] In our data, with annual sales, the shift is 2.3 percent. Applying the shift coefficient calculated by CBO to the average difference between cars and trucks in our data, we find that the switch results in an improvement of fuel economy of about .1 percent for every 1 percent increase in gasoline prices. We arrive at a similar estimate by calculating the change in the fleet average fuel economy compared to the average real price of gasoline.

One of the key findings of the CBO study is that fuel economy improved both because consumers shifted their purchases away from less fuel-efficient types of vehicles (trucks and large SUVs) and because "the average fuel economy of cars and light trucks alike have been increasing since 2002."[12] Our data shows (see Exhibit 10)

Exhibit 10:



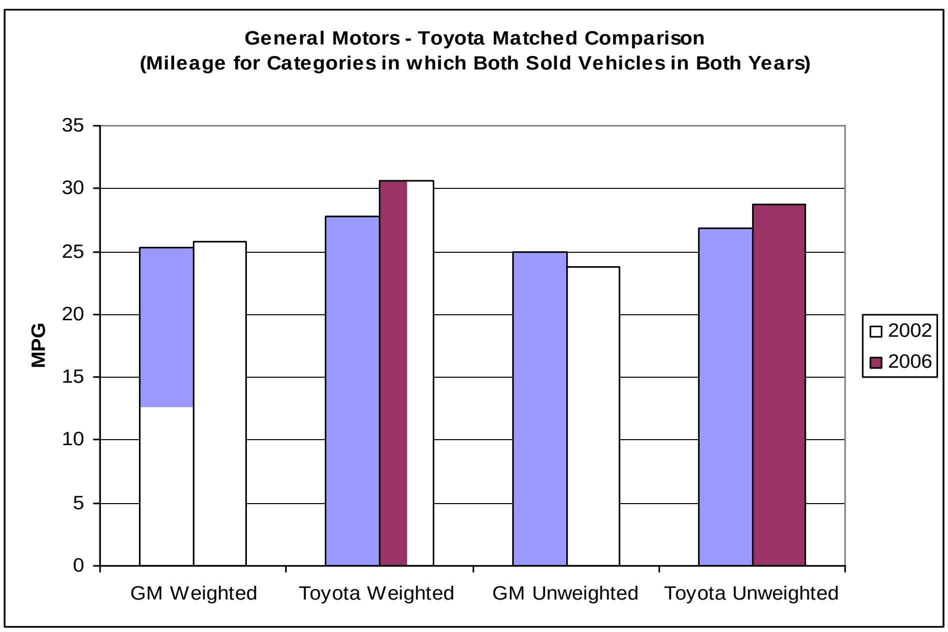
Source: Mark Cooper, *Ending America's Oil Addiction* (Washington, D.C.: Consumer Federation of America, April 2008).
http://www.consumerfed.org/pdfs/First_Quarterly_Gas_Report_2008.pdf

[11] CBO, Effects of Gasoline Prices, p. 16.
[12] CBO, Effects of Gasoline Prices, p. 20.

that the overall improvement in fuel economy was just under one mile per gallon (for 2002-2006) and 2 miles per gallon for 2002-2007; much less than consumers now say they want (8 mpg). And, the improvement in the fuel economy within the individual categories of cars and light trucks is uneven. The largest improvements came in minis, compacts, and mid-sized cars. Passenger vans and large SUVs did not improve much (which is why sales plummeted). While many consumers shifted to smaller more fuel-efficient vehicles, those who required larger vehicles could not find the fuel-efficiency they needed and wanted.

Fuel economy improvement was also very uneven across auto manufacturers. One of the more dramatic aspects of the past half-decade has been the competition between General Motors (GM) and Toyota for the top spot as the leader in sales in the American auto market. The following figure shows the average fuel economy for GM and Toyota based only on categories of cars in which both had sales in 2002 and 2007 (see Exhibit 11). This graph matches the two automakers by categories of product sold for which they compete head-to-head. It shows both the sales-weighted average fuel economy (mpg) and the unweighted average of the individual models they marketed. For Toyota, both the weighted and unweighted fuel economy averages improved. Toyota's mileage improved both because consumers shifted their purchases to more fuel-efficient categories of vehicles and Toyota offered, on average, significantly more fuel-efficient models. GM's average fuel economy improved because consumers shifted their sales between categories, but GM did not offer, on average, a significantly more fuel-efficient slate of models.

Exhibit 11:



Source: Mark Cooper, *Ending America's Oil Addiction* (Washington, D.C.: Consumer Federation of America, April 2008). http://www.consumerfed.org/pdfs/First_Quarterly_Gas_Report_2008.pdf

We were able to test the proposition that fuel economy became more important to consumers over the period since 2002 with an econometric model of fuel economy (see Exhibit 12). After controlling for the key vehicle characteristics that affect fuel economy (vehicle weight, engine traits like horsepower, displacement, number of cylinders, transmission type, drive ratio, dynamometer setting, wheel base, interior volume), each year after 2002, there was a statistically significant, though small, improvement in the fuel economy of cars. For cars, the effect became steadily larger over time. A car sold in 2006 got 2.377 more miles per gallon than one built in 2002, controlling for all the other factors included; for trucks, the increase was .879 miles per gallon.

Exhibit 12: Linear Regressions to Examine Factors Affecting Fuel Economy
(Unit of Analysis is the Sales Weighted Model)
(Regression Coefficients, All Statistically Significant at the .001 level)

Variable	Cars		Trucks	
	Fuel Economy	Product Sales	Fuel Economy	Product Sales
2003	.0662	15456	.982	10120
2004	1.084	-148	.482	-5090
2005	1.758	16763	.869	-16488
2006	2.377	3936	.879	-24092
Fuel Economy	na	945	na	.823
R^2	.56	.32	.24	.12

Control variables: engine (horsepower, displacement, cylinders), body weight, wheel base, interior volume); transmission type, drive ratio, dynamometer setting;
all coefficients are significant at the .05 level or higher

Truck sales were down 24,092 in 2006, compared to 2002; controlling for all the other factors, car sales were up 3,936. For trucks, the effect was large in 2003, declined in 2004 and rebounded in 2005 and 2006. We also find that fuel economy was positively related to product sales. We find the negative effect on truck/SUV sales in 2004, 2005, and 2006, with the effect growing larger over time. This is consistent with the CBO findings. In addition to the shift from trucks to cars and after controlling for all the other factors, a one mile per gallon increase in fuel economy resulted in an additional sale of just under 1,000 more cars and trucks for each model.

CONCLUSION

Over the past three or four years there has been a dramatic shift in the auto market, a shift that is not, but should be, reflected in NHTSA's approach to setting fuel economy standards. The automakers and NHTSA are looking backward, but consumers are looking forward. If the desire and willingness of consumers to purchase more fuel efficient vehicles were fully recognized in NHTSA's analysis, it would have proposed a much higher standard because erroneous assumptions about consumer attitudes constrain the extent to which fuel savings technologies influence the standard. Correcting underlying economic assumptions of the proposed fleet wide fuel economy rules for 2011-2015 would result in a higher range of alternatives examined in the DEIS, and greater environmental benefits as a result.

In our comments in this proceeding, we concluded that NHTSA should raise the standard to its "optimized plus 50" alternative, which we call the "50-50 standard."[13] With the economic flaws corrected, we concluded that the benefits to the nation of higher standards required NHTSA to move to at least that level. It was a close call between that level and the even higher level of total benefit equals total cost (TB=TC). Although we argued that total benefit equals total cost standard is economically practicable by definition, there were two considerations that suggested the "50-50 standard" was preferable. First, for 2011, NHTSA's estimate of the level of fuel economy that would be achieved (as opposed to the level at which the standard would be set) under the "TB=TC" and the "50-50" approaches was not very different. Second, this was the case because there was a higher level of individual auto manufacturer failure to achieve the higher standard (70% v. 50%).

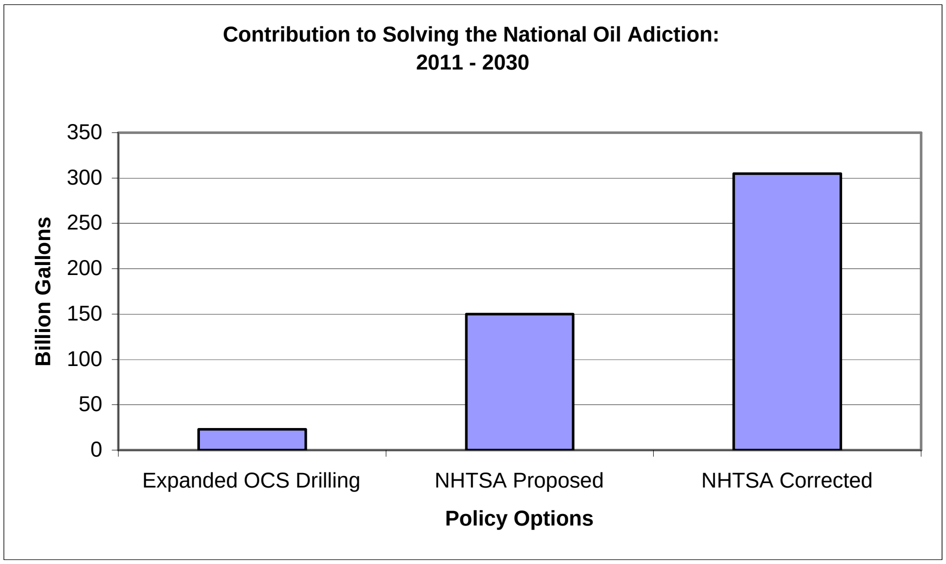
In light of the recent evidence on consumer and automaker behavior, we no longer believe that those two considerations are valid. Given the strong consumer interest in higher fuel economy and the dramatic changes in auto industry plans, if NHTSA sets a standard to lead the industry to higher level of fuel economy as it is required to do under the law, higher levels of fuel economy will be achieved and fewer auto makers will fail the "TB=TC" standard than previously anticipated by NHTSA. Indeed, when NHTSA revisits the fundamental assumptions in its model that slow the inclusion of fuel savings technology in the vehicle fleet, which have been called into question by developments in the market, it will arrive at a much higher level for standards across the board, but particularly for the "technology exhaust" and "TB=TC" scenarios. The old "TB=TC" level will become the new "50-50" standard.

There is no doubt that moving the standard to the higher level that we recommend is well worth the effort. To appreciate the importance of making such an improvement, we can put the impact of a higher fuel economy standard into context. The intense debate over expanded drilling on the Outer Continental Shelf (OCS) provides a useful context for understanding how important the setting of fuel economy standards is to the overall solution to the nation's oil addiction.

[13] Consumer Federation of America, "Comments and Technical Appendices," in National Highway Traffic Safety Administration, Notice of Proposed Rulemaking, Average Fuel Economy Standards, Passenger Cars and Light Trucks: Model Years 2011-2015, Docket No. HNTSA 2008-0089, RIN 2127-AK29, July 1, 2008.

Last year, the Energy Information Administration analyzed the increase in oil production that would result from allowing drilling in areas of the OCS that are currently unavailable for drilling.[14] EIA reckoned that production would not start until 2012 and would increase overall domestic production by 1.6 percent in the period between 2012-2030, which is .7 percent of the total consumed over the period. This is equal to approximately 23 billion gallons (see Exhibit 13).

Exhibit 13



Source: Calculated by author, based on Energy Information Administration, *Impacts of Increased Access to Oil and Natural Gas Resources in the Lower 48 Federal Outer Continental Shelf*, (available at http://www.eia.doe.gov/oiaf/aeo/otheranalysis/ongr.html); Office of Regulatory Analysis and Evaluation, *Corporate Average Fuel Economy for MY 2011-2015: Passenger Cars and Light Trucks* (National Highway Traffic Safety Administration, April 2008.

The level at which NHTSA should set the standard TB=TC would yield energy savings of over 300 billion gallons of gasoline between 2011 and 2030. NHTSA's proposed "optimized" standard would about half that.[15] Thus, a vigorous fuel economy standard would save 13 times as much oil as expanded drilling in the OCS. NHTSA's weak standard leaves a massive amount of oil savings on the table. Setting fuel economy standards to maximize fuel savings must be the cornerstone of ending our addiction to oil, but the Administration has failed in this vital part national energy policy.

[14] Energy Information Administration, *Impacts of increased Access to Oil and Natural Gas Resources in the Lower 48 Federal Outer Continental Shelf*, (available at http://www.eia.doe.gov/oiaf/aeo/otheranalysis/ongr.html)

[15] Office of Regulatory Analysis and Evaluation, *Corporate Average Fuel Economy for MY 2011-2015: Passenger Cars and Light Trucks* (National Highway Traffic Safety Administration, April 2008. Vehicle miles traveled (pp. VIII-15, VIII-16) are used to extent the analysis to 2030 assuming fuel savings in each year is proportionate to the weighted average of the vintaged fleet miles traveled by the fleet in existence in 2015. Fuel savings scenarios, p. VIII-51

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Docket	NHTSA-2008-0060
Docket Title	Notice of Intent to Prepare an Environmental Impact Statement for New Corp Economy Standards
Docket Type	Rulemaking
Document	NHTSA-2008-0060-0528
Document Title	Notice of Availability of a Draft Environmental Impact Statement (DEIS) for N Average Fuel Economy Standards; Notice of Public Hearing
Public Submission	NHTSA-2008-0060-0562
Public Submission Title	Dennis McGinn - Comments
Views	
Add Comments	
How To Comment	

Title	Dennis McGinn - Comments
Abstract	
Document Type	PUBLIC SUBMISSIONS
Document Sub-Type	Comment(s)
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Received / Filing Date	08/18/2008
Legacy ID	
Federal Reg Citation	
Federal Register Number	
Date Posted	08/18/2008
Comment Start Date	03/28/2008
Comment Due / Reply Date	
Implementation / Service Date	

Submitter Information

Comment Tracking Number	806cb6e8
First Name	Dennis
Middle Name	
Last Name	McGinn
Mailing Address	
Mailing Address 2	
City	Lexington Park
Country	United States
State or Province	MD
Postal Code	
Email Address	
Phone Number	
Fax / International Number	
Organization / Org Unit	

D-250

Submitter's Representative
Representative's Address
Rep's City, State & Zip
Government Agency Type
Government Agency

General Comment

Comment Docket No. NHTSA-2008-0060

Statement of Vice Admiral Dennis McGinn, USN, Retired
National Highway Traffic Safety Administration
Public Hearing on Proposed Fuel Economy Rulemaking
Washington, DC, August 4, 2008

Mr. Chairman, Ladies and Gentlemen, Thank you for the opportunity to share views which are based on over thirty-five years of service to the Nation in the United States Navy and as a senior executive presently involved on a daily ba with the science and technology of energy, transportation and the environme

I thank you for the opportunity to appear before you today to discuss the pro fuel economy rule, and the draft environmental impact statement aimed to pr a detailed analysis of potential impacts on energy resources, air quality and climate. As stated in your Federal Register announcement of this hearing the EPCA sets forth extensive requirements concerning the rulemaking to establis Model Year 2011–2015 CAFE standards. It requires the Secretary of Transportation to establish average fuel economy standards…. and, when setting ''maximum feasible'' fuel economy standards, the Secretary is require to ''consider technological feasibility, economic practicability, the effect of oth motor vehicle standards of the Government on fuel economy, and the need o United States to conserve energy.''

Today, I'd like to focus on that last requirement and, specifically, on the multi national security costs of our present level of oil dependency. In the interest time and in consideration of the many witnesses scheduled to appear before I want to give you my bottom line up front: Our continued dependence on oil constitutes a clear and present danger to our national security — economicall militarily and diplomatically.

These dangers involve real, quantifiable costs – and these costs do not appea be included in your assumptions for the proposed fuel economy rule. As a res your draft environmental impact statement is, at best, incomplete and, more importantly, fundamentally flawed by its reliance on outdated data and unsupported assumptions about the real costs of this nation's ever-growing consumption of oil.

Ignoring these costs is not just a mistake; it is a threat to our national securit because it precludes fuel savings our citizens and nation critically need at this moment in our history.

Our burgeoning demand for oil weakens U.S. diplomatic leverage around the globe, burdens our armed forces and leaves the U.S. economy vulnerable to unpredictable price spikes and an ever-growing trade imbalance. Taken toget these dynamics create a daunting national security challenge that must be m immediately.

• With oil at $130 a barrel, over a million dollars a minute is draining out of o country, increasing our trade deficit, creating huge opportunity costs and, mo significantly, putting money into the hands of regimes that are hostile to our interests.

• Terrorist networks have openly called for, planned and carried out attacks o global oil infrastructure because they know oil is the economic lifeblood of the U.S. and the world's economy. Former Republic National Committee Director Communications Clifford D. May wrote, "Every time we fill the tanks of our ca with gasoline we put money in the pockets of terrorists intent on killing Americans." (SHNS) Diversity can Pave 1/25/07

• OPEC recently warned that oil prices would experience an “unlimited” increa in the event of a military conflict involving Iran over its nuclear program.

• A very real consequence of such a confrontation is that Iran, in a bid to pre or respond to U.S. military action, would close the Strait of Hormuz, the Persi Gulf chokepoint through which 20 percent of the world's oil supply passes. Th impact would be swift and sure: unprecedented spikes in oil costs and a deep lasting effect on the US and world economy.

• Recently Venezuelan President Hugo Chávez and Russian President Dmitri A Medvedev declared that their countries would more closely coordinate their actions on global oil and gas markets and that they would work together on foreign policy, a sphere in which both countries have sought to counter Ameri influence. (NYT) EO Russia and Venezuela 7/23/08.

The economic impact of our oil dependency also threatens national security.

• We lose over $36 billion from our economy every month and oil imports nov account for over half of our Nation’s trade deficit. Our economy is exposed on daily basis to oil price shocks and supply disruptions. Regardless of how they caused, by global market dynamics, natural disasters, terrorist attacks, or politically motivated oil embargoes, the trends of our growing oil demand in a “business as usual” mode will make those price shocks much more frequent deeply felt and longer lasting.

Finally, there are national security costs involved in addressing global climate change.

• Top retired three and four star military leaders in a report from the Center f Naval Analysis, global warming poses a "serious threat to America's national security", acting as a "threat multiplier for instability" in some of the world's r volatile regions, adding tension to stable regions, worsening terrorism and lik dragging the U.S. into fights over water and other resource shortages.

Beyond these hard to quantify but clearly growing global environmental costs there is the military price tag – much easier to directly calculate – to protect s lanes, military bases of operations and maintaining continuous high level of forward presence simply to insure continued importation of oil.

• The US Military commits significant resources to protect energy supplies in some of the most volatile regions of the world. Our fine men and women in th Armed Forces serve our nation with honor, protecting American interests throughout the globe. The major focus of their activities for nearly thirty year centered in the Middle East, a region from which so much of the instability, st root causes of terrorism and Persian Gulf oil flow.

There have been multiple studies conducted that estimate the simple military externality costs for a gallon of gasoline, ranging from a low of .12 a gallon tc $8 a gallon. In my considered judgment and, based on a number of objective studies, the added cost is over $2.50 per gallon. I also believe that is very lik conservative number.

Vehicles directly account for more than 40 percent of our oil dependency, whi why Congress passed the Energy Independence and Security Act, and why increased higher fuel economy standards are at the heart of that act. It is the most effective, indeed, the only effective, regulation to curb oil consumption.

Congress set a floor, not a ceiling on CAFE standards. Your rulemaking is intended to take a host of factors into account into to set the right level.

Assuming there are no military costs to our dependence on oil is not only wro it is dangerous.

Throughout our history, Americans have successfully met critical challenges ir both war and peace. Building a new, clean energy economy has become one (the great challenges of our time.

The key questions for this hearing are: How will the actions on CAFE by this Agency and this Administration be viewed in ten or twenty years? Will we be a to look back and say that a bold, comprehensive and enlightened mandate produced substantial oil savings, increased our national security, helped our economy and significantly reduced carbon emissions?

We have less than ten years to change our oil dependency course in significar ways. Our Nation's security depends on the swift, serious and thoughtful response to these challenges and by the significant impact your deliberations rule making will have on carrying out the intent of our elected leaders in Cong

Thank you, Mr. Chairman, Ladies and Gentlemen.

Acc. No. 0563

Public Submission: NHTSA-2008-0060-0563 **Bookmark:** Learn more Public Subr

Docket	NHTSA-2008-0060
Docket Title	Notice of Intent to Prepare an Environmental Impact Statement for New Corp Economy Standards
Docket Type	Rulemaking
Document	NHTSA-2008-0060-0528
Document Title	Notice of Availability of a Draft Environmental Impact Statement (DEIS) for N Average Fuel Economy Standards; Notice of Public Hearing
Public Submission	NHTSA-2008-0060-0563
Public Submission Title	Adam Lee - Comments
Views	
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Title	Adam Lee - Comments
Abstract	
Document Type	PUBLIC SUBMISSIONS
Document Sub-Type	Comment(s)
CFR Citation	
Author / Document Date	08/18/2008
Answer Date	
Media Location	
Media Type	
Page Count	1
Start End Page	
Order Number	
Old Submitter Rep	
Old Submitter	
Effective Date	
OMB / PRA Approval Number	
Received / Filing Date	08/18/2008
Legacy ID	
Federal Reg Citation	
Federal Register Number	
Date Posted	08/18/2008
Comment Start Date	03/28/2008
Comment Due / Reply Date	
Implementation / Service Date	

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D-254

Submitter's Representative
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Rep's City, State & Zip
Government Agency Type
Government Agency

General Comment

Comment Docket No. NHTSA-2008-0060

Statement of Adam Lee, President, Lee Auto Malls
National Highway Traffic Safety Administration
Public Hearing on Proposed Fuel Economy Rulemaking
Washington, DC, August 4, 2008

Mr. Chairman, Members of the Committee, Ladies and Gentlemen, it is an hor to appear before you today.

My name is Adam Lee and I am president of Lee Automalls located throughou the state of Maine. I am a 3rd generation car dealer; I have been in this busir my whole life.

Our company was founded in 1936 by my grandfather, with a small Chrysler dealership. Today we have two Chrysler dealerships, a GM dealership and a Honda, Nissan and Toyota Dealership.

We are the number one seller of Hybrid cars in the state of Maine. We are als the largest Dodge and Jeep dealer in the state. Last year we sold approximate 7,000 new and used cars.

I am not an economist, nor am I a scientist. I don't know how to build a car o an automobile plant however for most of my life I have been selling new and cars and trucks. I still talk to customers every single day.

I came to Washington today because when I listen to the news, I sometimes like I must be the only person in the car industry actually talking to real customers.

Here is what I am hearing every single day:

How long a wait for a Prius?
Do you have any Honda Fit's in stock?
Do you have any Toyota Yaris' in stock?
Why doesn't Chrysler offer a car that gets 30 mpg?

Or the other type of calls I get.

What is my Tundra worth?
Can I get rid of my Suburban?

The answers to these questions are simple: The wait for a Prius is 6 months. have no Fits or Yaris' and your Suburban is not worth enough for you to be ab trade out of it.

Consumers want to buy vehicles that get more than 30 miles per gallon. I am just talking about hybrids. Car dealers have people waiting for good old-fashi small cars that get good fuel economy.

They have been demanding them for years with very few choices, and almost choices from Detroit. This is not a new situation; but with gas at $4.00 per ga the demand is overwhelming and the lack of choices dramatic.

When you talk to real customers, or stand in any of our showrooms it is hard to have a real sense of doom.

The average age of the new trucks and SUVs sitting on my lot is over 200 day old. Do you have any idea how expensive it is to have hundreds of trucks and

SUVs sitting around for 7 months?

Our big Chrysler dealership in Portland Maine has 1/2 as many sales people a we had around a year ago. We have fewer people working in our office and se department as well. They are no longer employed because we don't have the to sell that people want to buy. This means fewer salespeople frequenting the corner store, the dry cleaners, and the hardware store. It is bad for the econo

General Motors just announced a loss of $15.5 billion, and Ford just announce an 8.7 billion dollar loss. Standard and Poor's just lowered the Detroit threes credit rating to junk status and even Toyota who can do no wrong is shutting its' truck plant in Texas for three months. What they are doing is not working

So how did we get here?

In 1975 Congress mandated our first fuel economy standards. Unfortunately i the last 20 years these standards have not changed a bit. NHTSA could and should have done more.

So while the rest of the world increased the fuel economy of their fleets the U did nothing. Currently Japan and the European Union have fuel economy standards roughly double the U.S.'s. They must know something we don't.

I believe our lack of progress is largely a regulatory failure.

Anyone who watches the auto industry knows that the manufacturers have ne done anything in the name of safety or the environment unless they are force Whether it is seatbelts, airbags, or catalytic converters: Detroit has always insisted that they could not pay for them; until it becomes mandated: at whic point you would think they invented the word "unleaded gas."

NHTSA plays a real role in determining what our fuel economy will be. You analyze the impact of CAFE on Detroit. I think that your assumptions are base on incorrect data. Gas costs $4.00 a gallon, not two. The new technologies ar coming down in price. Clean diesels are now viable, plug in hybrids are on the horizon, and consumers have changed their habits and view of the future.

Now is the time for NHTSA to act. Don't drag your feet; don't look to Detroit f answers, look to the American consumers. They are demanding change.

They have cleaned our shelves of small cars. And they are desperate to trade their gas-guzzlers.

I have been selling Prius' since they came out 7 years ago. And since that tim every Toyota dealer has been selling them for list price and making a very nic profit on them. Demand is so strong that people stopped negotiating. This is a car dealers dream. A car people want so badly they don't negotiate.

It is frustrating to have a car sell this well and not have enough of them. I cu have a waiting list for a new Prius of 42 people that is a 6-month wait. I cann blame Toyota for having a hit. I can blame Detroit for not having one.

If you want to know how bad it really is, go read Automotive News. This is ou trade journal that is generally on the side of Detroit; I can assure you that th have few environmentalists on their staff.

"It is distressing the some automakers are back in Washington whining about meeting new fuel economy standards at a time when their customers are demanding vehicles that exceed the regulatory mandates," Automotives News editorial, July 14, 2008.

These cars, that Detroit bet their future on and my future, are not selling.

For over 70 years my family has been selling American made cars. I am the t generation running this family business. My 11 son thinks he will do what his father, grandfather and great grandfather did to earn a living: sell American c Will there be anyone left still making cars in Detroit?

WE NEED YOUR HELP.

Acc. No. 0564 (Consumer Federation of America) is a duplicate of Acc. No. 0561.1

Acc. No. 0572
Acc. No. 0572.1 duplicate of 0572

Comments of the Center for Biological Diversity on the Draft EIS for Proposed CAFE Standards MY 2011-2015; 73 Fed. Reg. 37922; Docket No. NHTSA-2008-0060

August 18, 2008

To: Docket Management Facility, M–30, U.S. Department of Transportation
West Building, Ground Floor, Room W12–140
1200 New Jersey Avenue, SE.
Washington, DC 20590
VIA UPLOAD TO DOCKET NO. NHTSA-2008-0060 at REGULATIONS.GOV

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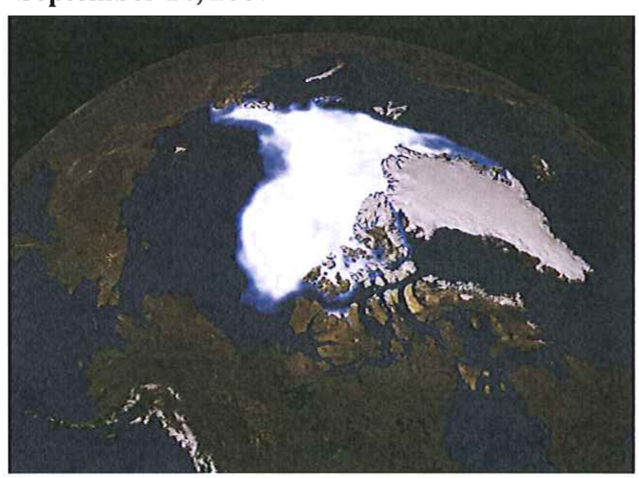
September 21, 1979

September 14, 2007



Courtesy NASA/Goddard Space Flight Center Scientific Visualization Studio

Table of Contents

I. Introduction

On July 2, 2008 the National Highway Transportation Safety Administration (NHTSA) published a notice of availability for the draft environmental impact statement (DEIS) for the proposed Corporate Average Fuel Economy (CAFE) standards for model years 2011-2015. 73 Fed. Reg. 37922. According to the notice, comments are due by August 18, 2008. Id.

The DEIS purports to respond to the Ninth Circuit's ruling in *Center for Biological Diversity v. NHTSA*, 508 F.3d 508 (9th Cir. 2007), overturning the standards for model years 2008-2011 and accompanying Environmental Assessment, in part for failing to consider the rule's impact on climate change, especially with regard to tipping points. *Id.* at 554. The rule at issue set "unreformed" light truck standards of 22.5 mpg for MY 2008, 23.1 mpg for MY 2009, and 23.5 mgp for MY 2010. 71 Fed. Reg. 17566, 17587 (April 6, 2006). In 2011, the standards were to be "reformed" so that fuel economy standards were based on vehicle footprint, resulting in an average fuel economy of approximately 24 mpg for MY 2011. *Id.* at 17624.

After these standards were struck down in *Center for Biological Diversity*, the NHTSA issued the current proposed rule to establish fuel economy standards for cars and light trucks MY 2011-2015. The proposed rule would result in the average fuel economy standards, in mpg, shown below.

Table 1: Proposed Fuel Economy Standards for MY 2011-2015 (in mpg). From 73 Fed. Reg. 24352, 24355 (May 2, 2008).

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars	31.2	32.8	34.0	34.8	35.7
Light Trucks	25.0	26.4	27.8	28.2	28.6
Average	27.8	29.2	30.5	31.0	31.6

Two months later, the NHTSA issued the instant draft environmental impact statement for the proposed rule (DEIS). 73 Fed. Reg. 37922 (July 2, 2008). The DEIS considers seven alternatives, from keeping fuel economy standards fixed at 2010 levels to a level defined by NHTSA as "technology exhaustion" pursuant to the Volpe model. See DEIS at 2-6 to 2-10. The fuel economy standards for MY 2015 under each alternative are shown below.

Table 2: CAFE Standards for the seven alternatives analyzed in the DEIS, from CAFE MY 2011-2015 Passenger Car and Light Truck PRIA (April, 2008). Each value is the harmonic average of car/light truck standards.

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Alternative 1	25.3	25.3	25.3	25.3	25.3
Alternative 2	27.1	28.0	29.4	29.8	30.2
Alternative 3 (preferred)	27.8	29.3	30.6	31.0	31.6
Alternative 4	28.5	30.6	31.5	32.2	33.0
Alternative 5	29.2	31.7	32.6	33.4	34.5
Alternative 6	30.6	33.9	34.4	35.7	37.3
Alternative 7	31.1	35.1	38.7	39.6	41.4

These comments supplement and incorporate by reference our July 1, 2008 comments on the proposed rule. The DEIS is fatally flawed as an informational document. As set forth fully below, its principal defects include the following:

- The DEIS does not conform to the statutory requirements of the National Environmental Policy Act, 42 U.S.C. §§ 4321 *et seq.* (NEPA) and the Energy Policy and Conservation Act, 49 U.S.C. §§ 32902 *et seq.* (EPCA);
- The NEPA analysis fails to comply with recent caselaw regarding environmental review of climate change impacts;
- The NHTSA has failed to consider the full, reasonable range of alternatives that is mandated by NEPA;
- The direct/indirect impacts analysis is incomplete, factually and procedurally flawed, and presented in a manner that unlawfully minimizes the apparent importance of the alternatives;
- The cumulative impacts analysis does not properly account for cumulative actions and is presented out of context;
- The NHTSA failed comply with the consultation provision of section 7 of the ESA;
- The inadequate environmental analysis is another example of the current Administration's active opposition to GHG regulations.

II. The NEPA Analysis Must be Conducted Consistent with the Underlying Statutory Scheme

The NEPA analysis must be conducted in a way that is both meaningful and appropriate given the underlying statutory scheme. The EPCA requires that NHTSA set fuel economy standards for each model year at the "maximum feasible" level, taking into account four factors: technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy. 49 U.S.C. § 32902(f). The EPCA is a "technology-forcing" statute, whereby a challenging standard encourages technological innovation.[1] As part of the statutory balancing, NHTSA must necessarily determine what is "technologically feasible." The NHTSA has discretion to set standards somewhere below that level based on its consideration of the three other statutory factors, <u>if it is reasonable to do so.</u>

In December 2007, Congress passed the Energy Independence and Security Act of 2007 (Pub. L. 11-140, 121 Sat. 1492 (Dec. 18, 2007) (EISA)). The EISA eliminates the previous 27.5 mpg standard for passenger cars with a mandate that NHTSA set separate passenger car and light truck standards annually at the "maximum feasible level," with a <u>minimum</u> fleetwide fuel economy of 35 mpg by 2020.

The NHTSA has also violated NEPA because the NEPA analysis has not informed the EPCA balancing and the Volpe model – rather, the NHTSA has done a post-hoc EIS on the "black box" number from the Volpe model. The federal NEPA regulations are clear on the order in which decisionmaking must proceed:

[1] At the time of passage, the Senate Commerce Committee remarked that "[t]he establishment of fuel economy standards for the next 10 years creates the necessary climate for investment in automotive technology leading to substantial energy conservation." S.Rep. No. 179, 94th Cong., 1st Sess. 9 (1975).

> The statement shall be prepared early enough so that it can serve practically as an important contribution to the decisionmaking process and will not be used to rationalize or justify decisions already made (§§ 1500.2(c), 1501.2, and 1502.2). For instance: ... ((d) For informal rulemaking the draft environmental impact statement shall normally accompany the proposed rule.

40 C.F.R. § 1502.5. *See also, Pit River Tribe v. U.S. Forest Service*, 469 F.3d 768, 785 (9th Cir. 2006) (reviewing relevant statutes and holding that a post-hoc EIS does not cure failure to complete an EIS before lease extensions were granted; "The purpose of an EIS is to apprise decisionmakers of the disruptive environmental effects that may flow from their decisions at a time when they retain a maximum range of options.").

The structure, methodology, and contents of the DEIS are at odds with the both NEPA and the underlying EPCA and EISA statutory scheme. See 40 C.F.R. § 1500.2(a). The DEIS has failed to analyze a reasonable range of alternatives, failed to adequately disclose the direct, indirect, and cumulative impacts of NHTSA's action, has presented the information in an inaccurate and misleading fashion designed to minimize the impact of the rulemaking, and is inadequate in numerous other ways as described fully below.

III. The NEPA Analysis Must be Conducted in Accordance with Applicable Caselaw, including *Massachusetts v. EPA* and *Center for Biological Diversity v. NHTSA*

Recent court decisions have shaped the context in which the NEPA analysis must be conducted with regard to global warming. The United States Supreme Court held in *Massachusetts v. EPA* that carbon dioxide and other greenhouse gases are "unquestionably 'agents' of air pollution" and unambiguously fall within the Clean Air Act's definition of an air pollutant. 127. S.Ct. 1438, 1460 n. 26 (2007). Furthermore, the Court held that the EPA could not avoid its statutory obligation to regulate greenhouse gases merely due to "some residual uncertainty" about the "various features of climate change." *Id.* at 1463. This holding underscores that priority that must be given to addressing climate change despite the lack of some details. The excessive use of "uncertainty" in the DEIS violates this mandate to act on what is already known.

The Court dismissed concerns about applying the statute to climate change, a phenomenon little known at the time of enactment: "[T]he fact that a statute can be applied in situations not expressly anticipated by Congress does not demonstrate ambiguity. It demonstrates breadth." *Id.* at 1462 (quoting *Pennsylvania Dept. of Corrections v. Yeskey,* 524 U.S. 206, 212 (1998)). Likewise, in the present case, both NEPA and EPCA are broad statutes that are well-suited to address climate change. Thus, the DEIS must thoroughly analyze greenhouse emissions and global warming.

An agency must regulate even if the result of the regulation will be only an "incremental" step towards solving the climate crisis. The Supreme Court noted that "[a]gencies, like legislatures, do not generally resolve massive problems in one fell regulatory swoop... [t]hey instead whittle away at them over time." *Mass. v. EPA* at 1457. Nonetheless, the court notes that "[j]udged by any standard, U.S. motor-vehicle emissions make a meaningful contribution to greenhouse gas concentrations and hence, according to petitioners, to global warming. *Id.* at 1457-58.

Moreover, the NHTSA's duty to set fuel economy standards in no way conflicts with the EPA's duty to regulate emissions from automobiles. "The two obligations may overlap, but there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency. *Mass. v. EPA* at 1462.

The NHTSA must be further guided by the Ninth Circuit's opinion in *Center for Biological Diversity*, 508 F.3d 508. The court found a proper alternatives analysis is crucial to properly assess the impact of a project on global warming. The court reprimanded the NHTSA for failing to adequately consider a reasonable range of alternatives: the NHTSA had presented only alternatives that were derived from its cost-benefit analysis and that covered a limited range of fuel economy standards. 508 F.3d at 551. The court explained that "[s]ince EPCA's overarching goal is energy conservation, consideration of more stringent fuel economy standards that would *conserve more energy* is clearly reasonably related to the purpose of the CAFE standards. Energy conservation and environmental protection are not coextensive, but they often overlap." *Id.* at 552.

The court also found the cumulative impacts analysis is particularly important: "[t]he impact of greenhouse gas emissions on climate change is precisely the kind of cumulative impacts analysis that NEPA requires agencies to conduct." *Center for Biological Diversity,* 508 F.3d 508, 550. The Court faulted the cumulative impacts analysis for failing to "discuss the *actual* environmental effects resulting from those emissions or place those emissions in context of other CAFE rulemakings." *Id.* at 549 (emphasis in original). The court also noted that "the fact that climate changes is largely a global phenomenon that includes actions that are outside the agency's control... does not release the agency from assessing the effects of *its* actions." *Id.* at 550 (internal quotes removed).

An EIS was required because the effects of fuel economy standards "*may have* a significant impact on the environment." *Id.* at 553 (emphasis in original). The court expressed particular concern with regard to the non-linear aspect of "irreversible adverse climate change" or "tipping points" wherein a seemingly small change in emissions can evoke a dramatic climate response. *Id.* at 554. This indicates that seemingly small increments between alternatives can not be disregarded as insignificant.

While the court allowed the cost-benefit approach, it cautioned against reliance on earlier caselaw that supported use of the cost-benefit analysis: "[the cases] were decided two decades ago, when scientific knowledge of climate change and its causes were not as advanced as they are today. The need of the nation to conserve energy is even more pressing today than it was at the time of EPCA's enactment." *Id.* 530.

In addition, the Ninth Circuit warned against "undervaluing benefits and overvaluing costs of more stringent standards" in the cost-benefit analysis. *Id.* at 531. In particular, the court rejected the analysis because it failed to place a monetary value on the "most significant benefit" of reducing carbon dioxide. *Id.* The court denied uncertainty as a basis for failing to monetize carbon dioxide reductions: "while the record shows there are a range of values, the value of carbon emissions reduction is certainly not zero." *Id.* at 533.

IV. The DEIS Fails to Consider a Reasonable Range of Alternatives

The heart of an environmental impact statement (EIS) is the alternatives analysis. 40 C.F.R. § 1502.14. Yet, the NHTSA has unreasonably limited the considered alternatives so that the DEIS fails to capture the true range of possibilities. In particular, the DEIS fails because: (1) the range of NEPA alternatives is unreasonably constrained by the Volpe model; (2) the range of NEPA alternatives is unreasonably constrained by NHTSA's incorrect and unlawful assumptions regarding the model inputs, and (3) NHTSA has failed to consider one or more "technology forcing" alternatives.

A. The Volpe model unlawfully constrains the alternatives such that there is no true "technology exhaustion" alternative

The NEPA analysis must be conducted in a way that is both meaningful and appropriate given the underlying statutory scheme. The EPCA requires that NHTSA set fuel economy standards for each model year at the "maximum feasible" level, taking into account four factors: technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy. 49 U.S.C. § 32902(f).

As part of the statutory balancing, NHTSA must necessarily determine what is "technologically feasible." While NHTSA has discretion to set standards somewhere below that level based on its consideration of the three other statutory factors, if it is reasonable to do so, NHTSA violates both EPCA and NEPA by failing to even consider or disclose what is truly "technologically feasible." An essential component of the DEIS must be disclosure of the "technologically feasible" fuel economy level, along with the environmental impact of choosing this level of fuel economy as compared to the NHTSA's preferred alternative and a reasonable range of additional alternatives. The DEIS fails to provide both the basic starting point for this analysis and the proper analysis that must follow.

"Technologically" is defined by Merriam-Webster's Dictionary as "of or relating to a capability given by the practical application of knowledge." Merriam-Webster Online Dictionary (2008) (definition 1b for technology). "Feasible" is defined as capable of being done or carried out." *Id.* (definition 1). Therefore, NHTSA must disclose what practical application of the knowledge [in the area of engineering] is capable of being done or carried out. NHTSA has failed to do so.

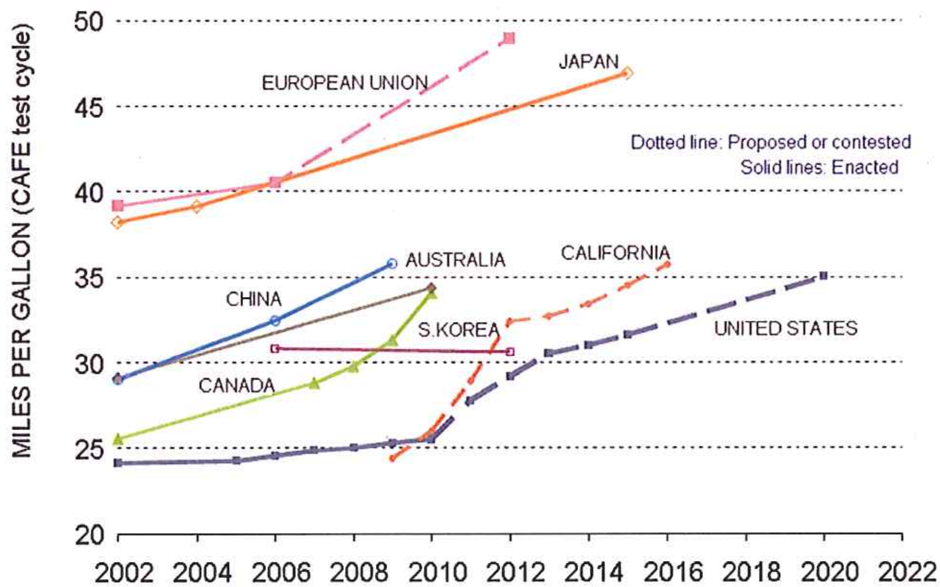
Table 3: Fuel economy standards for the "technology exhaustion" option, from CAFE MY 2011-2015 PRIA, Appendix A (April 2008).

Year	Car Standard	Light Truck Standard	Combined Standard
2010	27.5	23.5	25.3
2011	38.6	25.9	31.1
2012	45.4	28.6	35.1
2013	48.9	32.2	38.7
2014	50.1	33.1	39.6
2015	52.6	34.7	41.4

NHTSA's "technology exhaustion" would result in average fuel economy of 31.1 mpg in 2011 to 41.4 mpg in 2015. It is clear that this cannot, by any stretch of the imagination, be equated with what is "technologically feasible." First, cars on the road in the US today already achieve approximately the same or better gas mileage than what NHTSA has defined as the combined fleet "technology exhaustion" for model year 2015. These include the Toyota Prius (48/45; city/highway) and the Honda Civic Hybrid (40/45; city/highway).[2] Even more vehicles cars already achieve the "technology exhaustion" standard for the combined fleet in MY 2011: smartcar (33/41; city/highway); Mini Cooper (28/31); Toyota Yaris (29/36); Toyota Corolla (28/37); Nissan Altima Hybrid (35/33); Toyota Camry Hybrid (33/34); Hyundai Accent (27/32); Kia Rio (27/32); Mazda Tribute Hybrid 2WD (34/30); and Honda Fit (28/34).[3]

Second, NHTSA's "technology exhaustion" alternative results in fuel economy standards, even in 2015, which are below current standards in many other countries, and far below Japanese standards for 2015. In contrast, Europe and Japan had average fuel economy standards of approximately 40 mpg in 2006—over 15 mpg higher than U.S. standards. (ICCT 2007). Both Europe and Japan are predicted to continue increasing their fuel standards; even their high standards are not the technology maximum. That other countries have achieved higher fuel standards indicates that there are eminently feasible technology options available today that have not been included in the DEIS.[4]

Figure 1: Actual and Projected Fuel Economy for New Passenger Vehicles by Country/Region, 2002-2022. Source: *Passenger Vehicle Greenhouse Gas and Fuel Economy Standards: A Global Update*, ICCT (updated August 7, 2008).



By contrast, NHTSA's definition of "technology exhaustion" is the level that would "require every manufacturer to apply every feasible fuel saving technology to their MY 2011-2015 fleet." DEIS at 2-2. By what sleight of hand does NHTSA transform what is "technologically feasible" into

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[2] Estimates from *Model Year 2008 Fuel Economy Guide*, DOE/EE-0321, *available at* http:www.fueleconomy.gov.

[3] Id.

[4] We note the substantial overlap in manufacturers of the European fleet and U.S. fleet (ICCT 2007:13), and that at least one manufacturer, Ford, has already declared its intention to "make big changes to the vehicles it sells domestically" and bring "six small cars made in Europe to the North American market (Smith 2008)".

something called "technology exhaustion" that is so much lower? The answer lies in the unlawful constraints of the Volpe model itself.

As discussed in our July 1, 2008 comments on the NPRM, the Volpe model makes a number of assumptions that are unreasonable and conflict with the EPCA statutory scheme. For example, the NHTSA assumes that the US fleet mix will not change in response to consumer demand for more fuel efficient vehicles or due to a change in regulatory requirements. 73 Fed. Reg. 24394. This assumption is particularly outrageous. First, auto manufacturers who have for decades deliberately manipulated the market with advertising, incentives, financing schemes, and other methods towards the least fuel efficient vehicles, continue to do so. (See, e.g. Chevrolet Tahoe Hybrid website; GreenCar.com 'Chevrolet Tahoe Hybrid Green Car of the Year;' Chrysler $3 gas banner; KCRA.com 'Chrysler $3 gas;' Ford Escape Hybrid website; Lyons 'Ford Guilt Free SUV'). Consumer preferences, nonetheless, are now shifting dramatically towards more fuel efficient vehicles in response to higher gas prices. (Cooper 2008). For a manufacturer to change its fleet mix in response to regulation is a method of compliance that must be considered in both the EPCA and NEPA analyses. Any precedent to the contrary is inapposite.

The NHTSA also assumes that manufacturers will not update their vehicle models more frequently than once every 5 years, and, "in most instances" has simply "accepted the projected redesign periods from the companies who provided them through MY 2013" 73 Fed. Reg. 24386. In other words, the underlying analysis for a fuel economy standard which is supposed to conserve energy by pushing manufacturers to develop new technology and innovate to meet challenging standards which may even "appear impossible" today, is constrained by the assumption that manufacturers will do nothing other than what they are already doing, at least for a period of five years. This clearly violates both EPCA and NEPA. On a related note, the the Volpe model generally does not apply a new technology until a given vehicle is due for a "redesign or refresh," and assumes that some technologies, such as hybrid vehicles, already in use today cannot yet be adopted. 73 Fed. Reg. 24386.

All of these unreasonable assumptions lead to NHTSA's exclusion of an essential piece of information from the DEIS: the technologically feasible fuel economy level. Thus, the NHTSA failed to consider a reasonable range of alternatives as required by law. *See, e.g., Friends of Southeast's Future v. Morrison*, 153 F.3d 1059, 1065 (9th Cir. 1998).

B. Even were the alternatives not unlawfully constrained by the Volpe model in the first instance, the NHTSA's use of unreasonable model assumptions prevented the consideration of a reasonable range of alternatives

Even were the Volpe model not fundamentally rigged to provide an unreasonably low result, the inputs used by NHTSA ensured that the fuel economy levels that resulted were artificially low, again resulting in NHTSA failing to analyze a reasonable range of alternatives.

The NHTSA also abuses its discretion to balance the four EPCA factors by using inaccurate and unreasonably constrained values in the Volpe model. As discussed below, in each and every instance when NHTSA faced a choice of inputs, it chose the level that would minimize the resulting fuel economy level. Even if one or more of the NHTSA's choices were otherwise lawful under EPCA and the Administrative Procedures Act (APA), which they are not, the NHTSA's failure to disclose in the DEIS the impact of these input choices, and to provide an alternative based on choosing higher input numbers, violates NEPA as well.

Moreover, even if NHTSA's choice of the "optimized" alternative were otherwise lawful, the use of incorrect inputs in the model results means that even by the NHTSA's own twisted definitions, this alternative does not actually represent the point at which marginal benefits equal marginal costs. The NHTSA's inaccurate claim that it does violates NEPA's requirement to provide accurate information to the public.

1. The Use of a 7% Discount Rate is Unreasonable

One of the primary flaws is the use of a 7% discount rate. The DEIS acknowledges that discount rate and gasoline price have a significant impact on the cost-benefit analysis. Yet the DEIS adopts a 7% discount rate and does not present even the results for a 3% or lower discount rate. The significant influence of discount rate alone is reflected in the fact that the "optimized" fuel economy standard with a 3% discount rate is more than 50% higher than the "optimized" alternative presented in the DEIS. PRIA Appx. A at A-2, Table A-1. This important information is only available in the Preliminary Regulatory Impact Assessment (PRIA), which is insufficient. *Grazing Fields Farm v. Goldschmidt*, 626 F.2d 1068, 1072 (1st Cir. 1980) ("no indication in the [NEPA] statute that Congress contemplated that studies or memoranda contained in the administrative record, but not incorporated in any way into an EIS, can bring into compliance with NEPA an EIS that by itself is inadequate.").

The choice of a 7% discount rate is not supported by the evidence. As the DEIS states, OMB suggests the use of both 3% and 7% discount rates, with the 3% discount rate appropriate where the costs of regulations are likely to be passed on to consumers. DEIS at 3-60. The Volpe model assumes that costs will be passed to consumers. For instance, the cost of new technology is limited by consumer pay-back periods and willingness to pay higher vehicle prices. See, e.g., DEIS 2-1 (discussing "retail price equivalent"); DEIS Appx. C at V11-41 (discussing impact of higher costs on sales).

Other agencies have assumed discount rates of 3% in similar analyses. The EPA in its recent advance notice of proposed rule making for regulating greenhouse gas emissions under the Clean Air Act noted that changes in GHG emissions are "essentially long-run investments" that "yield returns in terms of avoided impacts over a period of one hundred years and longer. Furthermore, there is a potential for significant impacts from climate change, where the exact timing and magnitude of these impacts are unknown. These factors imply a highly uncertain investment environment that spans multiple generations." 73 Fed. Reg. 44354, 44414 (July 30, 2008). When there are important benefits or costs that affect multiple generations of the population, EPA and OMB allow for low but positive discount rates (e.g., 0.5–3% noted by U.S. EPA, 1–3% by OMB)." *Id.*

In recent testimony before the House of Representatives Energy Committee, Sir Nicholas Stern notes the inappropriateness of pure-time discounting in which future generations are valued less than the current generation (Stern 2008). He goes on to distinguish between current market rates, which reflect only near-term benefits, versus the value of "young or unborn" generations. *Id.*

The DEIS thus makes several crippling errors in its choice of discount rate. First, the NHTSA assumes that a substantial portion of the costs of the regulation will come from foregone capital investments by the auto industry. This is simply incorrect. All capital costs will be passed onto consumers in short order. Furthermore, the largest costs from the regulation come in the form of impacts from catastrophic climate change. This will most certainly be felt by consumers, both in this generation and the next. The choice of a 7% discount rate is based in part on assumptions regarding loan rates. DEIS Appx. C at VIII-2. Yet, this short-sighted context is entirely inappropriate. Given that the impacts of the alternatives are analyzed out to year 2100, the discount rate must also reflect this long time horizon for impacts.

2. The Cost of Fuel is Unrealistic

Another major determinant of the output from the Volpe model is the cost of fuel. DEIS at 2-2. The NHTSA used the EIA's Annual Energy Outlook Early Release Forecast to select fuel prices, and assumes future fuel prices ranging from $2.26 per gallon in 2016 to $2.51 per gallon in 2030. Considering that national average gasoline prices are currently $3.81 per gallon [5] and over a dollar higher than one year ago, there is every indication that the price of oil will continue to increase over the short term, and there is every indication that the price of oil will continue to remain in the short term higher than projected by the administration, this estimate is impossible to justify. It is important to note that these price projections are based in 2006 dollars, and include Federal, State, and local taxes. However, the estimated 2008 fuel price of $2.69 per gallon of gasoline in 2006 dollars, adjusted by a 3% estimated annual inflation rate, is approximately $2.85 per gallon of gasoline, far below the current prices and projections. The use of an inappropriate gasoline price projection greatly skews the results, since the savings in fuel expenditures are by far the largest components of the cost-benefit analysis, accounting for $2.27 of the $2.51 in net benefits from each gallon of gasoline reduced, overwhelmingly drives the conclusions of the cost-benefit analysis as constructed by NHTSA.

3. The Cost of Carbon has No Basis in the Facts

The NHTSA's methodology for the selection of an estimate of the value of reducing greenhouse gas emissions is arbitrary and designed to minimize the estimate. The Volpe model assumes that the value of CO_2 reductions is the midpoint between a so-called "high" of $14/ton CO_2 and a "low" of $0/ton CO_2. DEIS Appx. C at VIII-30. This valuation is flawed because: (1) it is based on an out-dated and otherwise flawed analysis; (2) the use of a $0 low value is unjustified; and (3) simply splitting the difference between two values does not take into account the distribution of economic projections for the cost of carbon.

The NHTSA relies entirely on the 2005 *Energy Policy* article, Tol (2005), as the source for the estimate of $14 per ton of CO_2, but fails to address the much higher estimates also reported by Tol. Tol (2005) states that "The marginal damages caused by a metric ton of carbon dioxide emissions in the near future were estimated in the [IPCC] Second Assessment Report at US$5-125 per tC." In addition, the NHTSA overlooks the fact that the studies cited in the Tol (2005) survey dated back as much as 18 years, to 1991, and 25 of the 28 studies cited were published more than five years ago. Considering that

[5] EIA current prices, *available at* http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_home_page.html (value for August 11, 2008).

the understanding of climate change has expanded dramatically in the past five years, and that impacts of climate change are progressing much more rapidly than were previously projected, this represents a fatal flaw in the analysis. Of the 28 papers cited by Tol (2005), only three were published since 2003, only one of which was peer reviewed. That paper estimated the social cost of carbon as high as $14 per ton of CO_2. (Pearce 2003).

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change also refers to the Tol (2005) survey, but is careful to point out, on page 813 of Yohe (2007), that "[it] is likely that the globally-aggregated figures from integrated assessment models underestimate climate costs because they do not include significant impacts that have not yet been monetized...," and, on page 17 of Adger (2007), that "taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time." The NHTSA concedes this point: "[taken] as a whole, recent estimates of the SCC may underestimate the true damage costs of carbon emissions because they often exclude damages caused by extreme weather events or climate response scenarios with low probabilities but potentially extreme impacts, and may underestimate the climate impacts and damages that could result from multiple stresses on the global climatic system." DEIS Appx. C at VIII-28.

In fact, the IPCC, on page 813 of Yohe (2007), estimates the cost of carbon as high as $350 per ton of carbon ($97.67/ton CO_2), and states that "It is virtually certain that the real social cost of carbon and other greenhouse gases will increase over time; it is very likely that the rate of increase will be 2% to 4% per year."

The DEIS places great weight on the fact that the IPCC Fourth Assessment report cites to Tol (2005). Yet, the DEIS does not acknowledge the many other studies that the IPCC refers to. For example, the IPCC contrasted the Tol estimate of carbon costs with that of Downing (2005), which indicated that the lower benchmark of $50/tC ($13.95/t CO_2) was reasonable. Most importantly, the IPCC gives great weight to the estimates in the Stern Review 2007. As the most recent and most comprehensive analysis of the costs of climate change, the Stern Review is the best available information. As the IPCC notes, the Stern Review 2007 estimates the cost of carbon at $85/t CO_2. The NHTSA must re-calibrate the Volpe model results to reflect the actual range of values in the current literature.

The NHTSA also uses an impermissible value for the lower bound on the cost of carbon dioxide reductions. The DEIS acknowledges that the IPCC indicates that the costs of global climate change will be non-zero. DEIS Appx. C at VIII-30. But then it jumps to the amazing and illogical conclusion that "it does not necessarily rule out low or zero values for the benefit to the U.S. itself from reducing emissions." *Id.* This statement is completely erroneous. The evidence is clear that the U.S. will be severely adversely affected by climate change. Just a few examples: some of the most expensive real estate and most densely populated regions are along our expansive coastlines; the desert Southwest is gripped by drought and projected to continue to be; much of our fresh water is supplied by annual snowpack, which is already declining; forest fires are raging through most of the forested regions of the country; and human health, especially in the Southwest where there are large retired populations, will be affected by extreme heat events and in many other ways. Furthermore, our economy depends heavily on imports and exports from other countries. If the rest of the world is economically harmed by climate change, the U.S. will undoubtedly pay. There is no doubt that the U.S. will suffer severe impacts along with the rest of the world: the cost of carbon is most certainly non-zero.

Finally, the DEIS uses an impermissible method for reducing the range of potential carbon costs to a single value. The DEIS takes the midpoint between its chosen "upper" and "lower" bound. But as emphasized by the IPCC there are numerous estimates of carbon cost. This constellation of carbon costs will have some distribution. It is very likely that the estimated values do not fall along a normal "bell" curve. Consequently, taking the midpoint between the extreme values does not reflect the true "consensus" value for the cost of carbon.

The NHTSA must first re-analyze the available and current estimates of the cost of carbon, with particular attention to the leading analyses in the Stern Review 2007. Next, the NHTSA must ascertain a proper non-zero lower bound for its estimates. Finally, the distribution of estimated values should be taken into account when a single value is selected for use in the Volpe model.

4. The Volpe Model Fails to Account for Changes in Fleet Mix and Market preference

The low CAFE standards have allowed United States automakers to pursue the profits associated with large, expensive trucks and SUVs, at the expense of the consumer and the environment. This market plan has proven untenable even to the automakers and their workers, with Ford posting an $8.7 billion loss in the second quarter of 2008, and GM closing four truck and SUV plants (NPR Big Three, Dwyer (NPR) Ford Shifts). Now the United States automakers are forced to attempt to catch up to consumer demand for higher fuel efficiency vehicles. One domestic automaker has attempted to obscure its paucity of fuel-efficient vehicles by offering consumers a special credit card that caps the cost of gasoline at $2.99 per gallon for three years (KCRA Chrysler $3 gas). Other domestic automakers have launched disingenuous advertising campaigns promoting trucks and SUVs with marginally higher fuel efficiencies, even though those higher-efficiency vehicles are being produced only in extremely small quantities and are not actually available in many markets (NPR Hybrid SUV, Ford Escape, Chevy Tahoe). That is, the U.S. automakers are currently responding to the changing market demand not by producing higher efficiency vehicles, but by offering advertising and gimmicks. This problem has been greatly facilitated by decades of stagnant CAFE standards, and can hardly be expected to be resolved by the Volpe model that relies so heavily on the marketing plans and short-sightedness of the automakers.

Fleet mix is a central component of average fuel economy and yet is absent from the Volpe model cost-benefit analysis. For instance, the Volpe model "does not attempt to account for…intentional over-compliance…Another possibility NHTSA and Volpe staff have considered but do not yet know how to analyze, is the potential that manufacturers might "pull ahead" the implementation of some technologies in response to CAFE standards that they know will be steadily increasing over time." Proposed CAFE Standards MY 2011-2015 at 73 Fed. Reg. 24352, 24393 (May 2, 2008).

This failure is particularly glaring in today's auto market. The media is full of stories of automakers that are facing poor economic returns on low-mileage vehicles and as a result shifting to smaller, more fuel-efficient models. Ford motor company, for instance, has plans to reduce SUV production and begin offering some of its European fuel-efficient vehicles for sale in the U.S. (Smith

2008). A recent report by the Consumer Federation of America indicates that the NHTSA's assumed fleet mix does not represent what consumers are actually buying (Cooper 2008). Furthermore, the average consumer desires a car that gets at least 32.7 mpg today (Cooper 2008), yet even the "technology exhaustion" alternative would only require an average fuel economy of 31.1 mpg in 2011. Including this shift in consumer demand in the Volpe model is essential to properly assess the potential for increased fuel economy in the U.S.

The NHTSA does not address the potential implications of a changing automobile market and to embrace its technology forcing mandate. The possibility that increasing consumer demand for more fuel efficient vehicles may affect the calculation of an individual automaker's CAFE under Reformed CAFE, and the opportunities available for individual automakers to take advantage of those changing demands through CAFE credits. 73 Fed. Reg. at 24393 & 24443. However, the proposed CAFE standards completely fail to consider the significant market advantage experienced by automakers that "pull ahead" to offer higher-efficiency vehicles.

In such a market, "overcompliance" can result in significant gains in market share and economic returns for innovative automakers. By failing to consider shifting consumer demand, NHTSA and the Volpe model significantly underestimate the economic benefits of increased efficiency vehicles, and artificially and inappropriately skew the cost-benefit analysis of developing and implementing efficiency technologies. Stated another way, NHTSA has illegally constrained its analysis by locking itself into the assumption that a manufacturer's fleet mix need not, and will not, change in response to the nation's need to conserve energy.

5. The Cost-Benefit Analysis Does Not Include All Available Technologies

The potential technologies for improving fuel economy are unreasonably limited. The extent to which the technology is unreasonably limited is amply illustrated by the fact that the "technology exhaustion" alternative barely reaches the <u>current</u> fuel economy standards in Japan and Europe, much less the projected fuel economy standards in Europe and Japan for 2015. *Supra* Table 3, Figure 1. A model that predicts maximal technology implementation to be unable to reach even current market standards in other countries is clearly not considering all available technologies.

Concrete examples of technologies that are unreasonably excluded are: electric vehicles, plug-in hybrids, and power-split hybrids. Electric vehicles are entirely excluded from the Volpe model. 73 Fed. Reg. at 24381, Table III-3. This is absurd considering that a major U.S. auto manufacturer produced and placed such vehicles on the road in the year 1996.[6] These vehicles were pulled from the market for commercial reasons over loud protests of drivers in 1999, and destroyed in 2003. (Biederman 2005). An auto manufacturer's commercial decision does not render a technology unsuitable for implementation—the only concern should be physical capability, which has been clearly demonstrated. Plug-in hybrids are also categorically excluded on the basis that they are not "market-ready" (73 Fed. Reg. at 24381), despite the fact that Toyota is planning to introduce plug-in hybrids by MY 2010. (Maynard 2008). The major U.S. auto manufacturers are also planning to offer similar vehicles around the same time. *Id.* Powersplit hybrids, like the Toyota Prius, are considered advanced technology that will not be available

[6] See http://www.sonyclassics.com/whokilledtheelectriccar.

under 2014. 73 Fed. Red. At 24381, Table III-3. This assumption is ludicrous given that the Toyota Prius has been sold in the U.S. since MY 2001 and is a top-selling vehicle.

Other technologies that are not yet commercially available, but could be if economy standards were sufficiently high, include replacement of spark-plugs with laser-pulse injection systems and engines that can switch between two-stroke and four-stroke modes. (Graham-Rowe 2008). Furthermore, the DEIS makes no mention of alternatives such as compressed-air vehicles. (Green Car Congress 2008).

There are abundant potential technologies for improving fuel economy that have not been included in the Volpe model. This leads to misleading and factually incorrect outputs from the model, and a failure to disclose basic relevant information under NEPA.

6. The Volpe Model Impermissibly Constrains Implementation Based on Manufacturer Development Cycles

The NHTSA has ignored the EPCA technology-forcing mandate by limiting technology implementation to manufacturer development cycles. As discussed in greater detail below in section IV(C), the EPCA is a technology-forcing statute. The principle of technology-forcing is that the market must be pushed to do more than it currently plans. Yet, the NTHSA disregards this principle when it limits technology implementation to manufacturer "redesign" and "refresh" cycles. 73 Fed. Reg. at 24385.

Manufacturers not only manipulate market demand as discussed above, but also respond to it. When economics demand, a manufacturer would certainly implement a change outside a normal development cycle. Similarly, if regulations required, automakers could make changes outside a normal development cycle. Development cycles are a product of commercial convenience, not practicability. As a result, they have no bearing on the considerations of technology implementation within the cost-benefit analysis.

In summary, in each and every instance discussed above, NHTSA unreasonably chose an input level that would depress the fuel economy level that resulted from the modeling. Then, NHTSA disclosed in the DEIS only the results of the modeling runs using these unreasonable input figures. NHTSA's modeling is arbitrary and capricious and violates NEPA (as well as the EPCA, as described throughout and in our July 1, 2008 comments on the proposed rule). Even if NHTSA's use of the Volpe model were otherwise valid (which it is not, as described above), at a minimum, NHTSA was required to consider alternatives based on modeling with reasonable inputs. In other words, NHTSA should also have disclosed the level of its so called "optimization" and "technology exhaustion" alternatives had the model been run with inputs that would have led to higher fuel economy outputs. NHTSA failed to do so.

Furthermore, the NHTSA makes the mistake of elevating the decisional process over the substantive character of the alternatives. As the court in *California v. Block* noted with regard to an EIS prepared under NFMA, "[a]lthough it is worthwhile to consider a broad range of variables in constructing policy alternatives, the procedure becomes meaningless if the variables are assigned numerical values such that only a limited range of outcomes result." 690 F.2d 753, 769 (9^{th} Cir. 1982). Here, NHTSA has limited its consideration, and range of alternatives, to the results of the model, yet those results are meaningless for a number of reasons, including the fact that the input values were simply incorrect. Thus, the range of values used as inputs to the Volpe model has unreasonably constrained the universe of alternatives under NEPA.

Moreover, as discussed above, the Volpe model arbitrarily constrains the universe of NEPA alternatives. The purpose of NEPA is to inform decision making, but application of a specialized tool designed for cost-benefit analysis indicates that a decision has already been made by the agency. If the cost-benefit analysis is applied to select alternatives, there is no potential for considering alternatives that may carry less environmental impact. Yet, the Volpe cost-benefit analysis was employed to define all alternatives, including the maximal technology alternative. This alternative was based on what the NHTSA "considered to be available" and based on market penetration rates defined in the Volpe model. DEIS at 2-10.

C. The NHTSA failed to include a "technology forcing" alternative

The EPCA is a "technology-forcing" statute, whereby a challenging standard encourages technological innovation. The EIS must consider alternatives in light of EPCA's technology-forcing character. As the court in *Center for Auto Safety v. Thomas* noted, "[t]he experience of a decade leaves little doubt that the congressional scheme in fact induced manufacturers to achieve major technological breakthroughs as they advanced towards the mandated goal." 847 F.2d 843, 870 (D.C. Cir. 1988) (overruled on other grounds); *see also Green Mt. Chrysler Plymouth Dodge Jeep v. Crombie*, 508 F. Supp. 2d 295, 358-359 (D. Vt. 2007) (discussing technology-forcing character of EPCA and the use of increased fuel efficiency to augment performance rather than mileage). As explained by the court in *Kennecott Greens Creek Min. Co. v. Mine Safety and Health Admin.*, "when a statute is technology-forcing, the agency can impose a standard which only the most technologically advanced plants in an industry have been able to achieve-even if only in some of their operations some of the time." 476 F.3d 946, 957 (D.C. Cir. 2007) (quoting *United Steel Workers of America, AFL-CIO-CLC v. Marshall*, 647 F.2d 1189, 1246 (D.C. Cir. 1980). With regard to a similarly technology-forcing statute, the Clean Air Act, legislative history indicates that the primary purpose of the Act was not "to be limited by what is or appears to be technologically or economically feasible," which may mean that "industries will be asked to do what seems impossible at the present time." 116 Cong. Rec. 32901-32902 (1970), 1 Legislative History of the Clean Air Amendments of 1970 (Committee Print compiled for the Senate Committee on Public Works by the Library of Congress), Ser. No. 93-18, p. 227 (1974); *see also Whitman v. American Trucking Associations*, 531 U.S. 457, 491 (2001).

Due to the technology-forcing nature of the statutory scheme, the NHTSA was required to include one or more technology-forcing alternatives in the DEIS. Such an alternative would include standards that may appear impossible today, but that would force innovation as industry strives to meet a challenging standard. NHTSA's "technology exhaustion" alternative, defined by the criteria "whether a particular method of improving fuel economy can be available for commercial application in the MY for which the standard is being established" (DEIS at 1-2) clearly cannot substitute for consideration of a technology-forcing alternative.

While NHTSA will likely argue that it was not required to consider a technology-forcing alternative because it has pre-determined that it would not select such an alternative, it is clear that all reasonable alternatives, even those falling outside the lead agency's jurisdiction, must be considered. *Natural Resources Defense Council. v. Morton*, 458 F.2d 827, 834 (D.C. Cir. 1972). Because EPCA is a technology-forcing statute, the failure to include a technology-forcing alternative was unreasonable and unlawful.

Having failed to include such an alternative, the NHTSA then failed to analyze the environmental impacts of a technology-forcing standard. This omission is particularly significant because such a technology forcing standard would have environmental benefits that not only amplify the ability of automakers to meet higher standards in later years, but that also ripple through the economy. NHTSA's failure to consider this important aspect of the analysis renders the DEIS inadequate.

V. The DEIS's Analysis of Direct and Indirect Impacts is Fatally Flawed and Designed to Minimize the Effect of NHTSA's Action

The failure to evaluate a reasonable range of alternatives is compounded by the DEIS's inadequate analysis of direct and indirect impacts. Fundamental purposes of the EIS include providing a meaningful discussion of the environmental problem, the agency's contribution to that problem, available solutions, and the agency's contribution to those solutions. The DEIS is lacking any such meaningful analysis. Instead, with regard to global warming, the analysis is systematically skewed in a way that minimizes both the severity of the problem and the NHTSA's contribution to it. The DEIS is lacking any discussion at all of solutions, and how the NHTSA's actions either contribute to, or detract from, the implementation of such solutions. These flaws render the DEIS worse than useless as an informational document, because it is affirmatively misleading to the reader.

A. The DEIS Systematically Understates the Severity of the Climate Crisis and Overstates Scientific Uncertainty

The NHTSA has failed to present, as it must, information and analysis in a way that provides meaningful insight into the relevant environmental problems and available solutions. The information in the DEIS on climate impacts is presented in a misleading manner and without appropriate context. Under NEPA an EIS must be written in "plain language" so that decisionmakers and the public can readily understand [it]." 40 C.F.R. § 1502.8. The ultimate purpose of an EIS is to inform decisions. To do so, the information must not only be comprehensible to non-experts, but also present the context for the information in a manner that elucidates and explains the importance of each aspect of the decision.

The DEIS fails in this regard because it presents the information on the impacts of climate change in a way that minimizes the apparent potential for substantial harm. Even more problematic is the minimization of the apparent influence of each alternative on climate change. Throughout the DEIS the impact of each alternative as well as the difference between alternatives is presented as insignificant and meaningless. Although the DEIS mentions many of the potential consequences of increased atmospheric CO_2, the data is presented in a disjointed manner and qualified as "uncertain." Yet it has been decades since there has been any real scientific uncertainty regarding whether climate change is occurring as a result of increasing concentrations of anthropogenic (Oreskes 2004).

The reality is that, as discussed in previous sections, there is a substantial risk of climate disaster if U.S. greenhouse gas emissions continue unchecked. This collision course towards climate disaster can be avoided through efforts to reduce quickly reduce emissions. The transportation sector is one of the largest sources of emissions, and therefore also an essential part of the solution. Stringent CAFE standards can be part of one of the most significant components of a national greenhouse gas emissions reduction program. This substantial opportunity, however, is never explained to the reader, but rather, the reader is left with the impression that NHTSA's actions will make very little difference one way or another. This is profoundly misleading and violates NEPA's disclosure requirements.

The statement of "uncertainty" is overused and abused throughout the DEIS. To avoid further analysis and consideration of environmental impact, the DEIS frequently presents background on climate change, but qualifies the information as "uncertain." In most instances this is uncalled for. The argument could be made that every piece of information in any EIS is uncertain, yet an agency is expected to make a good faith effort to consider impacts that are reasonably certain. While the IPCC may label the intensity of some effects as "likely" as opposed to "very likely," the effects are still just as certain as effects such as smog due to criteria pollutant emissions. For instance, the IPCC states that "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." (Alley et al. 2007). By overusing the uncertainty qualification, the DEIS fails to consider important impacts of climate change and obfuscates the issue so that the decisionmakers and public will not be able to adequately evaluate the balance of harms that may occur as a result of different alternatives.

One prime example of inadequate context and information is the analysis of abrupt climate change, or tipping points. The CEQ regulations require that an agency "describe the consequences of a remote, but potentially severe impact" based on credible scientific information. 50 Fed. Reg. 32234, 32237 (August 9, 1985). The DEIS acknowledges that the possibility of abrupt climate change exists, yet by asserting uncertainty downplays the significance of tipping points. This approach is untenable. While no one may be able to predict with certainty on exactly which date a threshold for abrupt climate change may be reached, there is ample evidence that unchecked greenhouse emissions will result in abrupt climate change. In fact, various studies have attempted to quantify when such a threshold may be reached. The most recent estimate by Hansen and colleagues is that prolonged time spent over 350 ppm CO_2 will result in catastrophic[7] impacts. Previous estimates considered 450 ppm the threshold for catastrophic climate change.

Given the certainty that abrupt climate change will occur above some level of atmospheric concentration, the alternatives must be analyzed in the context of avoiding catastrophic climate change.

B. The DEIS does not adequately address climate tipping points

[7] Although the climate literature often refers to "dangerous" levels of climate change to denote CO_2 concentrations above which climate impacts will be severe and irreversible, we use the term "catastrophic" here because current CO_2 levels have already surpassed the "dangerous" level of 350 ppm.

Among the many consequences of climate change, "tipping points" carry the greatest threat to wildlife, human welfare, and economic security. As such, it is of paramount importance that any federal action be executed in a manner that reduces the possibility of abrupt climate change.

The Volpe model is the sole decision-making tool used to balance the factors set out in the EPCA. It does not capture the costs of abrupt climate change or tipping points. One of the factors that NHTSA considers under EPCA when setting the fuel standards is "the need of the United States to conserve energy." Environmental implications of the need for large quantities of petroleum are included in this factor. One of the environmental effects of continued heavy petroleum consumption is the possibility of passing over "tipping point" thresholds, or catastrophic climate change.

Because this is an acknowledged possibility, it must be included in the NEPA analysis and the balancing of the EPCA factors. The DEIS concludes that the science surrounding tipping points is too uncertain to be included in the analysis. This is simply not true. It is well-accepted that there will be tipping points. (Meehl et al. at 775, 2007). A recent analysis of "tipping elements" indicates that contrary to the IPCC's conservative projections, there is a strong chance that tipping points will be crossed within this century. (Lenton et al. 2008). This study also indicates that it may be possible to identify thresholds for tipping points for the purposes of policy making. *Id.*

Furthermore, a recent study by Weitzman, an economics professor at Harvard, indicates that while traditional cost-benefit analysis can not properly capture the costs of climate change, including tipping points, a different analysis is more likely to capture the costs. (Weitzman 2007).

The economic impacts of climate change are astounding. The much-respected Stern Review, published in 2007, estimates that the costs of climate change will range from 5% to 20% of GDP. (Stern 2007). In contrast, the Stern Review estimated that rapid action to address climate change would only cost approximately 1% of GDP.[8] *Id.* In 2007, this would have corresponded to approximately $138 billion.[9] In contrast, the cost of inaction—abrupt climate change—has been estimated at over $400 billion.[10] (Bindschadler 2008). The message is clear: the U.S. can not afford to gamble with abrupt climate change.

Under all scenarios considered in the DEIS the atmospheric CO_2 concentrations would reach 550 ppm or greater—the "optimized" alternative would reach over 700 ppm. This is well above the threshold for abrupt and catastrophic climate change. As a result, no alternatives adequately address the need for deep reductions in CO_2 emissions.

The DEIS erroneously dismisses the potential for tipping points as an impact that will not occur this century and thus does not require consideration. The basis for this conclusory statement that abrupt climate change will not occur this century is a statement in the IPCC Fourth Assessment Report that

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[8] As Sir Nicholas Stern explained in testimony before the House of Representatives Energy Committee, other major bodies such as the IPCC, McKinsey & Co., and the International Energy Agency have produced similar estimates. N. Stern, *Climate Change: Costs of inaction, Targets for Action* (June 26, 2008).
[9] National GDP obtained from file "gdplev.xls" downloaded from http://www.bea.gov/national/index.htm#gdp (last visited August 12, 2008).
[10] Cost for 1 m rise in sea level this century.

"[a]brupt climate changes … are not considered likely to occur in the 21st century, based on currently available model results." *See* DEIS at 3-53 (emphasis added; citing Meehl et al. 2007). Yet, it is well-accepted that climate models can not capture the dynamical processes that lead to climate instabilities and rapid shifts such as occur during abrupt climate change. See, e.g., DEIS at 3-52.

Model predictions consistently underestimate observed climate change, and thus very likely also underestimate when tipping points will occur. For a discussion and examples, see Hansen et al., *Target CO_2* at page 10 (2008). There are numerous examples of accelerated changes occurring well in advance of model predictions. One is the rapid rate of sea ice loss in the Arctic. The summer sea ice extent in 2007 shattered all records, dropping below the level that most models predicted would not occur until 2050.

Figure 2: Sea Ice Concentration for September 2007, along with Arctic Ocean median extent from 1953 to 2000 (red curve), from 1979 to 2000 (orange curve), and for September 2005 (green curve). September ice extent time series from 1953 to 2007 is shown at the bottom. Source: Stroeve et al. (2008: 13, Figure 1).

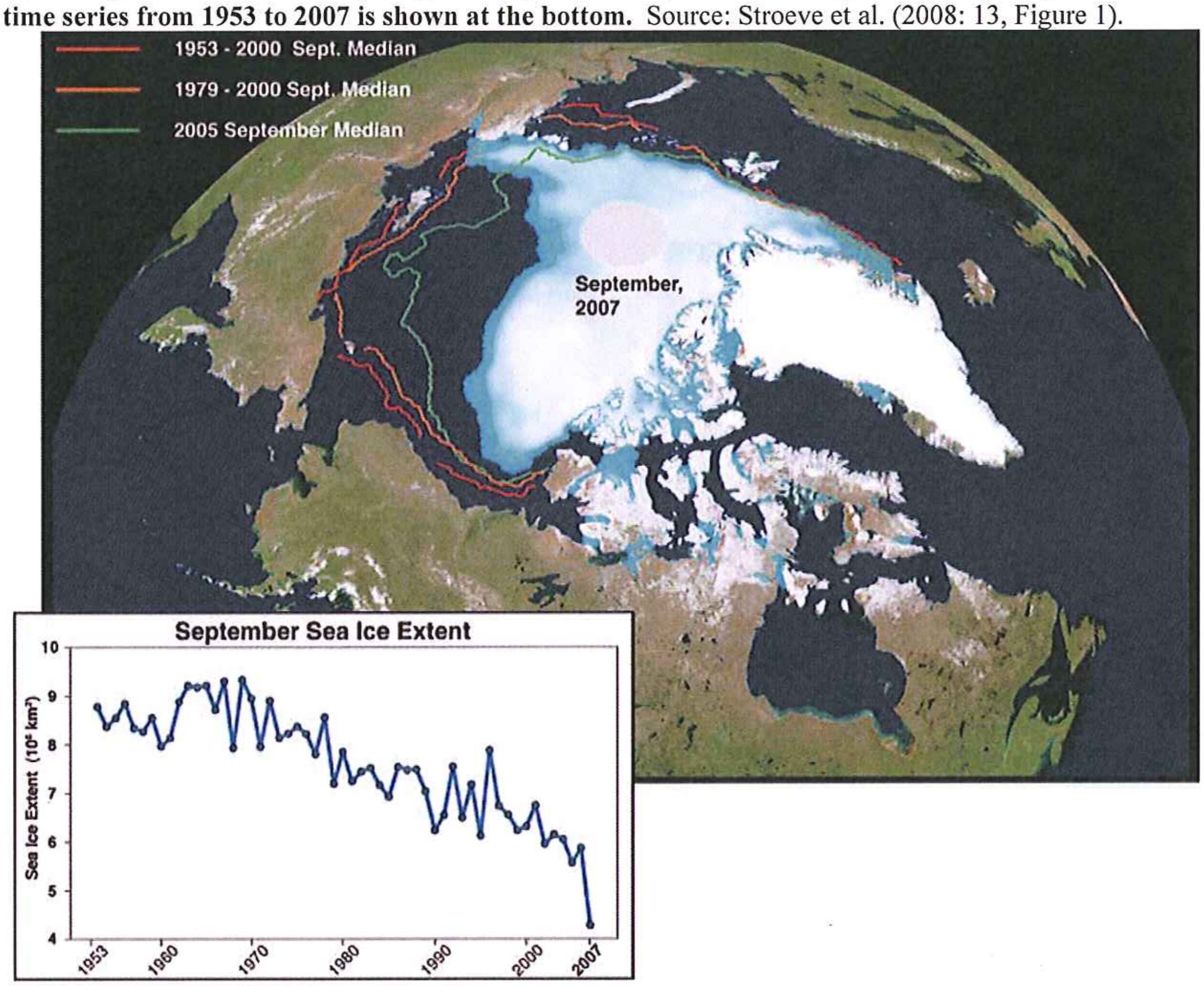
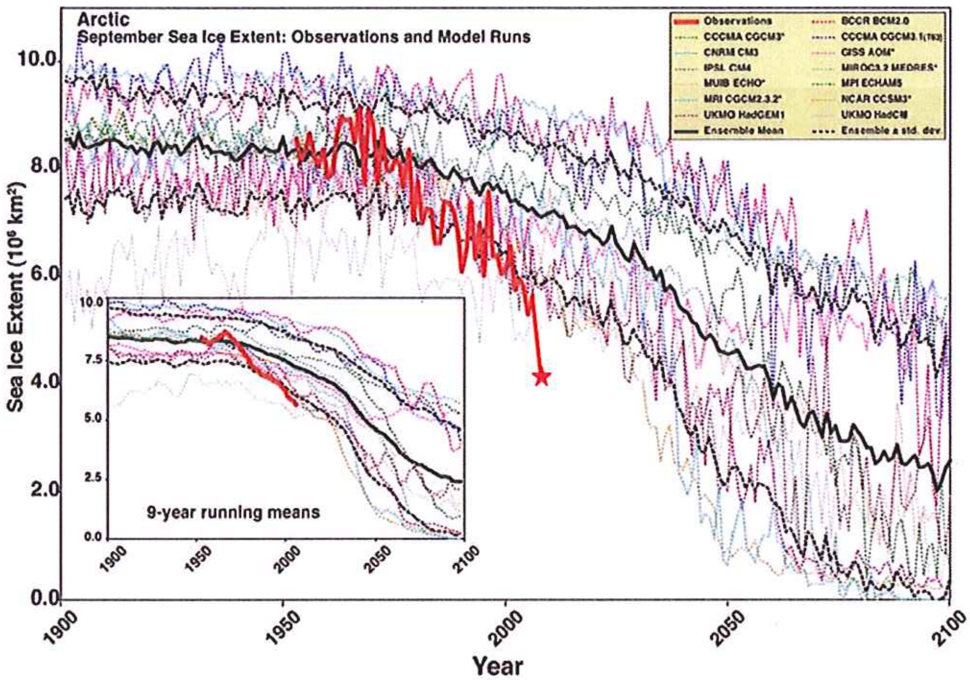


Figure 3: Arctic Summer Sea Ice Extent: Observations Compared to Model Runs. Source: After DeWeaver (2007); Stroeve (2007).



More recent models of Arctic sea ice predict that the Arctic could be sea-ice free by the summer of 2013. In a recent conference presentation, Professor Maslowski from the Naval Postgraduate School showed if current trends continue, the Arctic will be sea-ice free by 2013. (Maslowski et al. 2008). The summer sea ice predictions for 2008 suggest that the same precipitous decline may occur again,[11] with some scientists suggesting a 50:50 chance that the North Pole will be ice-free this summer.[12] Arctic sea ice is important both because of the albedo feedback effect and because sea ice melt leads to a warmer Arctic Ocean, which in turn accelerates the melt rate of the Greenland ice sheets.

The best basis for determining tipping points may be the use of paleoclimate data. Based on such data, Hansen and colleagues have estimated that remaining at CO_2 concentrations above 350 for a prolonged period of time is likely to invoke tipping points (Hansen et al. 2008). Paleoclimate data also indicate that in the past, at temperatures expected to be reached by 2100, Greenland and Antarctica contributed several meters to sea level. (Overpeck et al. 2006). The rate of rise at this temperature was approximately 1.6 m/century. (Rohling et al. 2008). Thus, the current CO_2 level of 385 ppm is not only "dangerous," but catastrophic and could lead to tipping points this century. No models, including those used by the IPCC, can capture the dynamic response of ice sheets or adequately predict current observations of sea level rise. (DEIS at 3-75; Rignot 2008).

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[11] For up-to-date information on sea-ice extent, see the National Sea Ice Data Center (NISDC) Arctic Sea Ice News and Analysis, *available at* http://nsidc.org/arcticseaicenews/ (last visited August 12, 2008). The May 5, 2008 report explains why there is a greater than 50% chance that the sea ice extent for the summer of 2008 will actually be smaller than that in 2007. The August 11, 2008 report documents extensive, recent sea ice loss. The annual minimum will not occur until September.
[12] Alan Duke, *North Pole Could be Sea-ice Free this Summer, Scientists Say*, reported at CNN.com, *available at* http://www.cnn.com/2008/WORLD/weather/06/27/north.pole.melting/ (last visited August 12, 2008).

This is not an excuse, however, for the DEIS to dismiss this critically important issue. The DEIS cannot rely solely on model results to predict sea level rise. Instead, the prediction should be based on the sea level measurements from paleoclimate data, which indicate that in the past sea level was approximately 25 meters higher at temperatures only 2-3° C of warmer and atmospheric CO2 concentrations of 350 – 450 ppm. (Hansen 2007). For comparison, the DEIS predicts that temperature in 2100 under the A1B "business as usual" scenario will be approximately 2.7° C warmer. DEIS at 3-63, Table 3.4-5. Although the DEIS acknowledges that Rahmstorf (2007) has predicted a sea level rise of over 1 m by 2100, even his prediction does not capture the non-linearity of ice-sheet loss (Hansen 2007). If this non-linearity is taken into account, "business as usual" sea level rise this century is more likely to be on other order of 5 m (*Id.*; Overpeck et al. 2006).

Given the strong scientific evidence that sea level will rise by substantially more than predicted in the IPCC Fourth Assessment report, the EIS's analysis, both qualitative and quantitative, must be adjusted to account for the economic impacts of severe and abrupt climate change. It is certain that sea level will rise significantly this century, and assuredly at a rate much greater than that reported in the DEIS. Regardless of the actual numerical value, the amount of increase will be enough to constitute a major environmental and economic impact. Economic analyses exist to estimate the economic impact of such an event. (Stern 2007).[13] As a result, the DEIS must include the substantial economic cost in the cost-benefit analysis.

Reaching any single tipping point can bring severe economic and ecologic consequences. But perhaps more worrisome is the linkage between tipping points such that reaching one tipping point may in turn trigger a second. An example is the connection between Arctic sea ice and permafrost melt rates. Permafrost refers permanently frozen land; this surface stores large amounts of carbon. As permafrost thaws due to global warming, it releases carbon, often as methane. (Christensen et al. 2004). Methane has a global warming potential that is approximately 25 times greater than that of carbon dioxide over 100 years. The release of methane as permafrost thaws creates a positive feedback loop that may result in a climate tipping point. *Id.* Recent evidence indicates that the loss of Arctic sea ice, one tipping point, accelerates permafrost thaw, a second tipping point. (Lawrence et al. 2008). The multiplicative effect of reaching several tipping points on a similar time scale would drastically increase the costs associated with climate change.

C. The DEIS lacks any discussion of solutions

After summarizing an environmental problem, the next required task of an EIS is to discuss ways to reduce the project's impact and solve the problem. This rulemaking is particularly well suited for such an analysis since EPCA requires the fuel economy standard to be set at the "maximum feasible" level and higher fuel economy standards result in lower greenhouse gas emissions. Yet the failure to discuss solutions is one of the DEIS's most glaring failures.

In the bizarre and constrained world presented in the DEIS, there is no solution to global warming. The full range of alternatives considered by NHTSA, combined with NHTSA's assumptions, discussed below, result in atmospheric CO_2 concentrations of between 705.4 and 708.6 ppm. DEIS at 2-

[13] *Available at* http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_Report.cfm.

16. While global warming is indeed a daunting problem, presenting the analysis in this truncated form leaves the false impression that nothing can be done about it, violating both the letter and the spirit of NEPA. Leading scientists are able to tell us with a high degree of certainty that allowing CO_2 concentrations to rise to more than 700 ppm by the end of this century will result in catastrophic climate impacts. NHTSA has a mandatory duty to disclose in the DEIS what NHTSA can do to contribute to the solution.

NHTSA's failure to do so flows in many ways from its failure to discuss a reasonable range of alternatives and conduct an adequate impacts analysis, as discussed above. NHTSA's failure to discuss more stringent alternatives precluded it from discussing how much smaller the environmental costs of those more stringent alternatives would be. But NHTSA also continued to improperly skew the analysis in additional ways as discussed below.

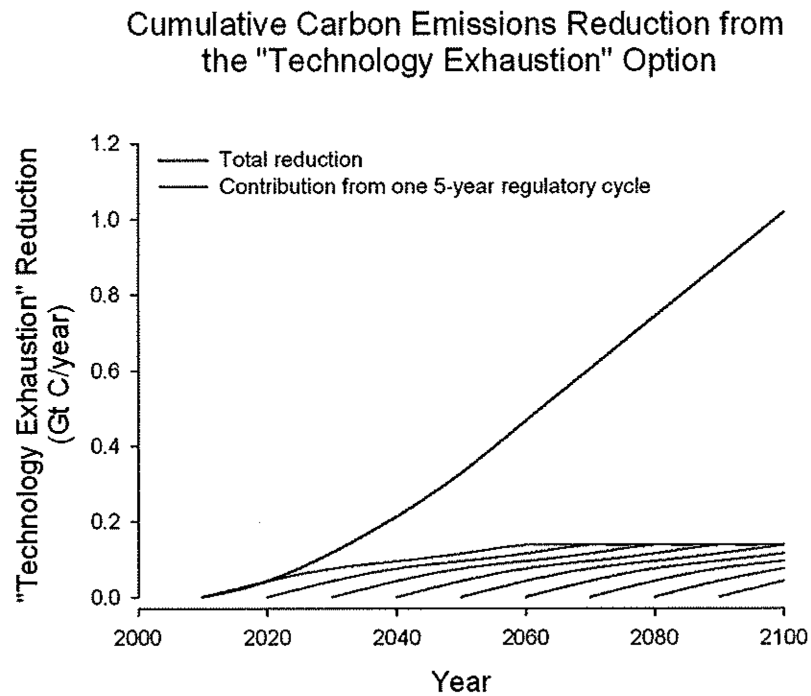
D. The DEIS impermissibly limits the analysis to assuming that future fuel standards will remain fixed at 2015 levels

One of the ways NHTSA minimizes the apparent impact of its rulemaking is to limit its analysis to a world in which fuel economy levels become fixed beyond the last year of the current rulemaking. To limit the analysis to this assumption is inconsistent with the statutory scheme, which of course requires that (1) fuel standards for the combined fleet reach a minimum of 35 mpg by 2020 and (2) the NHTSA set fuel standards must be set at the "maximum feasible level" each year. 49 U.S.C. § 32902(a); (b)(2)(C). This regulatory regime requires NHTSA to continue to raise standards each and every year through 2100. While the NHTSA may have been free to calculate and discuss the resulting environmental impact that would result from fixing the standard beyond the current rulemaking, disclosing only this piece of information was clearly not sufficient, especially given the statutory scheme that requires the NHTSA to continue increasing fuel economy to the maximum feasible level each year.

While the DEIS that the standards for 2011-2015 will impact the 2016-2020 standards, the DEIS improperly limits its analysis to the environmental impacts from the emissions of just those vehicles in the MY 2011-2015. Limiting the analysis in this manner allowed NHTSA to minimize the apparent impact of its action, because despite the fact that the lifetime emissions of these five model years of US vehicles will be massive, even this large chunk of emissions can be made to incorrectly appear insignificant if it is compared to a large enough number. In order to give a complete picture of this aspect of the problem, NHTSA should have compared its alternatives for model years 2011-2015 not just to the emissions that would result if fuel economy standards thereafter remained fixed, but also to the emissions that would result if fuel economy standards continued to improve along the trajectories established by each of a reasonable range of alternatives. Had NHTSA done so, the impact of its action would have appeared in a very different light. This is particularly true since technology innovation today will both amplify the gains that can be made in the auto industry in the future, and will also have spillover effects into other sectors of the economy. The NHTSA was required to address these issues in the DEIS, but failed utterly to do so.

Because of the application of technologies developed in response to a valid, technology-forcing CAFE standards to other sectors of the economy and in other countries, there should be a non-linear increase in projected reductions with increased stringency of fuel standards. The DEIS should have included an analysis of continual increases in fuel economy through year 2100. EPCA requires that *each year* the maximal fuel economy standard be established. It is certain that technology will continue to improve and thus that the maximum feasible fuel standards will continue to increase through 2100. As shown in the figure below, one way to estimate the emissions savings due to a continual increase in fuel economy would be to iteratively sum the projected reduction in CO_2 from the MY 2011-2015 standards (obtained from the difference between the "no action" and "technology exhaustion" alternative emissions in Table 3.4-2 of the DEIS) out to year 2100.

Figure 4: One potential mechanism for accounting for cumulative emissions reductions from continual compliance with the "maximum feasible" fuel standards requirement of EPCA. Each black line represents the reductions expected from a 5-year regulatory cycle. For illustrative purposes, the "technology exhaustion" reductions from DEIS Table 3.4-2 were used. The red line is the sum of reductions at each year. Year is shown on the abscissa, carbon emissions reduction per year is shown on the ordinate.



Employing this strategy results in a substantially greater effect than the artificial assumption in the DEIS that fuel economy will not improve after MY 2015. The cumulative carbon savings would be 39 Gigatons of carbon by year 2100, and a 15 ppm difference between "no action" and "technology exhaustion" in CO2 concentration in 2100. This value would be higher if the "technology exhaustion" option was not unreasonably constrained by the Volpe model. The DEIS doesn't include any information on this important issue.

The NHTSA then compounds the other errors in its analysis by presenting the effect of its action only as an improvement over the "no action" alternative, which NHTSA defines as leaving fuel economy standards unchanged. The true "no action" alternative is the technologically achievable fuel economy level. NHTSA's "action" is to reduce this level, based on its consideration of the other statutory factors. Therefore, NHTSA was required to disclose in the DEIS the additional greenhouse gas emissions that will result from its decision to set fuel economy standards far lower than the technologically feasible level. The NHTSA failed to do so, instead continuing to portray its rulemaking merely as an improvement over the status quo, when in fact the opposite is true: it has proposed standards that are far lower than what is achievable with today's and future technology, and far lower than current levels in other countries. The true effects of this decision must be disclosed.

Again, while NHTSA may have been free to quantify the environmental impacts that would result from fixing fuel economy standards at 2011 levels, including only this information and then analyzing only the difference between doing nothing and NHTSA's proposal, rather than the difference between NHTSA's proposal and the technologically feasible fuel economy level, violated NEPA.

E. The analysis of climate change resulting from each alternative is flawed

In addition to the structural flaws discussed above, the numerical results from the climate impacts analysis are invalid. Two methods are used to model the impact of each alternative: MAGICC 4.1 and a "scaling approach." DEIS at 3-50 & 3-51. The results from MAGICC are flawed because an old version of the software was used; the scaling approach is misleading and mischaracterizes climate impacts. Furthermore, the inputs to the MAGICC model were incorrectly constrained, as discussed above, by the Volpe model and thus the results do not represent the true climate impact of each alternative.

1. The presentation of MAGICC results creates the misleading impression that there is no difference between the alternatives.

MAGICC is used to estimate the increase in CO_2 concentration, global mean temperature, and sea level rise. The DEIS uses the SRES A1B-AIM scenario as a "baseline." The only comparisons in the DEIS are among the three SRES "business as usual" scenarios: B1, A1B, and B2. This analysis, however, is incomplete because it ignores the fact that in order to avoid catastrophic climate impacts greenhouse gas concentrations must be quickly reduced back to below 350 ppm. SRES A1B-AIM results in CO2 concentrations of 715 ppm in year 2100—far above dangerous CO_2 levels. A more appropriate comparison would be one of the "WRE" stabilization scenarios that are included in the MAGICC software. These stabilization scenarios are provided for 350 to 750 ppm stabilization.

Regardless of the baseline that is selected, the numerical results do not accurately reflect the state of the science. The DEIS relies heavily on the IPCC's Fourth Assessment Report, published in 2007. The model version used for numerical analysis, however, is calibrated to the Third Assessment Report, which was published in 2001. The MAGICC software has been updated to reflect the values reported in the Fourth Assessment report; the newest version is MAGICC 5.3. This update has important changes from version 4.1. These changes include:

- Values for climate forcings were updated and two new forcings for nitrates and land use were included
- The stabilization scenarios now include stabilization strategies for non-CO_2 gases as well as CO_2

- The method of sea level rise was improved to be more consistent with the IPCC Fourth Assessment Report
- Default climate sensitivity was changed from 2.6° C to 3.0° C, in conformance with the Fourth Assessment Report

Most importantly, the modeling results should be presented with the disclaimer that non-linear responses are not included in the predictions. Emphasis should be placed on the fact that (1) the model does not capture actual sea level rise predictions because it does not include ice sheet dynamics and (2) the model does not include the impact of rapid increases in methane from widespread loss of permafrost.

2. *The "scaling approach" is misleading and does not add any helpful information to the DEIS*

The "scaling approach" used in the DEIS is intended to test the effect of intermediate emissions scenarios. This is accomplished through linear interpolation between the relative outputs of three SRES scenarios: B1, A1B, and A2. This same estimate can be obtained by designating a "GAS" file in MAGICC that has intermediate CO_2 emissions.

From the skeletal description in the DEIS, it appears that (in a nutshell) the process involves taking the difference between the annual emissions (inputs) and the outputs (temperature, sea level, CO_2 concentration) associated with each of the SRES scenarios. The percentage change from "baseline" emissions for each alternative is then used to scale the outputs from the baseline scenario. See DEIS at 3-50. At a minimum, the calculation explanation must be improved, preferably with step-by-step examples to make the calculation accessible to the general public, as required by NEPA.

The underlying assumption to this process is that a linear transform will adequately describe the response to a change in emissions levels. Yet, as acknowledged in the DEIS at 3-52, climate interactions are non-linear. To test the linearity of the change between SRES scenarios, we ran an intermediate scenario in which the input annual carbon emissions were set at the midpoint between B1 and A1B. We then plotted the output variables. Examples are shown below. The numerical differences between each of the SRES scenarios and the intermediate scenario were not symmetrical. This indicates that climate outputs are not linearly related to emissions levels, violating the assumption of linearity upon which the scaling approach is based.

As acknowledged in the DEIS, the climate system is non-linear. DEIS at 3-52. Thus, it is not surprising that a linear transform between SRES scenarios is an inaccurate approximation of climate response.

Of course, comparing the scaling approach to MAGICC outputs assumes that MAGICC has accurately approximated the dynamics of the climate system. It seems likely, however, that MAGICC is the superior approximation. The MAGICC simulation routine has been extensively used by the IPCC and subjected to peer review. In contrast, no citations are provided in the DEIS that indicate the "scaling approach" has been subjected to similar scrutiny. Thus, the NHTSA should consider the MAGICC outputs more reliable. Furthermore, the DEIS provides no explanation why the "scaling approach" was deemed necessary.

In the following two figures, outputs from MAGICC are plotted as a function of year. In each plot, the values on the y-axes represent the difference between an SRES scenario (either B1 or A1B) and an "intermediate" scenario. The intermediate scenario was generated by creating a MAGICC "GAS" file that has emissions for each year that are the average of the emissions for B1 and A1B. One would expect that if there was a linear relationship between the change in outputs due to a change in inputs (emissions/year), these lines would overlap.

Figure 5: Difference in CO_2 Concentration between SRES Scenarios B1 and A1B and the "Intermediate" Scenario.

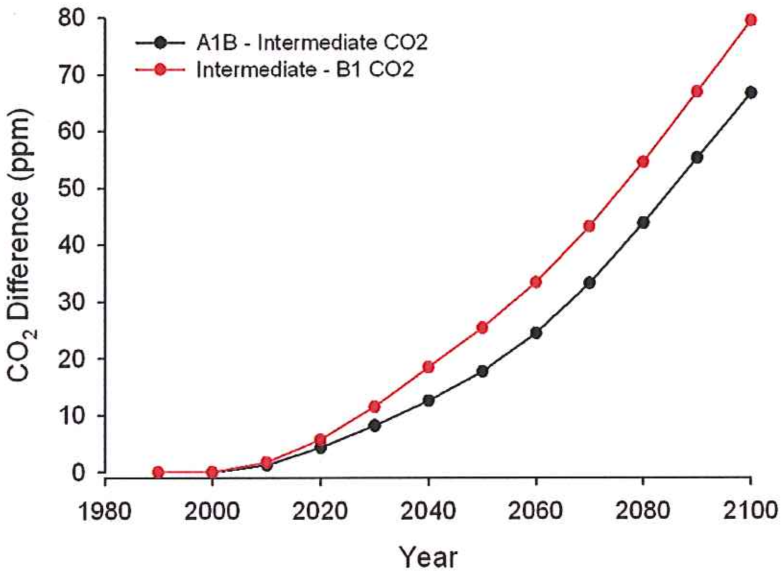
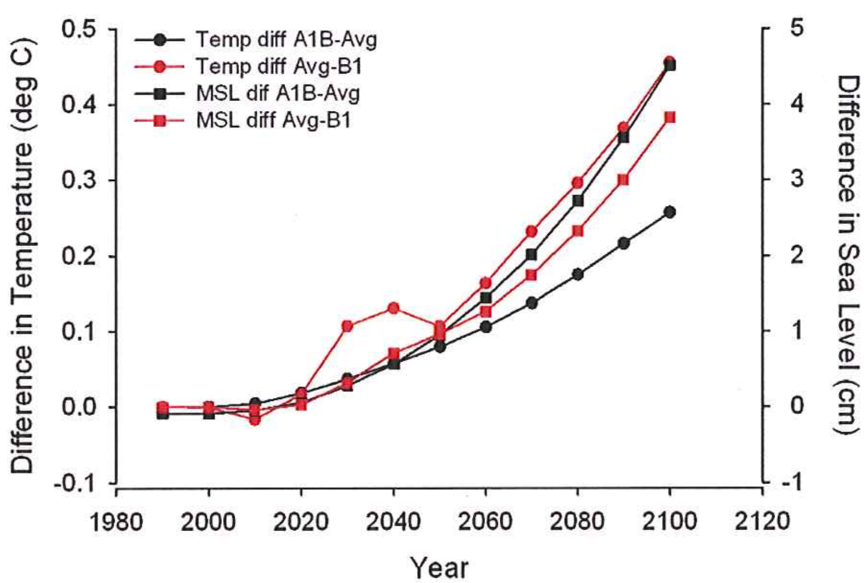


Figure 6: Difference in Temperature and Mean Sea Level between SRES Scenarios B1 and A1B and the "Intermediate" Scenario.



With regard to the scaling approach for temperature change, the results from the scaling approach indicate a smaller change in temperature at equilibrium than the MAGICC results [version 5.3]. Furthermore, if a comparison of temperature sensitivity is desired, this is easily accomplished by changing this one parameter in MAGICC. The "bounding analysis" for temperature change in 2100 is also unnecessary as one of the outputs of MAGICC is the temperature in year 2100. The temperature change for year 2100 as predicted by MAGICC is much larger than suggested by the "bounding analysis."

The "scaling approach" as applied to sea level is also misleading. First, MAGICC 5.3 reports increments of sea level rise of 0.1 mm – not 1 mm as reported in the DEIS. Thus, the MAGICC results can resolve sea level rise to the same precision as the "scaling approach."

The example of the scaling approach as applied to sea level and as illustrated in Table 3.4-14 is obscure and impossible to follow. Data appears to be missing from Table 3.4-14 (column 1) and the values do not appear to correspond to the steps outlined on page 3-77. This needs to be clarified so that readers can assess the validity of the numerical results. The value for sea level rise for "no action" corresponds to the midpoint for the B1 scenario (28.0 cm), not the A1B scenario (34.5 cm) that is purportedly represented in Table 3.4-14. If the steps provided on page 3-77 are carried out, it appears that the difference between alternatives for sea level rise is approximately double the range of values reported in Table 3.4-14.

Regardless, the approach itself is deeply flawed. First, using the IPCC estimates of potential sea level rise does not correct the shortcomings in MAGICC. The IPCC did not account for ice sheet dynamics in any of their estimates. As a result, any modeling or scaling attempt will not capture the most important components of sea level rise, as acknowledged in the DEIS at 3-76. As a result any attempt to estimate sea level rise from IPCC data will be deeply flawed. If a scaling approach is to be used, it should be based on paleoclimate data predicting the sea level rise associated with various temperature and CO_2 concentrations.

Second, the scaling approach purports to correct for "overstatements" due to inertia in the climate system. Yet any apparent "bias" is *created* by applying the "scaling approach" from the DEIS. If an accepted model such as MAGICC is employed, the effects of climate inertia will be properly accounted for without being overly represented in the results. Thus, the solution to "overstatements" of climate inertia is to avoid using the scaling approach.

Third, the scaling approach as applied to sea level change uses inaccurate values from Table 3.4-7, the temperature "scaling approach" results. When compared to the results from MAGICC at differing climate sensitivities, the scaling approach results in smaller differences in temperatures between alternatives. This in turn pollutes the results from the sea level scaling approach, making the sea level differences seem smaller.

F. The DEIS Fails to Adequately Address Ocean Acidification

The DEIS ignores one of the major, direct impacts of increased atmospheric CO_2: ocean acidification. Carbon dioxide is readily exchanged between the atmosphere and the sea surface. The increase in CO_2 is a direct result of human activity—fossil fuel burning. Due to the fact that the ocean has a carbonate buffer system, an increase in aqueous CO_2 reduces the concentration of carbonate while increasing the concentration of bicarbonate. The direct result is a decrease in ocean pH.

The reduction in free carbonate ions harms organisms that form calcium carbonate shells. There is a profound impact on the entire marine ecosystem due to the fact that many calcifying plankton, the basis of the food web, are severely affected by ocean acidification. Furthermore, organisms such as fish also experience direct effects from increased ocean CO_2, which include metabolic, immune, and reproductive dysfunction.

There is an extremely high level of scientific consensus regarding the destructive effects of ocean acidification. A recent comment letter signed by the top 25 marine scientists who study ocean acidification emphasized that the decrease in pH due to un-checked CO_2 emissions will be devastating and irreversible on human time scales (Caldiera and 25 others, 2007).

Ocean acidification has also been recognized by advisory bodies. For instance, the USCOP characterizes climate change as "among the most pressing scientific questions facing our nation and the planet." (USCOP Ocean Blueprint 2004). Furthermore, the USCOP report states that ocean acidification is impairing some organisms and has "potentially profound impacts on marine production and biodiversity." *Id.* The resulting recommendation is that scientific information be used to modify management strategies. Likewise, the Pew Commission discussed the myriad effects of climate change on marine life, including changes in ocean chemistry. The report stated that the Commission "feels strongly" that the U.S. must reduce its emission of greenhouse gases to limit injury to the marine environment. (Pew Oceans Commission Living Oceans, 2003).

The oceans have already taken up about 40% of the CO_2 that humans have produced since the industrial revolution, and this has lowered the average ocean pH by 0.11 units (Sabine et al. 2004). Although this number may sound small, it represents a significant change in acidity. The ocean takes up about 30 million metric tons of CO_2 each day (Feely et al., 2008). While preindustrial levels of atmospheric CO_2 hovered around 280 ppm (Orr et al. 2005)), they have now increased to 380 ppm; if current trends continue they will increase another 50% by 2030 (Turley et al., 2006). Over time, the ocean will absorb up to 90% of anthropogenic CO_2 released into the atmosphere (Kleypas et al. 2006).

Unlike future climate change, the pH change in response increased atmospheric CO_2 is relatively easy to predict because it involves basic chemical reactions and is unlikely to be affected by global temperature change (McNeil & Matear 2006). Thus, there is a strong consensus in the field that the oceans will undergo extensive acidification as the atmospheric CO_2 concentration rises.

Studies have established that anthropogenic CO_2 is the direct cause of the decrease in ocean pH. For instance, a tracer technique can be used to separate naturally occurring and dissolved carbon from that due to human activity (Gruber et al. 1996). Oceans absorb CO_2 more slowly than humans are currently releasing it. Current levels of anthropogenic CO_2 have virtually guaranteed that ocean pH will continue to decrease in the foreseeable future. Anthropogenic CO_2 emissions will result in a decrease in oceanic pH of 0.4 units by 2100 according to a model based on "business as usual" IPCC scenarios (Caldeira & Wickett 2003). This would constitute a catastrophic pH level (Zeebe et al. 2008). Disastrous impacts to marine ecosystems can only be avoided with rapid reductions in CO_2 emissions. *Id.*

Despite the strong scientific consensus and direct connection between CO_2 emissions and oceanic pH, the DEIS treats ocean acidification as an indirect, cumulative impact. This is unacceptable. The ecological impacts of the proposed CAFE standards on ocean acidification must be fully analyzed. Ocean acidification is even more predictable than changes in temperature or sea level rise, for instance. Yet, the DEIS makes no effort to quantify the influence of the alternatives on ocean pH. Furthermore, the DEIS fails to consider the economic costs of the collapse of the ocean food web. This cost must be included in any cost-benefit assessment conducted by NHTSA to accurately reflect the proper balance between the costs and benefits of reducing CO_2 emissions.

G. The DEIS Fails to Analyze the Impact of Black Carbon

Although the DEIS quantifies CO_2 emissions, it utterly fails to address black carbon, an important short-lived pollutant that contributes to global and regional warming. Black carbon is produced by incomplete combustion and is the black component of soot. Although combustion produces a mixture of black carbon and organic carbon, the proportion of black carbon produced by burning fossil fuels, such as diesel, is much greater than that produced by burning biomass. The CAFE standards will affect both gas and diesel engines, and may result in a higher percentage of diesel-fueled vehicles. Thus, it is essential to consider the impact of the new standards on black carbon emissions.

Black carbon heats the atmosphere through a variety of mechanisms. First, it is highly efficient at absorbing solar radiation and in turn heating the surrounding atmosphere. Second, atmospheric black carbon absorbs reflected radiation from the surface. Third, when black carbon lands on snow and ice, it reduces the reflectivity of the white surface which causes increased atmospheric warming as well as accelerates the rate of snow and ice melt. Fourth, it evaporates low clouds. Notably, black carbon is often complexed with other aerosols such as sulfates, which greatly increases its heating potential. (Ramanathan & Carmichael 2008; Jacobson 2001).

Due to black carbon's short atmospheric life span and high global warming potential, decreasing black carbon emissions offers an opportunity to mitigate the effects of global warming trends in the short term (Ramanathan & Carmichael 2008). Black carbon is considered a 'short-lived pollutant' (SLP) because it remains in the atmosphere for only about a week in contrast to carbon dioxide, which remains in the atmosphere for over 100 years. Furthermore, the global warming potential of black carbon is approximately 760 times greater than that of carbon dioxide over 100 years (Reddy & Boucher 2007) and approximately 2200 times greater over 20 years (Bond & Sun 2005). It is estimated that black carbon is the second greatest contributor to global warming behind carbon dioxide (Ramanathan & Carmichael 2008).

Unlike traditional greenhouse gases, which become relatively uniformly distributed and mixed throughout the Earth's atmosphere, black carbon exerts a regional influence. The impacts of black carbon on a regional level include both atmospheric heating, as discussed above, and hydrological changes. Hydrological changes occur due to alterations in cloud formation and heat gradients. *Id.* For instance, aerosol pollution has been linked to decreases in the summer monsoon season in tropical areas as well as the drought in the Sahel region of Africa. *Id.* Black carbon also impacts the drought-fire cycle. The more drought conditions prevail, the more forest fires burn, and the forest fires in turn emit massive quantities of black and organic carbon. The release of these aerosols intensifies the drought effect.

Another impact of black carbon is accelerated snowmelt; for instance, black carbon is likely contributing to the retreat of Himalayan glaciers and the resulting water shortage in areas of Asia. *Id.* When black carbon settles on snow, it makes the snow darker so that it absorbs more solar radiation. This directly leads to snow melt. In addition, local atmospheric heating due to black carbon increases the melting rate. These same effects may well be operating on mountain ranges in the U.S. such as the Sierra Nevada, which would reduce water availability throughout California, a highly populated region, at crucial times of the year.

Black carbon is also detrimental to human health. It has been linked to a variety of circulatory diseases. One study found an increased mortality rate was correlated with exposure to black carbon (Maynard 2007). The same is true for heart attacks (Tonne 2007). Another study found that residential black carbon exposure was associated with increased rates of infant mortality due to pneumonia, increased chronic bronchitis, and increased blood pressure (Schwartz 2007).

In developed countries, diesel burning is the main source of black carbon. Diesel emissions include a number of compounds such as sulfur oxides, nitrogen oxides, hydrocarbons, carbon monoxide, and particulate matter. Diesel particulate matter is approximately 75% elemental carbon. (EPA Diesel Health Assessment 2002). Furthermore, global inventories of emissions rates from a variety of sources exist to facilitate quantitative estimates. (See, e.g., Bond et al. 2004). Thus, it is crucial that black carbon be addressed in the DEIS.

1. Analyzing Particulate Matter is Insufficient to Address Black Carbon

Particulate matter (PM) refers to the particles that make up atmospheric aerosols. The primary constituents of PM are sulfates, nitrates, and carbon compounds. Sulfates and nitrates form in the atmosphere from the chemical reaction of sulfur and nitrogen dioxides. These may often be present as ammonium sulfate or nitrate salts. Carbon compounds may be directly emitted, e.g. black carbon emitted from combustion, or may form in the atmosphere from other organic vapors, e.g. oxidation of volatile organic compounds.

Because PM can be reduced through mitigation of other constituents of PM than black carbon, it is essential that black carbon emission reduction strategies be considered independently from PM reductions. The proportions of the constituents of PM vary over time and by location (see EPA Particle Pollution Report 2004). According to a recent series of surveys conducted at various U.S. cities under the EPA's "Supersite" program, black carbon was often only about 10% of total measured $PM_{2.5}$.[14]

[14] For an overview of the program and initial results see http://www.epa.gov/ttn/amtic/supersites.html

In contrast to total $PM_{2.5}$, diesel PM is composed largely of black carbon. Nonetheless, some diesel PM reduction strategies do not affect black carbon. For instance, diesel oxidation catalysts can reduce diesel PM emissions as a whole by approximately 20 to 40%, yet they do not decrease black carbon emissions (Walker 2004). In addition, while low-sulfur fuel will reduce sulfate emissions, in and of itself low-sulfur fuel will not reduce black carbon. Low-sulfur fuel is important because it *allows* for better technology to reduce black carbon. *See, e.g.* 69 Fed. Reg. 38957, 38995 (June 29, 2004). Yet those reductions can only occur once the technology has been implemented.

In summary, the climate and health impacts of black carbon are undeniable. The main source of black carbon in the U.S. is diesel. The CAFE standards may impact the diesel use if other regulatory mechanisms are not utilized. Thus, the cost-benefit analysis is incomplete because it does not include a monetization of the impacts of black carbon.

VI. The DEIS's cumulative impacts analysis is fundamentally flawed

A cumulative impact is defined under NEPA as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." 40 C.F.R. § 1508.7.

Global warming is the quintessential cumulative impact – the environmental problem caused by all contributing sources of greenhouse gas emissions together is far greater than that caused by any individual source. The purpose of the cumulative impacts section is to discuss the impact of the NHTSA's rulemaking on the problem overall when considered along with other actions. The NHTSA must place its action in the proper context in order to provide the reader with meaningful information about the impact of its action. For example, the DEIS should answer the question, "to what degree does the NHTSA rulemaking contribute to or hinder the achievement of the greenhouse gas emissions reductions necessary to avoid catastrophic climate change?" The DEIS fails utterly to do so.

The DEIS considered only a single factor in the cumulative impacts section beyond the rulemaking itself – the impact of fuel economy standards for model years 2016-2020. As discussed above, the impact of future fuel economy standards should have been incorporated into the analysis of direct and indirect impacts, as the level chosen by the NHTSA for one year will impact the level achievable in future years. Regardless, however, limiting the cumulative impacts analysis to only considering fuel economy standards for model years 2016-2020 is clearly inadequate on its face to comply with NEPA's requirements.

The DEIS must include a reasonable analysis of the combined impact of the NHTSA's rulemaking on U.S. transportation sector emissions overall, and U.S. emissions overall. For example, is the impact of the current rulemaking sufficient to ensure that the necessary emissions reductions from the U.S. transportation sector overall will be achievable? If the transportation sector does not achieve its "fair share" of necessary emissions reductions, after all, those reductions will have to come from a different sector. While the NHTSA will likely argue that it is difficult to conduct a cumulative impacts analysis for a problem such as greenhouse gas emissions, it is eminently feasible to do so. While the

NHTSA has some discretion in choosing the precise methodology of such an analysis, the agency was clearly not free to omit any such analysis altogether.

Recent scientific evidence indicates that to avoid tipping points and climate catastrophe, it will be necessary to reduce CO_2 emissions to 350 ppm (Hansen et al. 2008). This study uses the most comprehensive analysis to date of both slow and fast feedbacks on climate and reaches the conclusion that global CO_2 concentrations must be capped and reduced to 350 ppm to avoid dangerous and irreversible climate change. Much of the data is based on paleoclimate records, as opposed to computer modeling. The benefit of paleoclimate data is that the changes reflected in proxy measures actually occurred, as opposed to being predictions. The study provides evidence of large changes in sea level on decade time scales as well as past rates of sea level rise in excess of 1 m/century. Thus, a 350 ppm scenario should be included as context for analysis of cumulative impacts. This analysis is entirely possible because MAGICC, the software used to model the climate change impacts of each alternative, already includes various alternative scenarios in which future emissions are controlled so that atmospheric CO_2 concentrations do not exceed values ranging from 350 to 750 ppm.

Moreover, as discussed above, the DEIS is inadequate because it failed to take into account the real world iterative nature of fuel economy improvements, that is, the fact that fuel economy increases today contribute to the capacity for higher levels tomorrow. This DEIS's failure to analyze this crucial issue infected the cumulative impacts analysis as well.

VII. NHTSA must complete an Endangered Species Act Section 7 Consultation to ensure that its action will not jeopardize or adversely modify the critical habitat of any species listed as "threatened" or "endangered"

Congress enacted the Endangered Species Act ("ESA") to conserve endangered and threatened species and the ecosystems upon which they depend. 16 U.S.C. § 1531(b). The Supreme Court's review of the ESA's "language, history, and structure" convinced the Court "beyond a doubt" that "Congress intended endangered species to be afforded the highest of priorities." *Tennessee Valley Authority v. Hill*, 437 U.S. 153, 174 (1978). As the Court found, "the plain intent of Congress in enacting this statute was to halt and reverse the trend toward species extinction, whatever the cost." *Id.* at 184.

Species are added to the lists of endangered and threatened species by the U.S. Fish and Wildlife Service (with jurisdiction over most terrestrial and freshwater species) and the National Marine Fisheries Service (with jurisdiction over most marine species) (collectively, the "Services"). A species is "endangered" if it "is in danger of extinction throughout all or a significant portion of its range." 16 U.S.C. § 1532(6). A species is "threatened" if it "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." 16 U.S.C. § 1532(20).

Once a species is listed under the ESA, Section 7 requires all federal agencies to "insure" that their actions neither "jeopardize the continued existence" of any listed species nor "result in the destruction or adverse modification" of its "critical habitat." *Id.* at § 1536(a)(2). In addition, the "take" of listed species is generally prohibited. *Id.* at § 1538(a); 50 C.F.R. § 17.31(a). "Take" means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." 16 U.S.C. § 1532(19). The Services may, however, permit "incidental" take on a case-by-case basis if it finds, among other things, that such take will be minimized and mitigated and that such take will not "appreciably reduce the likelihood of survival and recovery of the species." *Id.* at § 1539(a).

Section 7 consultation is required for "any action [that] may affect listed species or critical habitat." 50 C.F.R. § 402.14. Agency "action" is defined in the ESA's implementing regulations to include "all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States or upon the high seas. Examples include, but are not limited to: (a) actions intended to conserve listed species or their habitat; (b) the promulgation of regulations; (c) the granting of licenses, contracts, leases, easements, rights-of-way, permits, or grants-in-aid; or (d) actions directly or indirectly causing modifications to the land, water, or air." 50 C.F.R. § 402.02 (emphasis added).

This regulatory definition of "action" clearly encompasses NHTSA's rulemaking, since the emissions from the regulated automobiles unquestionably will cause "modification to the land, water, or air." The U.S. Fish and Wildlife Service's and National Marine Fisheries Service's Consultation Handbook, Procedures for Conducting Consultation and Conference Activities under Section 7 of the Endangered Species Act (March 1998) explains the above terms and definitions. There can also be no question that the enormous volume of direct, indirect, and cumulative emissions from the regulated vehicles "may affect" listed species, and therefore the NHTSA must consult.

The NHTSA's rulemaking will impact species listed as threatened and endangered in several ways, yet the NHTSA has failed to initiate the required Section 7 consultations with the Services on its impact. The NHSTA must initiate and complete the required Section 7 consultations on the rulemaking, or it may be held liable for take of listed species from the impacts of its action, including increased greenhouse gas emissions and other emissions such as NOx.

On May 15, 2008, the U.S. Fish and Wildlife Service listed the polar bear as a threatened species throughout is range due to global warming. Endangered and Threatened Wildlife and Plants, Determination of Threatened Status for the Polar Bear (Ursus maritimus) Throughout its Range, 73 Fed. Reg. 28212-28303 (May 15, 2008). The NHTSA must consult on the impact of its rulemaking, and its proposal to set fuel economy standards far below what is technologically achievable, on the polar bear.[15]

[15] At the same time that the Secretary published the Final Listing Rule he also issued separate regulations, pursuant to Section 4(d) of the ESA, 16 U.S.C. § 1533(d), which authorize the widespread incidental take of polar bears and purport to exempt greenhouse gas pollutants from Section 7's consultation requirements. Endangered and Threatened Wildlife and Plants, Special Rule for the Polar Bear, 73 Fed. Reg. 28306-28318 (May 15, 2008) ("4(d) Rule"). In a section of the 4(d) Rule entitled "Consultation under Section 7 of the ESA," the Secretary alleges that "the best scientific data currently available does not draw a causal connection between GHG emissions resulting from a specific Federal action and effects on listed species or critical habitat by climate change, nor are there sufficient data to establish the required causal connection to the level of reasonable certainty between an action's resulting emissions and effect on species or critical habitat." 73 Fed. Reg. 28306, 28313. NHTSA must not rely on this rule as an excuse to forgo consultation because it is contrary to the best available science and the legal standards for Section 7 consultation. Moreover, exempting greenhouse gas emitting actions from Section 7 cannot be legally accomplished through section 4(d) of ESA. The Center and co-plaintiffs are currently challenging the 4(d) rule in court. See, e.g. Second Amended Complaint in *Center for Biological Diversity v. Kempthorne*, Civ. No. 08-1339 (CW) (N. Dist. Cal.).

On May 9, 2006, the National Marine Fisheries Service listed the staghorn and elkhorn corals as threatened due in part to increasing ocean temperature and ocean acidification due to anthropogenic greenhouse emissions. 71 Fed. Reg. 26852. The NHTSA must consult on the impact of its rulemaking on these coral species. The NHTSA must also consult on the impact of its rulemaking on the polar bear's and the corals' critical habitat, once such habitat is designated.

Global warming was cited by the U.S. Fish and Wildlife Service in its critical habitat rulemakings for the Quino Checkerspot and Bay Checkerspot butterflies. See 73 Fed. Reg. 3328-3373 and 72 Fed. Reg. 48178-48218. The NHTSA must consult on the impact of its rulemaking on these species and their critical habitat.

The NHTSA must not limit its consultation, however, to species like the polar bear, corals, and checkerspot butterflies for which anthropogenic greenhouse emissions were cited as a reason for listing or as an impact in the listing or critical habitat rules. The Center has identified 143 listed species for which a recovery plan has been adopted that specifically identifies climate change or a projected impact of climate change as a direct or indirect threat to the species, as a critical impact to be mitigated, as a critical issue to be monitored, and/or as a component of the recovery criteria. See Exhibit A. This is clear evidence that the NHTSA's rulemaking "may affect" these species. The NHTSA must consult on the impact of its action all listed species which may be affected.

While we are cognizant that federal agencies, for the most part, have not to date been complying with their obligation to consult on the impact of their greenhouse gas emissions on listed species, and therefore there may be some capacity building required for this consultation, this can in no way be used an excuse for continued non-compliance with the law. The direct, indirect, and cumulative impacts of setting fuel economy standards for all cars and light trucks nationally are extraordinarily significant, and therefore a large number of species may be implicated. Where, as here, the NHTSA's rulemaking is national in scope, the NHTSA should conduct a nationally focused consultation. Again, the NHTSA must not attempt to use the large scale of its action as an excuse for ignoring its environmental review duties, since the highly significant nature of the action only makes it more important to thoroughly review its impacts under all applicable laws. Nor can the mere fact that a large geographical area or large number of species be used an excuse for inaction. See, e.g., *Wash. Toxics Coalition v. EPA*, 413 F.3d 1024 (9th Cir. Wash. 2005) (upholding order requiring the EPA to consult on the impact of 54 pesticide ingredients on 25 species of fish.). If anything, a nationally focused consultation will provide the opportunity to most efficiently analyze the impact of the rulemaking on species and groups of species.

The rulemaking will impact listed species in ways beyond global warming and ocean acidification. For example, vehicles are a primary source of excess nitrogen in the environment. Excess nitrogen contributes to major environmental problems including reduced water quality, eutrophication of estuaries, nitrate-induced toxic effects on freshwater biota, changes in plant community composition, disruptions in nutrient cycling, and increased emissions from soil of nitrogenous greenhouse gases (Fenn et al. 2003). Nitrogen deposition therefore impacts species listed under the Endangered Species Act in a number of ways.

Nitrogen deposition has contributed to the severe decline of the threatened bay checkerspot butterfly, endemic to the San Francisco Bay Area. (Fenn et al. 2003). The bay checkerspot butterfly is restricted to outcrops of serpentine rock which are low in nitrogen and support a diverse native grassland with more than 100 species of forbs and grasses, including the butterfly's host plants. (Fenn et al. 2003). Nitrogen deposition in the soil creates a more hospitable environment for non-native grasses which crowd out the butterfly's host primary host plant, *Plantago erecta.* (Fenn et al. 2003). Nitrogen deposition and increasing non-native grass invasion has similarly acted in concert with global warming and drought to extirpate the Quino checkerspot butterfly in much of its range in southern California. (Fenn et al. 2003).

Nitrogen deposition also contributes to type conversion of Southern California's coastal sage scrub vegetation community to non-native grasslands, threatening a host of species listed under the Endangered Species Act including the California gnatcatcher (Fenn et al. 2003). Nitrogen deposition is a problem in desert ecosystems, as well. The threatened desert tortoise is also impacted by the increased spread of non-native plants with lower nutritional value for the species (Fenn et al. 2003). Protection and recovery efforts for many threatened and endangered species may therefore not succeed without regional and national level policies to reduce air pollution (Fenn et al. 2003).

The NHTSA must complete the required consultations on the impact of its rulemaking on species listed as threatened and endangered under the Endangered Species Act. The NHTSA remedy its violations of EPCA and NEPA, discussed throughout, which mask the true impact of the rulemaking, prior to completing the consultations so that the fundamental flaws in the EPCA and NEPA analyses do not infect the ESA analysis.

VIII. The NHTSA's Inadequate Analysis of its Unlawfully Low Fuel Economy Proposal is Reflective of the Current Administration's Opposition to the Regulation of Greenhouse Gas Emissions

The countless flaws and errors in the NHTSA's analysis are gravely troubling even when viewed in isolation, but are even more so when viewed in conjunction with other ongoing regulatory processes. The Bush administration has opposed all regulation of greenhouse gas emissions, and has resorted to extraordinary and illegal actions in order to block any such regulation. A brief review of other ongoing processes reveals this administration's truly unprecedented contempt for the law, and provides insight into how and why NHTSA released such a flawed proposal and DEIS.

In 2000, George W. Bush campaigned on a pledge to regulate carbon dioxide emissions as central component of his energy policy.[16] His administration's relentless opposition to such regulation, however, began immediately after he took office. In a March 13, 2001 letter, Bush proclaimed: "I do not believe, however, that the government should impose on power plants mandatory emissions reductions for carbon dioxide, which is not a 'pollutant' under the Clean Air Act."[17] Vice President Cheney said of Bush's campaign pledge, "It was a mistake because we aren't in a position today to...cap

[16] For example, on Sept. 29, 2000, while campaigning in Saginaw, MI, Bush said: "We will require all power plants to meet clean-air standards in order to reduce emissions of carbon dioxide within a reasonable period of time." http://thinkprogress.org/2006/07/07/co2-pledge/.
[17] http://www.whitehouse.gov/news/releases/2001/03/20010314.html.

emissions." That flip-flop set the stage for eight years of stubborn opposition to common sense and legally mandated controls for greenhouse gas emissions, as well as an ever expanding constellation of scandals.

The central scandal of the climate change arena is the administration's refusal to regulate greenhouse gas emissions pursuant to Section 202 of the Clean Air Act. The EPA's rejection of a petition from the International Center for Technology Assessment and others to regulate greenhouse gas emissions from automobiles caused years of delay but led ultimately to the Supreme Court's April 2007 ruling in *Massachusetts v. EPA*. In that decision, the high court ruled that carbon dioxide is a "pollutant" and ordered the EPA to determine whether it can "reasonably be anticipated to endanger public health or welfare." An affirmative answer, known as the "endangerment finding," would require regulation under the Clean Air Act.

The administration has thus far refused to release such a finding. Following the Supreme Court's ruling, the EPA produced a draft endangerment finding that concluded, according to notes produced by Senator Barbara Boxer's staff who viewed the document, that "elevated levels of [greenhouse gas] concentrations may reasonably be anticipated to endanger public welfare." (Senate EPW Staff Report 2008). While such a finding would have led to regulation, it is a vast understatement and addresses only the public welfare prong while omitting the public health prong.

Former EPA Associate Deputy Administrator Jason Burnett told Congress that EPA staff had hoped to win White House approval of the agency's finding by omitting discussion of health impacts, which the EPA has elsewhere admitted include increased heat-related illness and death, increased heart and lung illness from increased ozone levels associated with higher temperatures, increased spread of air and water-borne pathogens, and other impacts (Burnett Letter July 6, 2008; Burnett EPW Testimony July 22, 2008).

This omission is evidence of one of the most insidious results of the crushing political interference to which this administration has subjected virtually every major regulatory process: self-censorship among government employees. Many scientists and regulators now walk a tortured path between what a statute requires and what they think the administration might approve.

Not surprisingly, the appeasement approach didn't work with regard to regulation of greenhouse gas emissions from vehicles under the CAA. When the EPA transmitted the draft endangerment finding to the White House on December 5, 2007, the administration refused to "open the attachment," ultimately leading to Burnett's resignation. With the December 5 draft unopened, the EPA instead converted the endangerment finding into a bizarre advance notice of proposed rulemaking (73 Fed. Reg. 44354. "ANPR"). Even the ANPR, which is nothing more than a stall tactic to further delay regulation, was subjected to intense political manipulation. Between a May 30, 2008 draft and publication in the Federal Register, EPA's modeling inputs were changed in order to understate the benefits and overstate the costs of regulating greenhouse pollutants. Cf. May 30, 2008 Draft ANPR draft to 73 Fed. Reg. 44354.

EPA Administrator Stephen Johnson's announcement of the ANPR could easily have been lifted straight from a George Orwell novel. Johnson's statement, "I believe … the Clean Air Act, an outdated law originally enacted to control regional pollutants that cause direct health effects, is ill-suited for the task of regulating global greenhouse gases," perfectly encapsulates this administration's contempt for the law, science, and "reality-based" governance.

The reality is that the Clean Air Act is our most successful law for protecting the air we breathe and, consequently, our health and welfare. Since the law's enactment forty years ago, emissions of toxic lead have dropped 98 percent, emissions of sulfur dioxide, a major component of acid rain, have fallen by 35 percent, and emissions of carbon monoxide – a once-common, and deadly, pollutant in the air above most American cities – have been reduced by 32 percent even though driving has increased. Moreover, the economic value of the air quality improvements has been many times greater than the cost of the regulations.

The Clean Air Act has ready-made provisions to regulate greenhouse gas emissions not only from automobiles, but also from power plants, ships, airplanes, offroad engines, and other sources. It is a senseless tragedy that Americans have been deprived of the benefits of applying the Clean Air Act's successful regulatory strategies to greenhouse pollutants while emissions from automobiles, ships, airplanes and other sources continue unabated.

The administration's opposition to regulation was driven home with letters from agency heads placed at the beginning of the ANPR. These letters show the raw politics that pervaded the administrative process. A letter signed by Mary E. Peters, U.S. Department of Transportation Secretary and three other agency heads asserts that it is simply not "desirable" to regulate greenhouse gas emissions. 73 Fed. Reg. 44362. Moreover, the letter asserts (incorrectly) that regulation could not possibly do any good:

> Petroleum product prices have doubled in two years, equivalent to a carbon tax of $200 per metric ton, far in excess of the cost of any previously contemplated climate change measure. Operators are searching for every possible operating economy, and capital equipment manufacturers are fully aware that fuel efficiency is a critical selling point for new aircraft, vehicles, and engines. At this point, regulations could provide no more powerful incentive for commercial operators than that already provided by fuel prices.

Id.

Finally, the agency heads make the breathtaking assertion that "the United States can only effectively address GHG emissions and global climate change in coordination with other countries, and by addressing how to regulate GHG emissions while considering the effect of doing so on the Nation's energy and economic security." 73 Fed. Reg. 44365. It is astounding that after eight years of the Bush State Department relentlessly blocking even any discussion of, let alone movement towards, mandatory international limits on greenhouse pollutants through the U.N. Framework Convention on Climate Change, that the any political appointee would have the gall to assert that domestic action cannot proceed prior to international action. It is nothing short of insane for the U.S. Transportation Secretary, while asserting that the "maximum feasible" fuel economy that can be achieved in the U.S. in 2015 is less than the current standard in China, to simultaneously assert that it is lack of international progress that is holding the U.S. back.

While the administration has refused to regulate greenhouse pollutants pursuant to Section 202 of the Clean Air Act, it has also blocked California's efforts to implement its Clean Vehicle Law (AB 1493, 2002) by refusing to issue the required waiver under the Clean Air Act. Administrator Johnson announced his decision to deny the waiver on December 19, 2008. It later emerged that Johnson had overruled the explicit conclusions of his professional staff (House Oversight Committee Memo May 19, 2008). Administrator Johnson then apparently lied to Congress about the process, prompting Congressional calls for an investigation by Attorney General Michael Mukasey and calls for his resignation. (Senators Boxer et al. letter July 29, 2008; Senate EPW Call for Resignation July 29, 2008).

And while the administration continues to assert, incorrectly, that regulation of emissions from automobiles is equivalent to the regulation of fuel economy, the administration has, of course, just proposed the current set of pathetically inadequate fuel economy standards, despite the Ninth Circuits invalidation of the last set of inadequate standards in *Center for Biological Diversity* less than 9 months ago.

The administration has continued to block progress on implementing solutions to global warming at every level, and has resorted to a level of censorship and suppression of science never before seen in this country. Well publicized examples include attempts at censoring the nation's top climate scientist, Dr. James Hansen, at NASA (Revkin 2006), suppression of the scientific assessment of climate change impacts in the United States required by the Global Change Research Act of 1990 (*see Center for Biological Diversity v. Brennan*, No. C-06-7062 SBA (N.D. Cal. August 21, 2007), extensive editing of climate change assessment documents by Philip Cooney (Revkin 2005) and political interference in the Endangered Species Act listing process for the polar bear.

Political interference in government climate science has become pervasive in the past five years. As the Union of Concerned Scientists found:

> In the summer of 2006, the Union of Concerned Scientists distributed surveys to more than 1,600 climate scientists working at seven federal agencies and the independent National Center for Atmospheric Research (NCAR), asking for information about the state of climate research at federal agencies. Scientists' responses indicated a high regard for the quality and integrity of federal climate research itself, but also identified broad and substantial interference in their work.
>
> The reality of global warming, including the role of heat-trapping gases from human activities in driving climate change, has been repeatedly affirmed by scientific experts. Every day the government stifles climate science is a day we fail to protect future generations from the consequences of global warming. It is crucial that climate scientists be allowed to accurately inform government decisions. For this to occur, the federal government must pursue reforms that prohibit political interference and misrepresentation of federal climate science research, and affirm the right of scientists to communicate freely with the media and the public....

I. Political Interference with Climate Science

Large numbers of federal climate scientists reported various types of interference, both subtle and explicit:

- 73 percent of all respondents* perceived inappropriate interference with climate science research in the past five years.
- 58 percent of all respondents personally experienced interference with climate science research in the past five years. This number increased to 78 percent among scientists whose work always or frequently touches upon sensitive or controversial topics. In contrast, only 22 percent of NCAR scientists personally experienced interference with climate science research.
- Nearly half of all respondents (46 percent) perceived or personally experienced pressure to eliminate the words "climate change," "global warming," or other similar terms from a variety of communications. This number increased to nearly three in five (58 percent) among respondents from the National Oceanic and Atmospheric Administration (NOAA).
- 46 percent of all respondents perceived or personally experienced new or unusual administrative requirements that impair climate related work.

II. Scientific Findings Misrepresented

Federal climate scientists reported that their research findings have been changed by non-scientists in ways that compromise accuracy:

- Two in five respondents (43 percent) perceived or personally experienced changes or edits to documents during review processes that changed the meaning of scientific findings.
- 25 percent perceived or personally experienced situations in which scientists have actively objected to, resigned from, or removed themselves from a project because of pressure to change scientific findings.
- 37 percent of respondents perceived or personally experienced instances in which their agency misrepresented scientists' findings.

III. Barriers to Communication

Agency scientists are not free to communicate their research findings to the media or the public:

- 52 percent of respondents said their agency's public affairs officials always or frequently monitor scientists' communications with the media. In contrast, only seven percent of NCAR respondents reported that same level of monitoring.
- Two in five respondents (39 percent) have perceived or personally experienced "fear of retaliation for openly expressing concerns about climate change outside their agency."
- 38 percent of respondents perceived or personally experienced "disappearance or unusual delay of websites, reports, or other science-based materials relating to climate."

- A majority of NASA respondents (61 percent) agreed with the statement, "Recent changes to policies pertaining to scientific openness at my agency have improved the environment for climate research," in sharp contrast to the 12 percent of non-NASA respondents who agreed with the statement. The high percentage among NASA respondents is most likely the result of a recent policy implemented at the agency that affirmed that the role of public affairs officers was not "to alter, filter or adjust engineering or scientific material produced by NASA's technical staff."

IV. Climate Scientists are Disheartened

While a large majority of respondents (88 percent) agreed with the statement, "U.S. federal government climate research is of generally excellent quality," respondents reported decreasing job satisfaction and a worsening environment for climate science in federal agencies:

- Two-thirds of respondents said that today's environment for federal government climate research is worse compared to five years ago (67 percent) and 10 years ago (64 percent). Among scientists at NASA, these numbers were nearly four in five (79 percent and 77 percent, respectively).
- 45 percent of all respondents said that their personal job satisfaction has decreased over the past few years. At NASA, three in five (61 percent) reported decreased job satisfaction.
- More than a third of respondents from NASA, and more than one in five (22 percent) of all respondents, reported that morale in their office was "poor" or "extremely poor." Among NCAR respondents, only seven percent reported such low levels of morale.
- Insufficient resources are a source of concern among respondents. More than half (53 percent) disagreed with the statement, "The U.S. government has done a good job funding climate research."

Survey Demographics

Surveys were sent to 1,630 scientists at the National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, U.S. Department of Energy, U.S. Department of Defense, U.S. Geological Survey, U.S. Department of Agriculture, and the independent (non-federal) National Center for Atmospheric Research (NCAR).

Responses came from 279 federal scientists and 29 NCAR scientists. One hundred forty-four scientists provided narrative responses. The response rate (19 percent) was fairly consistent across agencies. Eighty percent of the scientists who responded had earned a Ph.D. and 40 percent had completed some post-doctoral research work. A significant number of respondents (44 percent) had been with their agency for more than 15 years, and more than half had been there for more than 10 years.

(UCS 2006[18]; see also Oversight Committee 2008).

The administration has also repeatedly touted the discredited statements of a small number of pseudo-scientists funded by industry groups in order to sow doubt in the minds of Americans about climate change by manipulating the media (UCS 2007). This campaign has been extremely successful. Oreskes (2004) looked at 928 articles in the peer reviewed scientific journals dealing with climate change, and found 0% in doubt as to the cause of global warming (See also Oreskes 2006). Boykoff and Boykoff (2004) looked at 636 articles in the "prestige media" (NYT, WaPo, LA Times, WSJ) and found 53% of articles included a statement of doubt as to the cause of global warming.

It is readily apparent that the NHTSA's fuel economy proposal and DEIS violate the EPCA and NEPA. Yet when viewed in light of the administration's opposition to any regulation of greenhouse gas emissions and pervasive use of censorship and political interference to enforce its policies, the NHTSA's legal violations are all the more disturbing.

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X. Conclusion

Setting fuel economy standards for all cars and light trucks nationally is one of the single most important actions that the government can take to reduce greenhouse emissions. The NHTSA should correct the flaws identified above in the EPCA and NEPA analyses, and promptly propose and then finalize new fuel economy levels which actually achieve the "maximum feasible" level.

Thank you for the opportunity to submit these comments. Please contact Brian Nowicki at (916) 201-6938 if you have any questions or concerns.

Yours Sincerely,

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Exhibit A: Climate Change Impacts to Endangered Species Act Listed Species Documented in Recovery Plans

The following is a list of 143 species (including subspecies and distinct population segments) listed as Threatened or Endangered under the federal Endangered Species Act, for which a Recovery Plan has been adopted that specifically identifies climate change or a projected impact of climate change as a direct or indirect threat to the species, a critical impact to be mitigated, a critical issue to be monitored, and/or a component of the recovery criteria.

For each species, some or all of the relevant text is excised and cited to the page number in the Recovery Plan. The vast majority of these Recovery Plans is available on the public websites of the U.S. Fish and Wildlife Service or National Marine Fisheries Service, and the direct link is provided. A small number may be available only in hard copy.

This list is not necessarily all-inclusive, due to the difficulty of obtaining some recovery plans, and the search includes only plans adopted before May 2008.

Steller sea-lion (eastern DPS) *Eumetopias jubatus* (Eastern DPS)
Recovery plan for the Steller sea lion, eastern and western distinct population segments (Eumetopias jubatus) revision. 2008
www.nmfs.noaa.gov/pr/pdfs/recovery/stellersealion.pdf

(N)o threats to continued recovery were identified for the eastern DPS...However, concerns exist regarding global climate change and the potential for the southern part of the range (i.e., California) to be adversely affected. Future monitoring should target this southern portion of the range. (XIII)

If nutritional stress is being caused by an anthropogenic factor, it is probably linked to removal of important sea lion prey species by commercial fisheries (Atkinson et al. in press), although anthropogenic effects on climate could potentially have increasingly important impacts on sea lion prey in the coming decades. However, environmental features, such as oceanographic regime shifts, could also affect the relative abundance and distributions of key prey. (I-33)

Global climate change. Characteristics of recent climate change in the North Pacific were discussed in detail in Section III.H. In that section it was noted that some features of the ecosystems of the Pacific Northwest (California to British Columbia and southeast Alaska) and the northern North Pacific (Gulf of Alaska and Bering Sea) are out of phase, including recruitment of Pacific salmon and some groundfish stocks (Hollowed and Wooster 1992, Hare et al. 1999), and zooplankton biomass (Brodeur et al. 1996, Roemmich and McGowan 1995). Such variability may be due to patterns of transport in the North Pacific Current when it bifurcates off the coast of British Columbia to form the northward-flowing Alaska Current and the southward-flowing California Current (Wickett 1966, Hollowed and Wooster 1992). How such variations may affect organisms at the top of the trophic system, such as Steller sea lions, is unknown.

Sydeman and Allen (1999) investigated correlations between oceanographic features and population dynamics of central California pinnipeds Multiple regression analysis of sea surface temperatures and upwelling index versus abundance found no relationship for Steller sea lions. Additionally, despite documented shifts in climate and oceanographic processes that may have affected productivity at multiple trophic levels, California sea lion pup production along the US west coast has increased at approximately 5% per year since 1975 and the eastern DPS of Steller sea lion has also increased at approximately 3%/year with no apparent variability associated with climatic variation. Thus, although there have been documented and perhaps more frequent oceanographic and climatic changes, the population of Steller sea lions has not responded negatively from a Steller Sea Lion Recovery Plan population perspective. The most evident change is that all of the new rookeries in the eastern DPS have been established in Alaska at the northern end of the range suggesting a population shift to the north. (VI-5-6)

(N)o threats to continued recovery were identified for the eastern DPS...However, concerns exist regarding global climate change and the potential for the southern part of the range (i.e., California) to be adversely affected. Future monitoring should target this southern portion of the range. (XIII)

Steller sea-lion (Western DPS) *Eumetopias jubatus* (Western DPS)
Revised Steller Sea Lion Recovery Plan, Eastern and Western Distinct Population Segments (Eumetopias jubatus) 2008
www.nmfs.noaa.gov/pr/pdfs/recovery/stellersealion.pdf

If nutritional stress is being caused by an anthropogenic factor, it is probably linked to removal of important sea lion prey species by commercial fisheries (Atkinson et al. in press), although anthropogenic effects on climate could potentially have increasingly important impacts on sea lion prey in the coming decades. However, environmental features, such as oceanographic regime shifts, could also affect the relative abundance and distributions of key prey. (I-33)

The two bottom-up factors hypothesized to have contributed most to the decline are reductions in prey biomass and quality resulting in nutritional stress (proximate cause) that subsequently decreases vital rates (Trites et al. 2006a). However, there are two hypotheses about the ultimate causes of nutritional stress. In one, nutritional stress stems from climate induced changes in the species composition, distribution or nutritional quality of the sea lion prey community (see review by Trites and Donnelly 2003, Trites et al. 2006a, and Trites et al. 2007b). In the other, fishery-induced reductions in localized or overall prey abundance cause nutritional stress (Braham et al. 1980, NMFS 1998a, 2000). Both climate shift and fisheries induced changes in prey communities may have affected the condition of Steller sea lions over the last 40 years, but the relative importance of each is a matter of considerable debate. (III-3)

Global Climate Change. Climate change has received considerable attention in recent years, with growing concerns about global warming and the recognition of natural climatic oscillations on varying time scales. Global air and ocean temperatures during this century and before are warming (IPCC 2007, see http://www.ipcc.ch), and evidence suggests that the productivity of the North Pacific is affected by changes in the environment (Quinn and Niebauer 1995, Mackas et al. 1998).

Increases in global temperatures are expected to have profound impacts on arctic and sub-arctic ecosystems, and some of these impacts have been documented over the last several decades. Specifically, (1) winter temperatures in Alaska and western Canada have increased as much as 3-4 °C over the past half century, (2) precipitation, mostly in the form of rain, has increased primarily in winter resulting in faster snowmelt, (3) sea ice extent has decreased about 8% over the past 30 years, with a loss of 15 to 20% of the late-summer ice coverage in the arctic, and (4) glacial retreat, particularly in Alaska, has accelerated contributing to sea level rise (ACIA 2004). These impacts, and others, are projected to accelerate during this century.

The effects of these changes to the marine ecosystems of the Bering Sea, Aleutian Islands, and the Gulf of Alaska, and how they may specifically affect Steller sea lions are uncertain. Warmer waters could favor productivity of certain species of forage fish, but the impact on recruitment dynamics of fish of importance to sea lions is unpredictable. Recruitment of large year-classes of gadids (e.g., pollock) and herring has occurred more often in warm than cool years, while the distribution (with respect to foraging sea lions) and recruitment of other fish (e.g., osmerids) could be negatively affected. Whether these patterns will continue as overall temperatures increase is uncertain, as are the effects on the duration and strength of atmospheric and oceanographic regimes (Trenburth and Hurrell 1994, Hare and Mantua 2000).

Climate-driven changes in productivity and community structure due to warming oceans may already be underway in the northern portion of the Bering Sea and Bering Strait, where sea ice plays a major role in structuring the food web and the ecosystem is particularly vulnerable to rapid system reorganization under global warming. Reduced seasonal sea ice cover, changing hydrographic conditions, and reduced primary production in the northern Bering Sea may be associated with apparent declines in ice-associated benthic species of mollusks and amphipods since the 1990s (Grebmeier et al. 2006). Benthic-feeding walrus, bearded seals, gray whales and diving sea-ducks such as Spectacled eider are all threatened by these changes, as are Arctic Native communities whose traditional subsistence culture has relied on these iceassociated mammals and birds for thousands of years. This ecosystem has short, simplified food chains; thus the potential for trophic cascades is higher. Warming seawater in the north could expand the range of groundfish from the south, putting more pressure on the benthic prey base. The northern Bering Sea may be poised for the sort of trophic cascade and system reorganization anticipated by the U.S. GLOBEC (Global Ocean Ecosystems) research program as a consequence of global warming at high latitudes (Grebmeier et al. 2006).

Warmer temperatures could shift the distribution of sea lions northward. The eastern DPS increased in size at a rate of approximately 3% per year from the early 1980s through 2004, despite a decline in the size of the breeding population at the southern extent of its range in California. All of the increase in the eastern DPS occurred north of California, and new rookeries established in the 1990s (White Sisters and Hazy Island) were near its northernmost extent in southeast Alaska.

As temperatures warm and global ice coverage decreases, sea levels will rise. This will directly affect terrestrial rookery and haulout sites currently used by Steller sea lions as well as those that may be used by a recovering population. Presumably, sea lions using terrestrial sites will simply move upslope as sea levels rise, assuming that the terrain at the site is suitable. However, sites on some islands with low relief (e.g., Agligadak Island) may be submerged. The net effect of a rise in sea level on overall terrestrial sea lion habitat amount or availability is uncertain, but at the projected rate it is unlikely to have a significant effect for many years.

Fluctuations or cycles in physical and biological characteristics of marine ecosystems may not necessarily affect higher trophic levels because of strategies for survival they have evolved to buffer them against environmental uncertainty. Based on their analyses of possible causes of the sea lion decline, Pascual and Adkison (1994) concluded that environmental cycles were unlikely to have caused declines of the magnitude and duration observed. Shima et al. (2000) did a comparative analysis of population dynamics of four species of pinnipeds in similar variable environments (Steller sea lions in the Gulf of Alaska, Cape fur seals in the Benguela Current, harp seals in the Barents Sea, and California sea lions in the California Current) and found a major decline only for Gulf of Alaska Steller sea lions. They concluded that the success of the other populations suggests that pinnipeds in general have the ability to adapt to environmentally driven changes in prey resources, and that other factors were involved in the decline of Steller sea lions.

Data gaps… More research is necessary to describe linkages between changes in the environment and the dynamics of apex predators such as Steller sea lions. Distinguishing between anthropogenic and environmentally-driven changes in the abundance and distribution of prey resources has eluded scientists and managers, but is necessary in order to understand the forces underlying change in population size and demographics. Furthermore, the direct effects of temperature increases on sea lion metabolic rates, foraging efficiencies, and disease transmission are unknown. (III-31-32).

The hypotheses proposed to explain the decline of the western stock fall into two categories. The first category, the bottom-up hypotheses, includes potential causes that would affect the physical condition of sea lions such as large-scale fishery removals that reduce the availability or quality of prey species, a climate/regime shift in the late 1970s that changed the abundance or distribution of prey species, nonlethal disease that reduced the foraging efficiency of sea lions, and pollutants concentrated through the food web that contaminated fish eaten by sea lions, possibly reducing their fecundity or increasing mortality. (IV-2)

In the last several decades, several new threats have developed; i.e., contaminants, global climate change, and both top-down (e.g., incidental take) and bottom-up (reduced prey biomass and quality) effects of fisheries. (IV-10)

Biological concerns: In general, NMFS expects to see that both juvenile survival and pup production (natality) have increased to the point that the population is not only able to sustain itself, but is able to grow at a modest rate. One feature of the North Pacific, decadal scale climate change, appears to have ecosystem-scale ramifications and may potentially influence the recovery of Steller sea lions. (V-16-17)

Design and implement an adaptive management program for fisheries, climate change, and predation. The mechanisms by which different threats affect sea lions can be similar, as are the responses that sea lions exhibit to these different threats. This represents a fundamental difficulty in identifying which threats are impeding recovery and which mitigation measures would be effective. A properly designed and implemented adaptive management program is needed to assess the relative impact of fisheries, climate change, and predation (Bowen et al. 2001, NRC 2003). (V-43)

To provide assurance that reclassification is warranted for the western DPS of Steller sea lion, several natural and anthropogenic threats to its continued existence including subsistence harvest, pollution, toxins, and management should be reduced as specified under this factor:...3. The influence of global climate change and oceanographic variability is examined, including in combination with other human influenced factors, and is determined unlikely to limit recovery. (V-20)

Nesogenes rotensis
Recovery plan for two plants from Rota 2007
http://ecos.fws.gov/docs/recovery_plans/2007/070503.pdf

There is some evidence that the frequency of severe storms (estimated gusts exceeding 160 kilometers (100 miles) per hour) is increasing in the Mariana Islands. With reference to Guam, the historical record shows increasing numbers of mild (estimated gusts in the range of 80 to 160 kilometers (50 to 100 miles) per hour) and severe storms over the last three centuries, as well as in just the last decade. While some underreporting of storms may have occurred in prior centuries, even mild storms were noticed in the colonial era because they destroyed the relatively flimsy structures used for early housing. Furthermore, these data are consistent with trends expected on the basis of increasing sea surface temperatures that have been documented in recent years (e. g. , Strong et al. 1998; U. S. Department of State 1999). The two populations of N. rotensis are especially vulnerable to the extreme impact of typhoons, storm surge, and high surf because their open scrubland habitats are located in coastal areas.

Osmoxylon mariannense
Recovery plan for two plants from Rota 2007
http://ecos.fws.gov/docs/recovery_plans/2007/070503.pdf

There is some evidence that the frequency of severe storms (estimated gusts exceeding 160 kilometers (100 miles) per hour) is increasing in the Mariana Islands. With reference to Guam, the historical record shows increasing numbers of mild (estimated gusts in the range of 80 to 160 kilometers (50 to 100 miles) per hour) and severe storms over the last three centuries, as well as in just the last decade. While some underreporting of storms may have occurred in prior centuries, even mild storms were noticed in the colonial era because they destroyed the relatively flimsy structures used for early housing. Furthermore, these data are consistent with trends expected on the basis of increasing sea surface temperatures that have been documented in recent years (e. g. , Strong et al. 1998; U. S. Department of State 1999). The two populations of N. rotensis are especially vulnerable to the extreme impact of typhoons, storm surge, and high surf because their open scrubland habitats are located in coastal areas. (16)

Attwater's prairie chicken *Tympanuchus cupido attwateri*
Attwater's prairie-chicken(Tympanuchus cupido attwateri) draft recovery plan, second revision 2007
http://ecos.fws.gov/docs/recovery_plan/071119.pdfhttp://ecos.fws.gov/docs/recovery_plan/071119.pdf

Disease...Hudson et al. (2006) speculated that increased temperatures and climatic disruption brought about by global warming will result in increased frequency and intensity of outbreaks of some parasite populations like Trichostrongylus tenuis. (40)

Chinook salmon (Puget Sound DPS) *Oncorhynchus tshawytscha* pop. 15
Puget Sound Salmon Recovery Plan 2007

...Puget Sound Chinook and Coastal-Puget Sound bull trout are affected by regional and global factors such as climate change and fluctuating ocean conditions. Although it is clear that these factors directly affect salmon and bull trout, scientists are only beginning to unravel the secrets of how these processes impact the food chain, precipitation and snowpack, and other habitat features. Temperature conditions and ocean cycles affect migration and the abundance of predators, and are essential in the production of the minute organisms that provide the food supply for salmon and bull trout to grow and flourish. (122)

Climate Change in the Pacific Northwest. Data collected during the 20th century revealed widespread increases in average annual temperature and precipitation, and decreases in the April 1 snow water equivalent. Snow water equivalent is a common measurement for the amount of water contained in snowpack and is an important indicator for forecasting summer water supplies. 1990-2000 was the warmest decade on record, and was warmer than any other decade by 0.9oF (CIG, 2004). Long term models for climate change in the 21st century show evidence of trends including, region-wide warming, increased precipitation, declining snowpack, earlier spring runoff, and declining trends in summer streamflow. (CIG, 2004) Most of the models predict warmer, wetter winters and warmer, drier summers for the Pacific Northwest. Figure 3.33 contains a summary of the observed and projected impacts of climate change relevant to salmon and bull trout populations.

Salmon and bull trout have lived in the Pacific Northwest for millions of years. As different species and populations of salmon have developed over time, they have acquired specific behaviors for their migration, rearing and spawning life cycles that are attuned to temperature and streamflow. This complex life cycle makes it difficult to predict how they will react to climate changes, and their response will also vary depending on the habitat conditions in a particular river system and estuary. Changes in temperatures away from optimal conditions can influence salmon and bull trout in each of their life stages. Even a small increase in temperature can change migration timing, reduce growth, reduce the supply of available oxygen in the water, and increase the susceptibility of fish to toxins, parasites and disease. The increase in stream temperatures can also contribute to a reduction in the preferred species of insects that are used for food (NWF, 2005). Earlier spring runoff and lower summer flows may make it difficult for returning adult salmon to negotiate obstacles. Excessively high levels of winter flooding can scour eggs from their nests in the streambeds and increase mortalities among overwintering juvenile salmon and bull trout.

Adaptive strategies to cope with the projected changes largely focus on the need to maintain salmon and bull trout populations through conservation and restoration of freshwater and estuarine habitat. Additionally, it has been recommended that harvest and hatchery managers pay particular attention to the time lag associated with impacts of natural variability in one season on the viability of populations in successive seasons. For example, productivity may decline following drought conditions and should be factored into hatchery production targets and harvest regimes; similar issues are already being considered during technical planning forums for harvest.

The predicted increased winter flooding, decreased summer and fall streamflows, and elevated warm season temperatures in the streams and estuaries are likely to further degrade conditions for salmon that are already stressed from habitat degradation. Although the impacts of global climate change are less clear in the ocean environment, early modeling efforts suggest that, warmer temperatures are likely to increase ocean stratification, which in the past has coincided with relatively poor ocean habitat for most Pacific Northwest salmon, herring, anchovies, and smelt populations. (CIG, 2004) (122-123)

Increased frequency and magnitude of high stream flows is due in part to the loss of forest cover from timber harvesting and the routing of surface runoff from forest roads into streams; thus the naturally challenging hydrology of the basin is exacerbated. High flows have contributed to scouring upstream salmon spawning beds, and smothering downstream spawning beds with high sediment levels. Peak flows may also flush juvenile salmon out of normally slower moving reaches of the river that are used for rearing habitat. In the future, climate change may lead to wetter winters and drier summers, aggravating the current flow challenges. (196)

Rate, timing, quantity and quality of water will potentially be negatively impacted due to population growth and increased impervious surfaces, cumulative impact of forest harvest and/or climate change. The degree to which cumulative impacts of forest harvest will impact hydrologic function is unknown. (197)

During the May 2005 review of watershed chapters and regional plan elements, the Technical Recovery Team and an interagency committee identified a preliminary list of issues that have high uncertainty and need to be incorporated into the adaptive management plan:...The potential impacts of climate change on salmon recovery. Climate change, both natural and induced, could have significant effects on Chinook salmon and other salmonids in the Puget Sound region and beyond. Possible effects include alteration of the hydrologic cycle resulting in changes in low and high flow patterns, changes to habitat forming processes, changes in terrestrial and riparian vegetation that affect habitat forming processes, changes in erosion patterns, and impacts to water quality. Significant research on this topic is being conducted in the region, however none of the watershed plans have proposed means of monitoring climate change or its impacts. This is a significant uncertainty in the Puget Sound Recovery Plan and should be addressed through the detailed watershed and regional adaptive management plan. (454-455)

Although the residents of Puget Sound may not have direct influence over climate change, ocean conditions or marine mammal populations, several of the adaptive strategies suggested by the scientific community stress the need to ensure that local habitat conditions are protected and restored as a buffer against the coming changes, and that harvest and hatchery management consider these long term factors in their decision-making. (122)

Chinook salmon (Upper Columbia River spring run DPS) *Oncorhynchus tshawytscha* pop. 12
Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan 2007
http://www.nmfs.noaa.gov/pr/pdfs/recovery/proposed_uppercolumbiasalmon.pdf

The potential impacts of global climate change are recognized at national and international levels (Scott and Counts 1990; Beamish 1995; McGinn 2002). Many climate models project changes in regional snowpack and stream flows with global climate change. The effects of these changes could have significant effects on the success of recovery actions and the status of listed fish populations in the Upper Columbia Basin. The risks of global climate change are potentially great for Upper Columbia stocks because of the sensitivity of salmon stocks to climate-related shifts in the position of the sub-arctic boundary, the strength of the California Current, the intensity of coastal upwelling, and the frequency and intensity of El Nino events (NPCC 2004). Bull trout are particularly sensitive to water temperatures and it is uncertain how global climate change will affect their habitat. More research is needed to address the effects of climate change on ocean circulation patterns, freshwater habitat, and salmon and trout productivity. (105)

Chiricahua leopard frog *Rana chiricahuensis*
Chiricahua Leopard Frog (Rana chiricahuensis) Recovery Plan 2007
http://www.fws.gov/southwest/es/arizona/Documents/SpeciesDocs/CLF/Final_CLF_Plan.pdf

Climate change is listed among threats/factors in decline. (iv, 21, 27, 34, B-74, C-8)

Global Climate Change, Pesticides and Other Non-Mining-related Contaminants, UV-B Radiation, and Other Stressors (Listing Factor A, D, E) Predation by non-native species, chytridiomycosis, habitat loss and degradation, and other factors discussed have been documented as the most likely causes of population decline and extirpation of the Chiricahua leopard frog. However, populations sometimes disappear from habitats in which no changes or deterioration of habitat are apparent, no non-native predators have been detected, and for which there is no evidence of disease. In these and potentially other cases, important stressors other than those just discussed may be adversely affecting Chiricahua leopard frog populations. These factors may include climate change or climatic extremes (Dimmitt 1979, Fellers and Drost 1993, Pounds et al. 1999, Alexander and Eischeid 2001); transport (sometimes over long distances) and deposition of contaminants, dust, gases (Stallard 2001), and pesticides (Lips 1998, Cowman et al. 2001, Davidson et al. 2002); increased levels of ultraviolet-B radiation and interactions with pathogens, particularly a water mold (Saprolegnia ferax) (Blaustein et al. 1994, Keisecker and Blaustein 1995); acid rain (Blanchard and Stromberg 1987, Vatnick et al. 1999); and over-collection (Jennings and Hayes 1985). Globally, the 22 hottest years on record have occurred since 1980, the 10 hottest years have all occurred since 1990, and 2005 was the hottest year in recorded history. The Intergovernmental Panel on Climate Change (2001) found that most of the observed warming over the last 50 years is likely attributable to greenhouse gases produced by human activities. Climate change is an ongoing process in the Southwest with associated effects to Chiricahua leopard frogs. Mean annual temperatures rose 2.0-3.10F in the American Southwest in the 20th century, and are predicted to rise 8.1-11.0 0F in the 21st century (Southwest Regional Assessment Group 2000).

Predictions of changes in precipitation are less certain; however, some models predict as much as a doubling of annual precipitation, with the largest increases in winter precipitation (Southwest Regional Assessment Group 2000). But these predictions contrast with current trends of a warming North Atlantic and cooling tropical Pacific, with associated changes from a relatively wet period to drought, insect outbreaks in southwestern forests, and increasing wildfires (Patterson 1997, Betancourt 2004). Some models predict dramatic changes in southwestern vegetation communities as a result of climate change (Thompson et al. 1997). Arizona's forested areas could decline by 15-30 percent as a result of hotter and drier conditions that fuel wildfires, as well as warmer winters that promote forest insect outbreaks. Arizona's two largest wildfires on record occurred in 2002 and 2005 (Arizona Climate Change Advisory Group 2006).

Climate change can occur abruptly, with associated major changes in the environment (National Academy of Science, Committee on Abrupt Climate Change 2002). The potential for climate change and the uncertainty as to how it may manifest, particularly in regard to precipitation patterns, add considerable uncertainty to predicting the future status and threats to the Chiricahua leopard frog, as well as the strategies needed to recover the species. For instance, drought driven by climate change could result in extirpations of Chiricahua leopard frogs from stock tanks and other marginal habitats subject to drying. If rainfall increases, potential habitat for Chiricahua leopard frogs may increase, as well. Yet, increased precipitation may provide more opportunities for predators to spread and adversely affect remaining frog populations, offsetting any benefits due to more mesic conditions for Chiricahua leopard frogs.

Drought would likely reduce habitat for and invasion by non-native predators. Increasing temperatures have the potential to alter frog breeding phenology, with unknown effects to frog populations and predators of Chiricahua leopard frogs (Blaustein et al. 2001, Beebee 2002). During drought, proximity of suitable drought-resistant habitats may be critical to persistence of each frog population. If Chiricahua leopard frogs cannot disperse from drying habitats and reach suitable habitat, droughts are likely to produce major, though not necessarily irreversible, population declines. Small drought refugia, such as crevices in concrete near an overflowing drinker, or an accessible water storage tank or drinker that the frogs can get into and out of can become critically important for survival of frogs.

Potential direct effects of increased temperatures on the species include earlier reproduction in spring, more rapid development, shorter period of hibernation, longer period of aestivation, changes in abilities to find food, spread of infectious disease, and changes in immune function (Blaustein et al. 2001, Beebee 2002). Increasing temperatures may affect the population dynamics of chytridiomycosis, because the fungi's growth (Collins et al. 2003, Piotrowski et al. 2004) and effectiveness of antimicrobial peptides on the skin of ranid frogs (Longcore et al. 1999) are temperature dependent. If increased temperatures are coupled with reduced precipitation, a variety of indirect effects could occur as well, including habitat loss and fragmentation, and changes in interactions with prey, competitors, predators and parasites, which may form the most serious adverse consequences of climate warming on amphibian populations.

Atmospheric ozone depletion over the last 40 years has resulted in increased ultra-violet (UV)-B radiation reaching the earth's surface. Potential direct effects of increased solar UV radiation on amphibians consist of abnormal embryonic and larval development, damage to the eye and skin, and systematic effects through the suppression of the immune system. Indirect effects include changes in the relative abundance and species composition of competitors, predators and/or parasites, as well as toxic effects of chemicals produced or released as a result of photochemical reactions. Nocturnal and secretive habits of many amphibians protect them from exposure to solar UV. Pigmentation and an ability to repair UV-induced damage are likely to determine the sensitivity of those species that are regularly exposed to solar radiation at different phases of their life cycle (Ovaska 1997). (42-43)

Chum salmon (Hood Canal summer run DPS) *Oncorhynchus keta* pop. 2
Hood Canal & Eastern Strait of Juan de Fuca Summer Chum Salmon Recovery Plan 2007

The reduction of stream and estuarine productivity and capacity, caused by habitat degradation, is cumulative with the negative effects of climate and excessive fishery exploitation. (49)

Three primary factors have combined to cause the decline of summer chum salmon in both Hood Canal and Strait of Juan de Fuca streams (WDFW and PNPTT 2000). They are: 1) climate related changes in stream flow patterns; 2) fishery exploitation, and 3) habitat loss. (71)

6. 3. 1. Climate Change and Fishery Exploitation The long-term loss of habitat productivity and capacity will impact summer chum salmon by lowering survival rates (population resiliency) and reducing potential population size. When Hood Canal/Eastern Strait of Juan de Fuca summer chum salmon began to experience the added pressures from climate change and new fishery exploitation, the populations collapsed. In 1979, summer chum run sizes and subsequent escapements were very low because of the effects of unfavorable stream flows on the 1975 and 1976 brood production (WDFW and PNPTT 2000). This poor performance was evident in chum salmon stocks statewide. The summer chum populations of Hood Canal (with the exception of Union River) were the only chum stocks that did not immediately recover from the low return levels of 1979 (WDFW and PNPTT 2000). WDFW and PNPTT (2000) discusses the potential impacts from climate change and particularly, the possible impacts to stream flows during spawning and incubation (see SCSCI section 2. 2. 2. 4). The co-managers further conclude, however, that (A)ny analysis of climate change in relation to stream flow and the decline of summer chum salmon populations cannot be isolated from human-caused habitat alterations. (72)

Climate shifts like those observed in the past 30 years, with their associated stream flow changes, likely have posed little threat to summer chum populations before the cumulative effects of habitat changes from human development became manifest. (72)

Evidence suggests decreasing trends in certain summer chum watersheds, a fact that may be exacerbated by climate change. (294)

...manage for the primary importance of maintaining metapopulation structure. In other words, while each local leopard frog population is important, it is the metapopulation that is essential. The occasional loss of individual leopard frog populations as a result of biological, climatic, economic, or other factors may therefore be acceptable, so long as the affected metapopulation persists. (A-3)

2) Restore hydrological regime through watershed management, retirement of stream diversions, and local restrictions on groundwater pumping on public lands...Water flows will vary with climatic cycles and thus may not be consistently maintained, particularly in drought conditions. Therefore, measures should be proposed and agreements implemented to secure the needed flows when diversions, impoundments, or urban wastewater flows threaten the integrity of the hydrological regime. (H-15)

Desert tortoise (Mojave DPS) *Gopherus agassizii* pop. 1
Draft revised recovery plan for the Mojave population of the desert tortoise (Gopherus agassizii) 2007

E. Other Natural or Manmade Factors Affecting its Continued Existence

Global climate change and drought are potentially important long-term considerations with respect to recovery of the desert tortoise. The Earth's climate has warmed by nearly 1.5 degrees Fahrenheit over the past 100 years (Walther et al. 2002), and anthropogenic emissions of greenhouse gases play a major role in this process (Weltzin et al. 2003). There is now sufficient evidence that recent climatic changes have affected a broad range of organisms with diverse geographical distributions (Walther et al. 2002). While little is known regarding direct effect of climate change on the desert tortoise or its habitat, predictions can be made about how global and regional precipitation regimes may be altered and the consequences of these changes (Weal. 2003; Seager et al. 2007). Such predictions need to be developed specifically for the desert tortoise to help inform recovery efforts. (16)

E. Other Natural or Manmade Factors Affecting its Continued Existence
Climate Change. The Earth's climate has warmed by nearl 1.5 degrees Fahrenheit over the past 100 years (Walther et al. 2002), and anthropogenic emissions of greenhouse gases play a major role in this process (Weltzin et al. 2003). While this warming is not uniform with regard to time and space, the rate of warming during the last 30 years has generally been greater than at any other time during the the last 1,000 years. In many regions there is an asymmetry in warming, as well as precipitation, which is likely to contribute to variation in ecological dynamics across ecosystems. There is now sufficient evidence that recent climate changes have affected a broad range of organisms with diverse geographical distributions (Walther et al. 2002). Interactions between altered precipitation patterns and other aspects of global change are likely to affect natural and managed terrestial ecosystems. For example, climate models predict that Joshua trees will no longer be able to persist within Joshua Tree National Park through the 21st century (Cole et al. 2005). While little is known regarding direct effects of climate change on the desert and habitat, predictions can be made about how global and regional precipitation regimes may be altered and the consequences of these changes (Weltzin et al. 2003; Seager et al. 2007).

Climatic regimes are believed to influence species' distributions through species-specific physiological thresholds of temperature and precipitation tolerance. Warming temperatures and altered precipitation patterns may result in distributions shifting toward the poles and/or to highens, depending on resource availability (Walther et al. 2002). We may expect this response in the desert tortoise, thereby reducing the viability of lands currently identified as refuges or critical habitat for the species. Seager et al. (2007) ran a series of climate models simulations on the precipitation history and future of the southwestern United States and northern Mexico that consistently showed a severe drying trend in this region throughout the 21st century, especially in areas where evapotranspiration exceeds precipitation.

Experiments in Nevada at the Free-Air Carbon Dioxide (CO2) Enrichment Facility to predict the possible complex ecological and biogeochemical changes in semi-desert ecosystems by increasing atmospheric CO2 have been ongoing since 1997 (Hamerlynck et al. 2000; Smith et al. 2000; Huxman and Smith 2001). Because deserts are both water- and nutrient- systems and native plants are so slow growing, it is still too early to say with any confidence how even the most intensively studied desert shrub communities of the southwestern States will respond to rising CO2 (Lioubimtseva and Adams 2004). However, results from the Free-Air CO2 Enrichment Facility site demonstrate that cheatgrass responds to increasessuch that it is far more productive than native plants during wet years (Smith et al. 2000). As discussed in the Fire section, non-native annual grass invasions are known to increase thecy and intensity of fires, which has a dramatic negative effect on desert water cycles and habitat (Hamerlynck et al. 2000).

Direct climatic effects on growth and development, spatial distribution, and species interactions are apparent in amphibians and reptiles, which, in common with other ectotherms, are heavily influenced by environmental conditions. Both seasonal temperature and humidity affect their reproductive physiology and population dynamics (Walther et al. 2002). It remains unclear how regional changes in climate may affect the desert tortoise; however, some observations relative to drought have been documented in the past. (99-100)

5.2.4 Determine the importance of corridors and physical barriers to desert tortoise distribution and gene flow...Determining the importance of corridors and barriers will allow population models to be made spatially explicit relative to current land management (e.g., population and habitat fragmentation due to roads and urbanization) and potential distributional shifts resulting from climate change. (57)

5.2.3 Model desert tortoise demography relative to habitat condition to determine the proportion of habitat that needs to be occupied (or is available to be occupied) for recovery….As habitat-specific demography is clarified (5.3.2), population models should be developed to refine estimates of habitat quantity and tortoise occupancy necessary to sustain populations into the future. Models should incorporate predicted effects of climate change on desert tortoise demography, as well as on the current composition of tortoise habitat. Information from this recovery action is essential to refining Recovery Criterion 3a relative to the amount of habitat needed to conditions for delisting. (57)

Indiana bat *Myotis sodalis*
Indiana Bat (Myotis sodalis) Draft Recovery Plan, First Revision 2007
http://ecos.fws.gov/docs/recovery_plans/2007/070416.pdf

Few specific drivers of this apparent population shift have been rigorously explored or identified, but inappropriate hibernacula temperatures (see Tuttle and Kennedy 2002) and regional climate change are either known or generally suspected in having had a role. We currently have an incomplete understanding of the links between M. sodalis' hibernation energetics, its biogeographical distribution, and climate change. However, the predictive modeling approach recently used by Humphries et al. (2002) for M. lucifugus could provide some insight into M. sodalis' potential winter distribution if global climate change occurs. (22)

Apparent Regional Population Trends and Climate Change
It is nearly impossible to consider the geographic positions of states where Indiana bat populations are declining and states where they are stable or increasing without considering the possibility that regional and/or global climate change is driving some changes in Indiana bat populations. Table 3 reveals a clear division in apparent population trends between states in the northern portion of the Indiana bat's range versus states in the southern portion of the range (Clawson 2002). Steep declines in Kentucky and Missouri hibernacula have largely contributed to the apparent decline in the southern population during the 45-year period from 1960 through the present. In contrast, there apparently has been an overall increase in population in northern states over the same time period. The role of climate change and its effect on temperatures in hibernacula need investigation. Although current data are not sufficient to definitively determine the cause of apparent regional disparities, it appears that both protection of hibernacula and suitable temperature regimes may be key to understanding trends in the overall population and recovery of the species. (37)

Climate Change. Potential impacts of climate change on temperatures within Indiana bat hibernacula were reviewed by V. Meretsky (pers. comm. , 2006). Climate change may be implicated in the disparity of population trends in southern versus northern hibernating populations of Indiana bats (Clawson 2002), but Meretsky noted that confounding factors are clearly involved. Humphries et al. (2002) used climate change models to predict a northern expansion of the hibernation range of the little brown bat; such modeling would likely result in predictions of range shifts for Indiana bats as well. Potential impacts of climate change on hibernacula can be compounded by mismatched phenology in food chains (e. g. , changes in insect availability relative to peak energy demands of bats) (V. Meretsky, pers. comm. , 2006). Changes in maternity roost temperatures may also result from climate change, and such changes may have negative or positive effects on development of Indiana bats, depending on the location of the maternity colony. The effect of climate change on Indiana bat populations is a topic deserving additional consideration. (100-101)

Climate change and wind turbines may present additional threats to the species; the full impact of these factors will be realized with time. (113)

Research is necessary in numerous key areas including but not limited to...effect of global warming on the species' distribution and hibernacula. (114)

Peripheral populations can play an important role in conservation. Their relative isolation and lower abundance typically results in less genetic diversity than core populations due to genetic drift caused by reduced gene flow and founder effects (Lesica and Allendorf 1995, Vucetich and Waite 2003). However, concomitant processes in peripheral populations may also produce distinctive genetic characteristics…. As previously discussed, peripheral populations may occupy atypical or less favorable habitats (Lomolino and Channell 1995, Channel and Lomolino 2000a, 2000b). To persist, these individuals must adapt to different and possibly more extreme environmental factors and selective forces. Additionally, peripheral populations may be genetically and ecologically different from other peripheral populations and the core populations (Lomolino and Channell 1995). Further, peripheral populations may be better adapted to long-term rangewide environmental changes, such as global climate change (Hunter 1991, Araujo and Williams 2001). These individuals may be best adapted to establishing themselves in the shifting habitats created by changing climate (Fraser 2000). (115-116)

3.2.3 Model the potential impact of climate change, alterations to physical structure, and surrounding habitat modifications on projected use of hibernacula by Indiana bats.

Alterations to cave and mine entrances have been generally recognized to change temperature and other conditions within hibernacula, as gross modifications to surrounding habitat (e. g. , deforestation, construction of buildings). Recent scientific studies have also called attention to the likelihood that global climate change is influencing the distribution of bats, including the geographic distribution of hibernacula. An improved understanding of Indiana bat physiological requirements for hibernation and characteristics of hibernacula will be achieved under objectives 3. 2. 1 and 3. 2. 2. Based on these studies, modeling efforts should be conducted that consider the influence of structural alterations, surrounding habitat modifications, and climate change on the future suitability of hibernacula used by Indiana bats throughout the species current and projected future distribution. (162-163)

Northern spotted owl *Strix occidentalis caurina*
Draft Recovery Plan for the Northern Spotted Owl (Strix occidentalis caurina) 2007
http://ecos.fws.gov/docs/recovery_plans/2006/060118.pdf

The panel identified disease and the effect of climate change on vegetation as potential and more uncertain future threats. (18, 25)

Spalding's catchfly *Silene spaldingii*
Recovery Plan for Silene spaldingii (Spalding's Catchfly) 2007
http://ecos.fws.gov/docs/recovery_plan/071012.pdfhttp://ecos.fws.gov/docs/recovery_plan/071012.pdf

S. spaldingii is affected by a variety of factors including...annual climatic conditions (i.e., drought cycles); climate change… (1)

Causes aside, global temperatures are increasing (USEPA, in litt. 2000, p. 1). The effects of this climate change are speculative, but it has the potential to affect rare plants such as Silene spaldingii. Researchers speculate that this warming will alter rainfall patterns, with some regions becoming drier and others wetter (Given 1994, pp. 33-34). Within the Pacific Northwest a recent model predicts warmer and wetter winters in 80 years (U.S. Department of Energy 2004, p. 1). Plants are stationary, moving through dispersal, colonization, and recruitment events. Because plants are stationary and move slowly through the aforementioned events, it is thought they can't move quick enough to keep up with a shifting climate, and are more susceptible to global warming than are wildlife species (Wilson 1989, p. 114). Furthermore, fragmentation and isolation limits movement opportunities. (46)

Impacts from Drought and Global Warming: 1. conserve and expand populations in each physiographic region; 2.1 general management plans; 2.3 habitat management plans; 2.4 monitor; 2.10 funding. (C-3)

Impacts from Drought and Global Warming: 1. conserve and expand populations in each physiographic region; 2.1 general management plans; 2.3 habitat management plans; 2.4 monitor; 2.10 funding (C-3)

Impacts from Drought and Global Warming: 2, 3, 4 (C-3)

2.3. Habitat management plans and recovery actions should manage for impacts and threats to Silene spaldingii populations and habitat both at key conservation areas as well as at smaller populations. Threats include...impacts from prolonged drought and climate change; and an inadequacy of existing regulatory mechanisms. All of these threats should be addressed both through habitat management plans and recovery actions both at key conservation areas as well as at smaller populations. (92)

Steelhead trout (Upper Columbia River DPS) *Oncorhynchus mykiss* pop. 12
Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan 2007
http://www.nmfs.noaa.gov/pr/pdfs/recovery/proposed_uppercolumbiasalmon.pdf

The potential impacts of global climate change are recognized at national and international levels (Scott and Counts 1990; Beamish 1995; McGinn 2002). Many climate models project changes in regional snowpack and stream flows with global climate change. The effects of these changes could have significant effects on the success of recovery actions and the status of listed fish populations in the Upper Columbia Basin. The risks of global climate change are potentially great for Upper Columbia stocks because of the sensitivity of salmon stocks to climate-related shifts in the position of the sub-arctic boundary, the strength of the California Current, the intensity of coastal upwelling, and the frequency and intensity of El Nino events (NPCC 2004). Bull trout are particularly sensitive to water temperatures and it is uncertain how global climate change will affect their habitat. More research is needed to address the effects of climate change on ocean circulation patterns, freshwater habitat, and salmon and trout productivity. (105)

Whooping crane *Grus americana*
International Recovery Plan for the Whooping Crane (Grus americana), Third Revision 2007
http://ecos.fws.gov/docs/recovery_plans/2005/050111.pdf

Global warming and associated climate changes constitute a potential threat to whooping crane recovery. Based on climate records and calculated rates of rises in greenhouse gas concentration from human activities, models of global climate change suggest that average global surface temperatures will increase by 1.4 and 5.8ºC (2.5 and 10.4ºF) by the end of this century (National Academy of Sciences 2005 website: http://www4.nas.edu/onpi/webextra.nsf/web/climate?OpenDocument). In the Northern Hemisphere, from 1951 to 1990, average minimum winter temperature rose 2.9ºC, while average summer maximum temperature rose 1.3ºC (Crozier 2003). In addition to rising temperatures, other climate factors such as the rising of sea level, flooding of coastal wetlands, drying of interior wetlands, and intensifying of precipitation events may impact the whooping crane. Although the frequency of future hurricanes is uncertain, hurricanes are expected to become stronger and bring more intense rainfall than hurricanes at present, due to increases in sea surface temperatures (NOAA website: http://www.gfdl.noaa.gov/~tk/glob_warm_hurr.html, updated March 23, 2006). Coastal wetlands are particularly vulnerable to erosion, changes in salinity and microclimate conditions, changes in groundwater tables, and habitat loss from expected rises in sea level and hurricane damage (EPA Global Warming Impacts Coastal Zones website: http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ImpactsCoastalZones.html).

Climate change is expected to alter the physiology, distribution, phenology, and adaptation of organisms (Hughes 2000, Menzel et al. 2001, Stenseth et al. 2002, Peterson 2003, Parmesan and Yohe 2003). In turn, these processes may affect growth rates, individual size, individual mobility, overall fitness, reproductive success, and population demographics (Stenseth et al. 2002). Changes in ecosystem functioning, such as cycling of nutrients, and interactions among whooping cranes and their biotic resources, such as food species, plant communities, predators, parasites, competitors, and mutualists, are difficult to predict and involve an understanding of an ecosystem's resistance and resiliency to interference (Chapin et al. 2000). Habitat specialization of birds has been associated with sharper declines in population abundance (Julliard et al. 2003, Peterson 2003, Thomas C. et al. 2004, Thomas J. et al. 2004). Warming temperatures have caused a northward shift in bird species' ranges, hastened the timing of winter and summer activities, and are predicted to decrease biodiversity world-wide (Thomas and Lennon 1999, McCarty 2001, Thomas C. et al. 2004). For the whooping crane, this could affect current wintering areas, summering locations, and the timing of breeding and migration. These changes may alter the extent to which a bird's life cycle is synchronized with its food supply and nest site availability.

If climate change results in drier conditions either on the summer or wintering grounds, whooping cranes would face great difficulties from disruptions to the ecology of those areas. Any changes that adversely affect the water regime of WBNP could have severe impacts on whooping crane reproduction. Permanently lowered water tables, for example, would shrink wetlands, reduce the availability of quality nesting sites, reduce invertebrate food availability, and allow predators to access nests and young. Chick survival is reduced during dry years in WBNP (Kuyt et al. 1992). On the winter area, a reduction in rainfall would reduce inflows and reduce the blue crab population that the cranes rely on for food. Global warming and associated sea level rise, combined with land subsidence, is projected to be about 17 inches on the Texas coast over the next 100 years (Twilley et al. 2001). This would reduce suitability of salt marsh and open water areas, making much of the present acreage too deep for use by whooping cranes (Tom Stehn, ANWR, pers. comm.). (25-26)

The majority of breeding habitat is located in WBNP...the potential critical habitat is protected from a number of anthropogenic threats. It may be threatened however, by climate change that could result in more severe weather events including drought. (31-32)

1.5.3.1. Maintain WBNP. Whooping Crane Recovery Plan 2006 Effective management and research is needed on the wintering grounds to maintain the quality of crane habitat at WBNP. Long-term studies are needed to detect and address any detrimental changes from climate change or other causes. (49)

1.5.3.9. Monitor global warming. The potential for sea level rise and climate change related to global warming should be monitored to address possible impacts to whooping crane habitat. Research and appropriate management response will be needed to protect coastal ecosystems and nesting habitat. (50)

1.5.2.6. Monitor global warming The expected sea level rise along with climate change caused by global warming will have a major negative impact on whooping crane wintering habitat. Continued research and management will be needed to protect this habitat. (51)

Akiapolaau (honeycreeper) *Hemignathus munroi*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

2.5.1.4 Work to stop global climate change. (Priority 1) Global warming and local climate change are a serious threat to listed species in Hawai`i primarily because of the potential for movement of disease carrying mosquitoes into higher elevation avian refugia currently free of mosquito breeding sites. This work will require cooperation by appropriate agencies and entities to develop agreements and technologies needed to slow greenhouse gas emissions, asignificant factor contributing to global climate change. (4-66)

Akohekohe (crested honeycreeper) *Palmeria dolei*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

2. 5. 1. 4. Work to stop global climate change. (Priority 1) Global warming and local climate change are a serious threat to listed species in Hawai`i primarily because of the potential for movement of disease carrying mosquitoes into higher elevation avian refugia currently free of mosquito breeding sites. This work will require cooperation by appropriate agencies and entities to develop agreements and technologies needed to slow greenhouse gas emissions, asignificant factor contributing to global climate change. (4-66)

Fin whale *Balaenoptera physalus*
Draft Recovery Plan for the Fin Whale (Balaenoptera physalus) 2006
http://www.nmfs.noaa.gov/pr/pdfs/recovery/draft_finwhale.pdf

G.14 Climate and Ecosystem Change Climate change has received considerable attention in recent years, with growing concerns about global warming and the recognition of natural climatic oscillations on varying time scales, such as long term shifts like the Pacific Decadel oscillation or short term shifts, like El Niño or La Niña. Evidence suggests that the productivity in the North Pacific (Quinn and Neibauer 1995; Mackas et al. 1989) and other oceans, is affected by changes in the environment. Increases in global temperatures are expected to have profound impacts on arctic and sub-arctic ecosystems and these impacts are projected to accelerate during this century. The potential impacts of climate and oceanographic change on fin whales will like impact habitat availability and food availability. Site selection for whale migration, feeding, and breeding for fin whales may be influenced by factors such as ocean currents and water temperature. Any changes in these factors could render currently used habitats areas unsuitable. Changes to climate and oceanographic processes may also lead to decreased productivity in different patters of prey distribution and availability. Such changes could affect fin whales that are dependent on those prey. (I-32)

Hawaii 'Akepa *Loxops coccineus coccineus*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

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Hawaii creeper *Oreomystis mana*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

2. 5. 1. 4 Work to stop global climate change. (Priority 1) Global warming and local climate change are a serious threat to listed species in Hawai`i primarily because of the potential for movement of disease carrying mosquitoes into higher elevation avian refugia currently free of mosquito breeding sites. This work will require cooperation by appropriate agencies and entities to develop agreements and technologies needed to slow greenhouse gas emissions, asignificant factor contributing to global climate change. (4-66)

Hawaiian monk seal *Monachus schauinslandi*
Recovery Plan for the Hawaiian Monk Seal (Monachus schauinslandi), Revised 2006
http://www. nmfs. noaa. gov/pr/pdfs/recovery/draft_hawaiianmonkseal.pdf

The loss of terrestrial habitat is a significant issue of concern in the NWHI, especially habitat loss due to environmental factors such as storms and sea level rise that could further exacerbate this problem in the future. While some habitat loss (e. g. , the subsidence of Whaleskate Island at FFS) has already been observed, sea level rise over the longer term may threaten a large portion of the resting and pupping habitat in the NWHI (Baker et al. , 2006). (34)

Changes in climate and oceanographic conditions may affect pinnipeds by changing availability of their prey.... (37)

There has been no known alteration of habitat to preclude attainment of this presumed post-WWII population level (though there are outstanding questions about effects of fisheries and about normal or global climate change effects on the productivity of the NWHI ecosystem). (132)

5. 2. 2 Examine relationship between pupping habitat type and juvenile survival...Predicted increases in sea level this century and beyond may severely reduce the amount of habitat for seals to rest, breed and rear their pups in the NWHI (Baker et al. , 2006). Feasibility of restoration should be evaluated as soon as possible (e. g. Whaleskate Island, East I, Tern I, FFS) to rebuild habitat essential for the reproduction of monk seals and other protected species (e. g. turtles and sea birds) at several alternate sites that may lead to rebuilding preferred, stable pupping habitat (i. e. accessibility, long shoreline, stable beach) that can be permitted by the FWS (5. 3). Also, other sites within the Hawaiian monk seal range may serve as sites for population enhancement studies (e. g. Johnston Atoll) if appropriate. (80)

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Holmgren milk-vetch *Astragalus holmgreniorum*
Astragalus holmgreniorum (Holmgren Milk-Vetch) and Astragalus ampullarioides (Shivwits Milk-Vetch) Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060929.pdf

Other natural or manmade factors affecting the species' continued existence.... Climate change has emerged as a significant concern, particularly in regard to the potential for increasingly prolonged drought cycles (Miller 2005; R. Van Buren, pers. comm. 2006). Both A. holmgreniorum and A. ampullarioides have higher germination and survivorship rates during and following years of increased precipitation (Van Buren and Harper 2003a), and if consecutive years of low reproductive output caused by drought conditions outlast seedbank longevity, the affected populations could become extirpated (R. Van Buren, pers. comm. 2006). Given that drought events occur at a regional scale (Miller 2005), this could prove to be a serious limiting factor for both species. Frost kill also affects both species and could become a more prevalent problem with long-term seasonal changes (R. Van Buren, pers. comm. 2006). Additionally, some A. holmgreniorum and A. ampullarioides are small-sized and could be threatened by stochastic events. (29)

Pervasive threats to this species include land development/urban expansion, invasive plant species, and the prospect of prolonged drought caused by climate change...Although long-term changes in regional precipitation and temperature regimes may affect the distribution and viability of this and other endemic plant species in the future, much uncertainty remains about climatic trends and the ability of A. holmgreniorum to adapt to gradual changes. The primary concern at this point with regard to climate change is the potential for drought--whether part of a broader climatic trend or not--to outlast the period over which the species can withstand consecutive years of reduced reproductive output and seedbank depletion. Thus, while climate change is viewed as a potential rather than current threat, drought years warrant close observation for effects on each population. Measures to mitigate loss of reproductive adults and seed output may be necessary on an emergency and ongoing basis. (30-31)

The primary concern at this point with regard to climate change is the potential for drought --whether part of a broader climatic trend or not--to outlast the period over which the species can withstand consecutive years of reduced reproductive output and seedbank depletion. (31. Threat ranked among others on p 35)

Thus, while climate change is viewed as a potential rather than current threat, drought years warrant close observation for effects on each population. Measures to mitigate loss of reproductive adults and seed output may be necessary on an emergency and ongoing basis. (31)

Thus, while climate change is viewed as a potential rather than current threat, drought years warrant close observation for effects on each population. Measures to mitigate loss of reproductive adults and seed output may be necessary on an emergency and ongoing basis. (31)

The other major concern for both species, the potential for prolonged drought caused by climate change, cannot be resolved at the species-recovery level. However, during prolonged periods of drought, more aggressive management, which may seem unrealistic, may become necessary, including steps to ameliorate rangewide population losses through solutions such as watering, seed storage and propagation, and establishment of new populations in areas that may be more hydrologically conducive to survival of the plants and seedbanks through dry periods. (47)

Kauai akialoa *Akialoa stejnegeri*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

2.5.1.4 Work to stop global climate change. (Priority 1) Global warming and local climate change are a serious threat to listed species in Hawai`i primarily because of the potential for movement of disease carrying mosquitoes into higher elevation avian refugia currently free of mosquito breeding sites. This work will require cooperation by appropriate agencies and entities to develop agreements and technologies needed to slow greenhouse gas emissions, asignificant factor contributing to global climate change. (4-66)

Kauai 'o'o *Moho braccatus*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

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Large Kauai thrush (=Kama'o) *Myadestes myadestinus*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

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Maui 'akepa *Loxops coccineus ochraceus*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

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Maui parrotbill *Pseudonestor xanthophrys*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

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Moloka'i creeper (=Kakawahie) *Paroreomyza flammea*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

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Moloka'i thrush (=Molokai Oloma'o) *Myadestes lanaiensis rutha*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

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Nukupu'u *Hemignathus lucidus*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

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'O 'u *Psittirostra psittacea*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

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Oahu alauahio (Oahu creeper) *Paroreomyza maculata*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

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Oahu 'Elepaio *Chasiempis sandwichensis ibidis*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

4. 8. 2 Determine the effects of long-term climate change on disease transmission. (4-6) 4.6.2.3 Document source/sink metapopulation structure along gradients in density, particularly elevational gradients. (Priority 2)...Management for disease, especially in light of climate change, requires knowledge of metapopulation structure. (4-106)

2. 5. 1. 4 Work to stop global climate change. (Priority 1) Global warming and local climate change are a serious threat to listed species in Hawai`i primarily because of the potential for movement of disease carrying mosquitoes into higher elevation avian refugia currently free of mosquito breeding sites. This work will require cooperation by appropriate agencies and entities to develop agreements and technologies needed to slow greenhouse gas emissions, asignificant factor contributing to global climate change. (4-66)

Orca (southern resident DPS) *Orcinus orca* (Southern resident population)
Proposed Recovery Plan for Southern Resident Killer Whales (Orcinus orca) 2006
http://www. nwr. noaa. gov/Marine-Mammals/Whales-Dolphins-Porpoise/Killer-Whales/ESA-Status/upload/SRKW-Prop-Recov-Plan.pdf

Extensive climate change caused by the continuing buildup of human-produced atmospheric carbon dioxide and other greenhouse gases is predicted to have major environmental impacts along the west coast of North America during the 21st century and beyond. Warming trends in water and air temperatures are ongoing and are projected to disrupt the region's annual cycles of rain and snow, alter prevailing patterns of winds and ocean currents, and result in higher sea levels (Glick 2005, Snover et al. 2005). These changes, together with increased acidification of ocean waters, will likely have profound effects on marine productivity and food webs, including populations of salmon and other fish used as prey by Southern Resident killer whales. Climate change is expected to impact salmon production in a number of ways. These include 1) alterations in river and stream flows and temperatures caused by changing patterns in precipitation and snowmelt that affect the survival of eggs, fry, smolts, and adults, as well as the ability of adults to migrate upstream for spawning, 2) loss of nearshore habitats important to juvenile salmon, and 3) changes in food availability in freshwater and marine habitats (Glick 2005). Although no formal predictions of impacts on the Southern Residents have yet been made, it seems likely that any changes in weather and oceanographic conditions resulting in effects on salmon populations will have consequences for the whales. (84)

B. 8 Determine the effects of variable oceanographic conditions on the Southern Residents and their prey. Cyclic changes in climate trends across the North Pacific Ocean, such as the Pacific Decadal Oscillation, produce fluctuating oceanographic and atmospheric conditions that strongly affect ocean productivity and prey abundance.... The influences of global climate change on regional climate regimes and prey abundance should also be evaluated. (163)

Palila *Loxioides bailleui*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

2. 5. 1. 4 Work to stop global climate change. (Priority 1) Global warming and local climate change are a serious threat to listed species in Hawai`i primarily because of the potential for movement of disease carrying mosquitoes into higher elevation avian refugia currently free of mosquito breeding sites. This work will require cooperation by appropriate agencies and entities to develop agreements and technologies needed to slow greenhouse gas emissions, asignificant factor contributing to global climate change. (4-66)

Po'ouli *Melamprosops phaeosoma*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

2. 5. 1. 4 Work to stop global climate change. (Priority 1) Global warming and local climate change are a serious threat to listed species in Hawai`i primarily because of the potential for movement of disease carrying mosquitoes into higher elevation avian refugia currently free of mosquito breeding sites. This work will require cooperation by appropriate agencies and entities to develop agreements and technologies needed to slow greenhouse gas emissions, asignificant factor contributing to global climate change. (4-66)

Puaiohi (small Kauai thrush) *Myadestes palmeri*
Revised Hawaiian Forest Birds Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060922a.pdf

Climate change could enable the transmission of pox and malaria at higher elevations, further threatening remaining populations of endangered birds (Benning et al. 2002). (1-5)

2. 5. 1. 4 Work to stop global climate change. (Priority 1) Global warming and local climate change are a serious threat to listed species in Hawai`i primarily because of the potential for movement of disease carrying mosquitoes into higher elevation avian refugia currently free of mosquito breeding sites. This work will require cooperation by appropriate agencies and entities to develop agreements and technologies needed to slow greenhouse gas emissions, asignificant factor contributing to global climate change. (4-66)

Rota bridled white-eye *Zosterops rotensis*
2006

Typhoons are a common occurrence in the Mariana Islands. Guam, for example, has been affected by typhoons in 37 of the last 50 years (based on records compiled by U. S. Navy, Joint Typhoon Warning Center) and supertyphoons occur with regularity (about once every 5 to 10 years). There is some evidence that the frequency of severe storms is increasing in the Mariana Islands. With reference to Guam, the historical record shows increasing numbers of mild and severe storms over the last three centuries (Figure 9), as well as in just the last decade (Figure 10). While some underreporting of storms may have occurred in prior centuries, even mild storms were noticed in the colonial era because they destroyed the relatively flimsy structures used for early housing. Furthermore, these data are consistent with trends expected on the basis of increasing sea surface temperatures that have been documented in recent years (e. g. , Strong et al. 1998; U. S. Department of State 1999).

Typhoons have both direct and indirect effects on birds (Wiley and Wunderle 1993). Direct effects include loss of nests, eggs, and nestlings from high winds or death from exposure to high winds and rain. Indirect effects include the loss or reduction of foraging resources or substrates, increased predation due to the temporary loss of cover, and long-term changes in habitat suitability.

How these direct and indirect impacts specifically affect nosa Luta populations is uncertain due to the lack of data specific to this species. However, nest failure due to typhoons has been reported for the Mariana crow (Morton et al. 1999) and likely occurs with nosa Luta as well...Long-term changes in the availability of mature forests may also be impacting nosa Luta populations (see also Habitat Loss and Degradation). Typhoon damage to vegetation is typically greatest along edges and on slopes facing the wind (Brokaw and Walker 1991, Frangi and Lugo 1991). (26-28)

Assessing the need for establishing a second population is needed due to the susceptibility of the single current population to random catastrophic events such as typhoons, which could bring the population to the edge of extinction. In order to adequately prepare for this possibility, initial planning for establishing a captive population (Recovery Action 2. 1) and/or experimental population (Recovery Action 2. 2) is needed. (vi)

Shivwitz milk-vetch *Astragalus ampullarioides*
Astragalus holmgreniorum (Holmgren Milk-Vetch) and Astragalus ampullarioides (Shivwits Milk-Vetch) Recovery Plan 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060929.pdf

Other natural or manmade factors affecting the species' continued existence.... Climate change has emerged as a significant concern, particularly in regard to the potential for increasingly prolonged drought cycles (Miller 2005; R. Van Buren, pers. comm. 2006). Both A. holmgreniorum and A. ampullarioides have higher germination and survivorship rates during and following years of increased precipitation (Van Buren and Harper 2003a), and if consecutive years of low reproductive output caused by drought conditions outlast seedbank longevity, the affected populations could become extirpated (R. Van Buren, pers. comm. 2006). Given that drought events occur at a regional scale (Miller 2005), this could prove to be a serious limiting factor for both species. Frost kill also affects both species and could become a more prevalent problem with long-term seasonal changes (R. Van Buren, pers. comm. 2006). Additionally, some A. holmgreniorum and A. ampullarioides are small-sized and could be threatened by stochastic events. (29)

The threats matrix in Table 6 shows that all known A. ampullarioides populations are threatened by ORV and other recreational uses, invasive plants and the fires associated with their establishment, prolonged droughts caused by climate change, and herbivory...Any prolonged drought (whether or not part of a broader climatic trend) that outlasts seedbank longevity constitutes an extinction risk for A. ampullarioides. (34, 36).

Any prolonged drought (whether or not part of a broader climatic trend) that outlasts seedbank longevity constitutes an extinction risk for A. ampullarioides. While climate change is viewed as a potential rather than current threat, the species needs to be carefully monitored during periods of drought in order to predict and mitigate loss of reproductive adults and seed output. (36)

Any prolonged drought (whether or not part of a broader climatic trend) that outlasts seedbank longevity constitutes an extinction risk for A. ampullarioides. While climate change is viewed as a potential rather than current threat, the species needs to be carefully monitored during periods of drought in order to predict and mitigate loss of reproductive adults and seed output. (36)

The other major concern for both species, the potential for prolonged drought caused by climate change, cannot be resolved at the species-recovery level. However, during prolonged periods of drought, more aggressive management, which may seem unrealistic, may become necessary, including steps to ameliorate rangewide population losses through solutions such as watering, seed storage and propagation, and establishment of new populations in areas that may be more hydrologically conducive to survival of the plants and seedbanks through dry periods. (47)

Spalding's catchfly *Silene spaldingii*
Draft Recovery Plan for Silene spaldingii (Spalding's Catchfly) 2006
http://ecos.fws.gov/docs/recovery_plans/2006/060316.pdf

S. spaldingii is impacted by a variety of factors including...annual climactic conditions (i. e. , drought cycles); climatic change; (1) 10. Impacts from Prolonged Drought and Global Warming (Factor E) ...Causes aside, global temperatures are increasing (U. S. Environmental Protection Agency 2000). The effects of this global warming are speculative, but it has the potential to affect rare plants such as Silene spaldingii. (33)

Impacts from Prolonged Drought and Global Warming 2, 3, 4 1. conserve and expand populations in each physiographic region; 2. 1 general management plans; 2. 3 habitat management plans; 2. 4 monitor; 2. 10 funding (121)

Impacts from Prolonged Drought and Global Warming 2, 3, 4 1. conserve and expand populations in each physiographic region; 2. 1 general management plans; 2. 3 habitat management plans; 2. 4 monitor; 2. 10 funding (121)

Sperm whale *Physeter macrocephalus*
Draft Recovery Plan for the Sperm Whale (Physeter macrocephalus) 2006
http://www.nmfs.noaa.gov/pr/pdfs/recovery/draft_spermwhale.pdf

G.13 Climate and Ecosystem Change Climate change has received considerable attention in recent years, with growing concerns about global warming and the recognition of natural climatic oscillations on varying time scales, such as long term shifts like the Pacific Decadel oscillation or short term shifts, like El Niño or La Niña. Evidence suggests that the productivity in the North Pacific (Quinn and Neibauer 1995; Mackas et al. 1998) and other oceans, is affected by changes in the environment. Increases in global temperatures are expected to have profound impacts on arctic and sub-arctic ecosystems and these impacts are projected to accelerate during this century. The potential impacts of climate and oceanographic change on sperm whales will likely impact habitat availability and food availability. Site selection for whale migration, feeding, and breeding for sperm whales may be influenced by factors such as ocean currents and water temperature. There is some evidence from Pacific equatorial waters that sperm whale feeding success and, in turn, calf production rates are negatively affected by increases in sea surface temperature (Smith and Whitehead 1993; Whitehead 1997). This could mean that global warming (regardless of whether it is driven primarily by natural or anthropogenic processes) will reduce the productivity of at least some sperm whale populations (Whitehead 1997). Any changes in these factors could render currently used habitats areas unsuitable. Changes to climate and oceanographic processes may also lead to decreased productivity in different patters of prey distribution and availability. Such changes could affect sperm whales that are dependent on those prey. (I-37)

White abalone *Haliotis sorenseni*
Draft White Abalone Recovery Plan (Haliotis sorenseni) 2006
http://www.nmfs.noaa.gov/pr/pdfs/recovery/draft_whiteabalone.pdf

Indirect and direct effects of long-term climate change on white abalone habitat parameters are unknown. (vii)

Factors such as pollution, harvesting of algae (e.g. Macrocystis pyrifera) and climate change have the potential to affect abalone habitat, but are not known to have affected white abalone habitat. (28)

Current threats...Habitat modification through environmental/climate change (34) In spite of the fact that the fishery has been closed since 1996, illegal take of the animals, disease, predation, and habitat degradation through long-term climate change pose the greatest threats to the conservation and recovery of the species. (42)

Warmer water conditions associated with climate change and El Niño events may thus result in increased manifestation of withering syndrome (a bacterial infection). (26)

Atlantic salmon (Gulf of Maine DPS) *Salmo salar* pop. 5
Final Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar) 2005
http://ecos.fws.gov/docs/recovery_plans/2005/051220.

Factors that may contribute to elevated water temperatures include improper or unregulated land use practices, impoundment of free-flowing reaches, discharge of industrial processing or cooling water, low flows that increase net insolation (exposure to sun) and broad climatic changes (Maine TAC 2002). Water temperature may be an important factor limiting Atlantic salmon rearing habitat in Maine rivers (Maine TAC 2002). (1-44)

Climate Change poses a high threat to the conservation and recovery of the DPS. The Gulf of Maine DPS is at the southern end of their range in North America. An examination of the effect of warming climate on fishery resources illustrates the challenges to fish on the southern end of their range. Climate models predict significant warming over the next century as the carbon dioxide content of the atmosphere increases. Records show that there have been periods of warming and cooling of the North Atlantic Ocean, but changes have not been uniform over all areas. Global warming can have an effect on sea temperatures, wind currents, fresh water input, and mixing of the ocean's surface layer. The NRC (2004) concludes that any prolonged or significant warming of Maine's climate would probably make the survival of Atlantic salmon in Maine more difficult due to a number of factors. Some degree of climate warming or change in the hydrologic regime could probably be tolerated if most other problems affecting the DPS were reduced (NRC 2004). (1-96. As part of a list on vi, 2-page discussion of climate change at pp. 1-91 thru 1-92)

1) Implementation of the Priority 1 recovery actions (see Part Five: Implementation Schedule) that will reduce the severest threats (i. e. , acidified water and associated aluminum toxicity, salmon aquaculture, avian predation, changing land use patterns, climate change, depleted diadromous fish communities, incidental capture by recreational fishermen, introduced fish species, low marine survival, poaching, recovery hatchery program, sedimentation and water extraction). (II-I)

Butte County meadowfoam *Limnanthes floccosa* ssp. *californica*
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon 2005
http://ecos.fws.gov/docs/recovery_plans/2006/060307.pdf

Climate and environmental change. Habitat alteration may result from global climate and environmental changes including nitrogen deposition, increase in atmospheric carbon dioxide, changes in precipitation patterns, and global warming. On a local scale, these changes may result in altering current vernal pool habitat to be more suitable to nonnative species and less suitable for native species. Thus native species could be out-competed resulting in changes to the species' ranges (Dukes and Mooney 1999). Climate and landscape ultimately define a species' range and conditions for growth and survival (Sutherst 2000). Species having larger ranges with individuals in the centers of those ranges will have the greatest chance for survival (Sutherst 2000). (I-25)

The vernal pool regions and core areas in this plan have been selected to include the current known habitat for these species; however, planning for such global changes is complex and beyond the scope of this plan. (I-25)

Should the California and Oregon climate become less hospitable to these species where they currently exist, it may be possible that new areas of suitable habitat would eventually evolve. It is also possible that protecting large blocks of vernal pool habitat, may help moderate the impacts of widespread changes by providing refugia and corridors to new habitat. Future management of preserves may also need to consider management options that respond to new moisture patterns (Peters 1988). (I-25-26)

All habitat occupied by featured taxa is important for recovery of listed species or conservation of species of concern for two reasons: (1) vernal pool species are primarily threatened with extinction due to habitat loss and fragmentation, so additional habitat loss is counterproductive to recovery; and (2) genetic diversity within each taxon must be retained to increase a species likelihood of persistence through unpredictable events (e. g. , drought, climate change). (III-5)

Colusa grass *Neostapfia colusana*
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon 2005
http://ecos.fws.gov/docs/recovery_plans/2006/060307.pdf

Climate and environmental change. Habitat alteration may result from global climate and environmental changes including nitrogen deposition, increase in atmospheric carbon dioxide, changes in precipitation patterns, and global warming. On a local scale, these changes may result in altering current vernal pool habitat to be more suitable to nonnative species and less suitable for native species. Thus native species could be out-competed resulting in changes to the species' ranges (Dukes and Mooney 1999). Climate and landscape ultimately define a species' range and conditions for growth and survival (Sutherst 2000). Species having larger ranges with individuals in the centers of those ranges will have the greatest chance for survival (Sutherst 2000). (I-25)

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Conservancy fairy shrimp *Branchinecta conservatio*
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon 2005
http://ecos.fws.gov/docs/recovery_plans/2006/060307.pdf

Climate and environmental change. Habitat alteration may result from global climate and environmental changes including nitrogen deposition, increase in atmospheric carbon dioxide, changes in precipitation patterns, and global warming. On a local scale, these changes may result in altering current vernal pool habitat to be more suitable to nonnative species and less suitable for native species. Thus native species could be out-competed resulting in changes to the species' ranges (Dukes and Mooney 1999). Climate and landscape ultimately define a species' range and conditions for growth and survival (Sutherst 2000). Species having larger ranges with individuals in the centers of those ranges will have the greatest chance for survival (Sutherst 2000). (I-25)

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Contra Costa goldfields *Lasthenia conjugens*
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon 2005
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Delta green ground beetle *Elaphrus viridis*
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Few-flowered navarretia *Navarretia leucocephala* ssp. *pauciflora*
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon 2005
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Fleshy owl's-clover *Castilleja campestris* ssp. *succulenta*
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Green's tuctoria *Tuctoria greenei*
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Hairy orcutt grass *Orcuttia pilosa*
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Hoover's broomspurge *Chamaesyce hooveri*
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Lake County stonecrop *Sedella leiocarpa*
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Loch Lomond coyote-thistle *Eryngium constancei*
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon 2005
http://ecos.fws.gov/docs/recovery_plans/2006/060307.pdf

The extremely restricted distribution of Eryngium constancei is an additional threat to this species. Although the individual populations of E. constancei are sufficiently large that intrinsic problems such as genetic drift are not a concern, other random events could cause the species to go extinct. Catastrophic weather events, climate change, or other unforeseen circumstances potentially could eliminate all of the populations, due the very limited distribution of this plant. (I-23)

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Longhorn fairy shrimp *Branchinecta longiantenna*
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Many-flowered navarretia *Navarretia leucocephala* ssp. *plieantha*
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Sacramento orcutt grass *Orcuttia viscida*
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San Joaquin Valley orcutt grass *Orcuttia inaequalis*
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon 2005
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Short-tailed albatross *Phoebastria albatrus*
Draft Recovery Plan for the Short-tailed Albatross 2005
http://ecos.fws.gov/docs/recovery_plans/2005/051027.pdf

Climate Change According to the recently published report, Impacts of a Warming Arctic (ACIA 2004), the Arctic is now experiencing some of the most rapid and severe climate change on Earth. In the past few decades, average arctic temperature has risen at almost twice the rate of temperatures in the rest of the world. Arctic warming has been accompanied by widespread melting of glaciers and sea ice and rising permafrost temperatures. Increases in glacial melt and river runoff add more fresh water to the ocean, raising global sea level and possibly altering the ocean circulation and patterns of upwelling. Perturbations of these oceanic parameters may affect the availability of food for the short-tailed albatross and other marine birds. Climate changes may also affect vegetation and other characteristics of short-tailed albatross breeding colony sites. An acceleration of these climatic trends is projected to occur during this century, due to ongoing increases in concentrations of greenhouse gases in the earth's atmosphere (ACIA 2004). (9-10. iii)

Slender orcutt grass *Orcuttia tenuis*
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon 2005
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Solano grass *Tuctoria mucronata*
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon 2005
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Vernal pool fairy shrimp *Branchinecta lynchi*
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon 2005
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Vernal pool tadpole shrimp *Lepidurus packardi*
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Climate and environmental change. Habitat alteration may result from global climate and environmental changes including nitrogen deposition, increase in atmospheric carbon dioxide, changes in precipitation patterns, and global warming. On a local scale, these changes may result in altering current vernal pool habitat to be more suitable to nonnative species and less suitable for native species. Thus native species could be out-competed resulting in changes to the species' ranges (Dukes and Mooney 1999). Climate and landscape ultimately define a species' range and conditions for growth and survival (Sutherst 2000). Species having larger ranges with individuals in the centers of those ranges will have the greatest chance for survival (Sutherst 2000). (I-25)

The vernal pool regions and core areas in this plan have been selected to include the current known habitat for these species; however, planning for such global changes is complex and beyond the scope of this plan. (I-25)

Should the California and Oregon climate become less hospitable to these species where they currently exist, it may be possible that new areas of suitable habitat would eventually evolve. It is also possible that protecting large blocks of vernal pool habitat, may help moderate the impacts of widespread changes by providing refugia and corridors to new habitat. Future management of preserves may also need to consider management options that respond to new moisture patterns (Peters 1988). (I-25-26)

All habitat occupied by featured taxa is important for recovery of listed species or conservation of species of concern for two reasons: (1) vernal pool species are primarily threatened with extinction due to habitat loss and fragmentation, so additional habitat loss is counterproductive to recovery; and (2) genetic diversity within each taxon must be retained to increase a species likelihood of persistence through unpredictable events (e. g. , drought, climate change). (III-5)

Coastal dunes milk-vetch *Astragalus tener* var. *titi*
Recovery Plan for Five Plants from Monterey County, California 2004
http://ecos.fws.gov/docs/recovery_plans/2004/041220a.pdf

Ongoing impacts from air pollution and climate change: Use research results and monitoring data to determine effectiveness of management (Actions 5. 2. 1, 5. 2. 2). (C-6)

Threat: Ongoing impacts from air pollution and climate change. Recovery action: Use research results and monitoring data to determine effectiveness of management (Actions 5.2.1, 5.2.2). Develop a public outreach program (Actions 7.1, 7.2, 7.3). (C-6)

Cumberland elktoe *Alasmidonta atropurpurea*
Recovery Plan for Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot 2004
http://ecos.fws.gov/docs/recovery_plans/2004/040524.pdf

Stochastic events, such as droughts, may be exacerbated by global warming and water withdrawals. (45)

Cumberlandian combshell *Epioblasma brevidens*
Recovery Plan for Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot 2004
http://ecos.fws.gov/docs/recovery_plans/2004/040524.pdf

Stochastic events, such as droughts, may be exacerbated by global warming and water withdrawals. (45)

Gowen cypress *Cupressus goveniana* ssp. *goveniana*
Recovery Plan for Five Plants from Monterey County, California 2004
http://ecos.fws.gov/docs/recovery_plans/2004/041220a.pdf

Additional threats may include urban edge effects, ongoing impacts from air pollution and climate change, possible genetic contamination from planted native, local (and possibly non-local) trees, current and increasing presence of nonnative local (and possibly non-local) trees, current and increasing presence of nonnative invasive plant species, and risk of mortality from introduced insects or disease. (46)

Ongoing impacts from air pollution and climate change: Use research results and monitoring data to determine effectiveness of management (Actions 5. 2. 1, 5. 2. 2). (C-6)

Hickman's cinquefoil *Potentilla hickmanii*
Recovery Plan for Five Plants from Monterey County, California 2004
http://ecos.fws.gov/docs/recovery_plans/2004/041220a.pdf

Ongoing impacts from air pollution and climate change: Use research results and monitoring data to determine effectiveness of management (Actions 5. 2. 1, 5. 2. 2). (C-6)

Laysan duck Anas laysanensis Draft Revised Recovery Plan for the Laysan Duck (Anas laysanensis) 2004
http://ecos.fws.gov/docs/recovery_plans/2004/041104.pdf

Long-term threats include the accelerated filling of Laysan's freshwater seeps and lake (Factor A); these changes result from 20th century devegetation of the islands by rabbits and may be exacerbated by sea level rise due to global warming. Sea level rise resulting from global climate change may result in the loss of terrestrial habitat (Factor E) The actions proposed in this plan are designed to address these threats to the Laysan duck and to reestablish multiple populations on additional islands in order to achieve recovery objectives for the species. (iv) Extremes...of anthropogenic disturbance, such as an introduction of rats to Laysan or sea level rise resulting from global warming, may be catastrophic for the Laysan duck under current circumstances. (29)

The Laysan Island duck population experiences periodic crashes due to chance events, and given the small size of the population, such events pose a significant threat to its existence. The most recent population crash was in 1993, when the island suffered a severe drought. Laysan Island is vulnerable to severe storms, and global warming could increase the frequency and intensity of storms. (32)

Global warming and sea level rise (Factor E). Because Laysan is such a low island (12 meters (39 feet) at its highest point) it is especially vulnerable to a rise in sea level. Atmospheric temperatures are expected to increase between 1. 4 and 5. 8 degrees Celsius (2. 5 and 10. 4 degrees Fahrenheit) in the next century, with a concomitant rise in sea levels of 21 centimeters (8. 3 inches) by the year 2050 (IPCC (International Panel on Climate Change) 2001). Even a slight rise in sea levels would destroy a large portion of the duck's current habitat through increased flooding of the terrestrial upland habitats and increased salinity of the groundwater supply. Another anticipated effect of global warming is increased frequency and severity of storms (IPCC 2001) (see Storms, below). (34-35)

The impact of these threats can be reduced by: 1) having many populations geographically spaced to decrease the chance of a catastrophe simultaneously affecting all populations; 2) reestablishing birds on larger islands, for example, Kaua`i and Kaho`olawe, that provide more protection from storms and sea level changes; and 3) developing post-disaster contingency plans to restore populations affected by catastrophes. (29)

Monterey clover *Trifolium trichocalyx*
Recovery Plan for Five Plants from Monterey County, California 2004
http://ecos.fws.gov/docs/recovery_plans/2004/041220a.pdf

Ongoing impacts from air pollution and climate change: Use research results and monitoring data to determine effectiveness of management (Actions 5. 2. 1, 5. 2. 2). (C-6)

Monterey piperia *Piperia yadonii*
Recovery Plan for Five Plants from Monterey County, California 2004
http://ecos.fws.gov/docs/recovery_plans/2004/041220a.pdf

Ongoing impacts from air pollution and climate change: Use research results and monitoring data to determine effectiveness of management (Actions 5. 2. 1, 5. 2. 2). (C-6)

North Atlantic right whale *Eubalaena glacialis*
Second Revised Recovery Plan for the Northern Right Whale, Eubalaena glacialis 2004
http://www.nmfs.noaa.gov/pr/pdfs/recovery/whale_right_northatlantic.pdf

G.7 Climate and Ecosystem Change. There is a close linkage between right whale foraging and the physical forcing processes that concentrate prey in the oceanic environment (Kenney et al. 2001). Interannual, decadal, and longer time-scale variability in climate can alter the distribution and biomass of prey available to right whales. For example, decade-scale climatic regime shifts have been related to changes in zooplankton in the North Atlantic (Fromentin & Planque 1996). Decadal trends in the North Atlantic Oscillation (Hurrell 1995) can affect the position of the Gulf Stream (Taylor et al. 1998) and other circulation patterns in the North Atlantic that may be important to right whales. The effects of climate-induced shifts in productivity, biomass, and species composition of zooplankton on the foraging success of right whales has received little attention. Such shifts in community structure and productivity may alter the distribution and occurrence of foraging right whales in coastal habitats, as well as affecting their reproductive potential. (IG-4)

Oyster mussel *Epioblasma capsaeformis*
Recovery Plan for Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot 2004
http://ecos.fws.gov/docs/recovery_plans/2004/040524.pdf

Stochastic events, such as droughts, may be exacerbated by global warming and water withdrawals. (45)

Purple bean *Villosa perpurpurea*
Recovery Plan for Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot 2004
http://ecos.fws.gov/docs/recovery_plans/2004/040524.pdf

Stochastic events, such as droughts, may be exacerbated by global warming and water withdrawals. (45)

Rough rabbitsfoot *Quadrula cylindrica strigillata*

Recovery Plan for Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot 2004
http://ecos.fws.gov/docs/recovery_plans/2004/040524.pdf

Stochastic events, such as droughts, may be exacerbated by global warming and water withdrawals. (45)

California bighorn sheep (Sierra Nevada DPS) *Ovis canadensis* pop. 3
Draft Recovery Plan for the Sierra Nevada Bighorn Sheep (Ovis canadensis californiana) 2003
http://ecos.fws.gov/docs/recovery_plans/2003/030730.pdf

Climate change may cause significant habitat changes. (65, listed on 74, 146)

6. 8 Investigate effects of climate change on bighorn sheep habitat and environmental contaminants, such as mining wastes or acid rain, on the health of Sierra Nevada bighorn sheep.... Climate change may cause significant habitat changes. (65, listed on 74, 146) Delisting Criterion B3: Recovery tasks related to monitoring and research goals have been accomplished, allowing the severity of secondary threats (including ...climate change) to be adequately assessed. Threats have either been ameliorated or have been determined not to pose a significant risk to the population. (50)

Delisting Criterion B3: Recovery tasks related to monitoring and research goals have been accomplished, allowing the severity of secondary threats (including ...climate change) to be adequately assessed. Threats have either been ameliorated or have been determined not to pose a significant risk to the population. (50)

Gentner's fritillary *Fritillaria gentneri*
Recovery Plan for Fritillaria gentneri (Gentner's Fritillary) 2003
http://ecos.fws.gov/docs/recovery_plans/2003/030828.pdf

2.2 Delineate Fritillaria management area boundaries...Factors to consider when delineating Fritillaria management area boundaries include provision of adequate unoccupied habitat to allow for population expansion (particularly into higher elevations in the face of global warming)…Where possible, the inclusion of higher elevation habitat is desired when determining boundaries for Fritillaria management areas to allow for the potential of shifting populations in response to global warming trends. (36, 46)

Karner blue *Plebejus melissa samuelis*
Final Recovery Plan for the Karner Blue Butterfly (Lycaeides melissa samuelis) 2003
http://ecos.fws.gov/docs/recovery_plans/2003/030919.pdf

Global warming may also pose a threat to the Karner blue. A hotter longer growing season may cause a reduction in the habitat quality of some areas by causing early senesce of lupine. (43)

However, agriculture in sandy soil areas favored by the Karner blue may diminish in Wisconsin over time as it is becoming increasingly costly, and therefore less profitable to support agriculture on sandy soils. Global warming is expected to reduce agriculture on these more arid soils over the next century (39).

Global warming may also pose a threat to the Karner blue. A hotter longer growing season may cause a reduction in the habitat quality of some areas by causing early senesce of lupine. Recovering Karner blues in the more northern recovery units of its existing range should help address this concern. (43)

Quino checkerspot butterfly *Euphydryas editha quino*
Recovery Plan for the Quino Checkerspot Butterfly (Euphydryas editha quino) 2003
http://ecos.fws.gov/docs/recovery_plans/2003/030917.pdf

Other factors contributing to the species' population decline likely have been, and will continue to be, enhanced nitrogen deposition (Allen et al. 1998), elevated atmospheric carbon dioxide concentrations (Coviella and Trumble 1998), and climate change (Parmesan 1996, Field et al. 1999, Parmesan in press). (55)

8. Climate Change Evidence of local climate change and a corresponding change in the Quino checkerspot butterfly's range-wide distribution supports the conclusion that climate change is a substantial threat to the species' survival in the foreseeable future. A trend toward warming in the last century has been linked to elevated greenhouse gases globally... (64)

Increasing Atmospheric Carbon Dioxide Concentration. Increasing atmospheric carbon dioxide gas concentration has direct effects upon the vegetation and indirect effects on associated insects.... (62-63)

2) Conduct research including...determine the effects of elevated atmospheric carbon dioxide, nitrogen fertilization, and invasive plants on the Quino checkerspot butterfly and its host plant...(93)

8. Determine the effect of elevated atmospheric carbon dioxide and nitrogen fertilization on the Quino checkerspot butterfly and its host plant. It is scientifically well established that carbon dioxide levels in the atmosphere are increasing, and this increase will have profound ecological effects above and beyond associated global climate change. Although information is accumulating about the effects of elevated carbon dioxide on host plants and insect species, we know little about specific ecosystem level effects, or possible effects on Euphydryas editha. Indirect effects of elevated carbon dioxide, like climate-driven range shifts, are likely to affect not only all aspects of the Quino checkerspot butterfly recovery strategy in the foreseeable future, but also the future of every other native species in southern California. (108)

In light of the recent warming and drying trends, prudent design of reserves and other managed habitats should include landscape connectivity to other habitat areas and ecological connectivity with undeveloped lands in order to accommodate range shifts northward and upward in elevation. (65)

We believe sufficient emphasis is given in the plan to threats presented by urban growth and development, and global warming is a future, if not current, threat to the Quino checkerspot butterfly potentially equal to and exacerbated by habitat destruction. We edited the text to better explain current knowledge of the threat of global warming, and added suggestions for how to begin addressing local recovery actions and planning. In most cases recovery actions addressing global warming effects are the same as or reinforce those addressing habitat destruction and development. (171)

In making any downlisting determination we will consider...anthropogenic global change factors (i. e. , enhanced nitrogen deposition, elevated atmospheric carbon dioxide concentrations, and climate change). (95)

San Francisco lessingia *Lessingia germanorum*
Recovery Plan for Coastal Plants of the Northern San Francisco Peninsula 2003
http://ecos.fws.gov/docs/recovery_plans/2003/031006.pdf

The recovery plan acknowledges that San Francisco lessingia would be likely to establish along the stable dune roadside of the Great Highway, along Ocean Beach, if it were reintroduced to Sutro Heights dune remnants. This is not a recommended strategy, however, because sea level rise may erode the Great Highway and force its replacement, because the habitat there is highly degraded by imported fill and weeds, and because the habitat is unstable due to the high degree of wind scour. (VI-8)

Bull trout (Columbia River DPS) *Salvelinus confluentus* pop. 2
Draft Recovery Plan for Three of the Five Distinct Population Segments of Bull Trout (Salvelinus confluentus) 2002
http://ecos.fws.gov/docs/recovery_plans/2002/021129.pdf

The primary drought risk to these watersheds appears to be more a result of possible major global climate change, rather than single events. Climate changes would likely affect bull trout rangewide. Due to the high elevation nature of most of the bull trout waters in the Saint Mary and Belly River drainages, the effects of drought in the Saint Mary - Belly River Recovery Unit are probably minimal. However, the gradual melting of the glaciers has an associated consequence in the gradual warming of water temperatures. (25, 65)

Bull trout (Klamath River DPS) *Salvelinus confluentus* pop. 1
Draft Recovery Plan for Three of the Five Distinct Population Segments of Bull Trout (Salvelinus confluentus) 2002
http://ecos.fws.gov/docs/recovery_plans/2002/021129.pdf

The primary drought risk to these watersheds appears to be more a result of possible major global climate change, rather than single events. Climate changes would likely affect bull trout rangewide. Due to the high elevation nature of most of the bull trout waters in the Saint Mary and Belly River drainages, the effects of drought in the Saint Mary - Belly River Recovery Unit are probably minimal. However, the gradual melting of the glaciers has an associated consequence in the gradual warming of water temperatures. (25, 65)

Bull trout (St. Mary and Belly Rivers DPS) *Salvelinus confluentus* pop. 5
Draft Recovery Plan for Three of the Five Distinct Population Segments of Bull Trout (Salvelinus confluentus) 2002
http://ecos.fws.gov/docs/recovery_plans/2002/021129.pdf

The primary drought risk to these watersheds appears to be more a result of possible major global climate change, rather than single events. Climate changes would likely affect bull trout rangewide. Due to the high elevation nature of most of the bull trout waters in the Saint Mary and Belly River drainages, the effects of drought in the Saint Mary - Belly River Recovery Unit are probably minimal. However, the gradual melting of the glaciers has an associated consequence in the gradual warming of water temperatures. (25, 65)

Pitchers thistle *Cirsium pitcheri*
Pitcher's Thistle (Cirsium pitcheri) Recovery Plan 2002
http://ecos.fws.gov/docs/recovery_plans/2002/020920b.pdf

Global warming may also pose a risk. As described previously, the long-term survival of Pitcher’s thistle requires a shifting mosaic of suitable habitat available at all times so that, as areas are made unsuitable by succession, new areas of suitable habitat are created close enough for seed dispersal. Fragmentation prevents the creation of new areas of suitable habitat and likely interferes with seed dispersal. (39)

Global warming may increase drought frequency. Droughts may account for the poor success of Cirsium pitcheri populations at the Indiana Dunes National Lakeshore (McEachern et al. 1989) and at other southern locations. Global warming may affect the water table levels along the Great Lakes shorelines and impact Pitcher’s thistle through altered shoreline processes. (40)

Sonoran pronghorn *Antilocapra americana sonoriensis*
Recovery Criteria and Estimates of Time for Recovery Actions for the Sonoran Pronghorn: A Supplement and Amendment to the Final Revised Sonoran Pronghorn Recovery Plan 2002
http://ecos.fws.gov/docs/recovery_plans/1998/981203.pdf

After a thorough review of the best available information and considerable discussion, the Recovery Team concluded that given the nature and significance of current threats (e. g. , lengthy and recurring dry seasons, long-term and perhaps irreversible habitat changes brought about by past overgrazing and continued global warming...(and other factors), establishing delisting criteria (i. e. , defining a population level and an amount and distribution of habitat that would provide for long-term persistence of the entire subspecies) at this time is not practicable. (36-37)

Bighorn sheep (Peninsular ranges DPS) *Ovis canadensis* pop. 2
Recovery Plan for Bighorn Sheep in the Peninsular Ranges, California 2000
http://ecos.fws.gov/docs/recovery_plans/2000/001025.pdf

f. Unpredictable changes in global climate warrant retention of future options in habitat conservation strategies. (75)

Hoffman slender-flowered gilia *Gilia tenuiflora* ssp. *hoffmannii*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Hoffmann's rock cress *Arabis hoffmannii*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Island barberry *Mahonia pinnata* ssp. *insularis*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Island bedstraw *Galium buxifolium*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Island malacothrix *Malacothrix squalida*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Island phacelia *Phacelia insularis* var. *insularis*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000

http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Island rush-rose *Helianthemum greenei*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Santa Cruz Island bush mallow *Malacothamnus fasciculatus* var. *nesioticus*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Santa Cruz Island dudleya *Dudleya nesiotica*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Santa Cruz Island lacepod *Thysanocarpus conchuliferus*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Santa Cruz Island malacothrix *Malacothrix indecora*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Santa Rosa Island manzanita *Arctostaphylos confertiflora*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000
http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Soft-leaved Indian paintbrush *Castilleja mollis*
Thirteen Plant Taxa from the Northern Channel Islands Recovery Plan 2000

http://ecos.fws.gov/docs/recovery_plans/2000/000926.pdf

The (delisting) criteria should be adjusted when additional research indicates otherwise, as we are apparently entering a dry climatic cycle complicated by the trend of global warming. (63)

Applegate's milk-vetch *Astragalus applegatei*
Recovery Plan for the Applegate's Milk-vetch (Astragalus applegatei) 1998
http://ecos.fws.gov/docs/recovery_plans/1998/980410d.pdf

Although stochastic events, such as floods, droughts, and fires may have the most significant short term effects on small plant populations, it is believed that genetic variability may be crucial for adaption to longer-term changes such as climate, not to mention. Therefore until demographic studies show otherwise, self-sustaining populations will be defined as containing a minimum of 1,500 reproductive plants, plus sufficient individuals in younger age classes to suggest population stability or growth. (14)

Bay checkerspot butterfly *Euphydryas editha bayensis*
Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area 1998
http://ecos.fws.gov/docs/recovery_plans/1998/980930c.pdf

Disease, catastrophic fire, prolonged extreme weather, air pollution, or climate change could threaten one or more core populations--events that a satellite population or two might survive, due to isolation, differences in local serpentine soils, airflow or local climate patterns, or for unforeseeable reasons. (II-180)

Effects of Climate Change. The bay checkerspot would likely be very sensitive to climate change, because its development and mortality are critically dependent on temperature and the development of its host plants, which in turn are controlled by climate (Murphy and Weiss 1992). Climate models do not yet agree on exactly how global climate change is expected to change Bay Area climate, but both temperature and rainfall are likely to be affected. Murphy and Weiss (1992) argue that the Kirby bay checkerspot population, the largest and sometimes considered the most viable population, is not well-buffered against climatic change. This area receives the least rainfall in the species' range, and many small populations in the area disappeared during the 1975 to 1977 drought, whereas small populations in wetter San Mateo County survived. Simulation modeling suggested that three out of four climate-change scenarios (colder and wetter, colder and drier, warmer and drier) would adversely affect the bay checkerspot, as would a change in the timing of rainfall (Murphy and Weiss 1992). Climate change might also affect the relative dominance of native vs. nonnative vegetation in serpentine habitats. Because there can be little local control over global climate changes, preservation of bay checkerspot habitats and populations in as broad a range of local climate conditions as possible is prudent. (II-197)

Leedy's roseroot *Rhodiola integrifolia* ssp. *leedyi*
Sedum integrfoIium ssp. leedyi (Leedy's roseroot) Recovery Plan 1998
http://ecos.fws.gov/docs/recovery_plans/1998/980925.pdf

The cool microclimates in which S. integrifolium ssp. leedyi survives may be affected by global warming or other unforeseen circumstances. The risk of lost viability or extinction resulting from stochastic events is exacerbated by the fact that each population is genetically distinctive. (14)

7. Develop and maintain a genetic bank The cool microclimates in which S. integrifolium ssp. leedyi survives may be affected by global warming or other unforeseen circumstances. The risk of lost viability or extinction resulting from stochastic events is exacerbated by the fact that each population is genetically distinctive. For this reason, redundant collections of seeds or cuttings from each population should be preserved in a genetic bank for possible reintroduction in the event of a natural catastrophe at any one of the sites. Should results of monitoring over time suggest that populations are declining because of inbreeding depression, material from other populations maintained in this bank could then be introduced

into sites at risk to provide opportunity to increase their genetic diversity. Plants collected in Minnesota have been brought into cultivation at a Center for Plant Conservation garden (Brian Parsons, The Holden Arboretum, pers. comm. 1993). (14)

Pacific green sea turtle *Chelonia mydas agassizii*
Recovery Plan for U. S. Pacific Populations of the Green Turtle (Chelonia mydas) 1998
http://ecos.fws.gov/docs/recovery_plans/1998/981201e.pdf

American Samoa: Recent weather records indicate that a severe tropical storm or hurricane hits somewhere in the Samoan island chain approximately every three years, causing extensive erosion. A predicted rise in sea level due to global warming would increase erosion problems...FSM: Minor problem, although severe tropical storms and typhoons are not uncommon for this region. Seasonal changes in wind direction (which occur towards the end of the main nesting season -- late July/early August) result in the erosion of beaches. Yap State's low coralline atolls are extremely vulnerable to rises in sea levels and will be adversely affected by greenhouse gas emissions, if current hypotheses are correct...RMI: Moderate problem. Shoreline erosion occurs naturally on many islands in the atolls of the Marshalls due to storms, sea level rise and from ENSO's (El Niño - Southern Oscillation) and currents. On the outer atolls erosion has been aggravated by airfield and dock development, as well as by urban development on Majuro and Kwajalein Atoll. (33)

Natural Disasters...RMI: Moderate problem, however the low elevation of these islands makes them particularly susceptible to typhoons, large waves and sea level rise. (38)

Pacific hawksbill sea turtle *Eretmochelys imbricata bissa*
Recovery Plan for U. S. Pacific Populations of the Hawksbill Turtle 1998
http://ecos.fws.gov/docs/recovery_plans/1998/981201c.pdf

American Samoa: Recent weather records indicate that a severe tropical storm or hurricane hits somewhere in the Samoan island chain approximately every three years, causing extensive erosion. A predicted rise in sea level due to global warming would increase erosion problems...FSM: Minor problem, although severe tropical storms and typhoons are not uncommon for this region. Seasonal changes in wind direction (which occur towards the end of the main nesting season -- late July/early August) result in the erosion of beaches. Yap State's low coralline atolls are extremely vulnerable to rises in sea levels and will be adversely affected by greenhouse gas emissions, if current hypotheses are correct...RMI: Moderate problem. Shoreline erosion occurs naturally on many islands in the atolls of the Marshalls due to storms, sea level rise and from ENSO's (El Niño - Southern Oscillation) and currents. On the outer atolls erosion has been aggravated by airfield and dock development, as well as by urban development on Majuro and Kwajalein Atoll. (33)

Spruce-fir moss spider *Microhexura montivaga*
Recovery Plan for the Spruce-fir Moss Spider 1998
http://ecos.fws.gov/docs/recovery_plans/1998/980911b.pdf

Numerous other factors are also likely threatening the long-term existence of the spruce-fir moss spider. The majority of the high-elevation spruce-fir forests of the Southeast have suffered extensive changes and declines in size and/or vigor during the past century as a result of a number of factors--past logging and burning practices, storm damage, atmospheric pollution, climatic changes, disease, insect damage, exposure shock, and others not yet fully understood. (10)

Warner sucker *Catostomus warnerensis*
Recovery Plan for the Native Fishes of the Warner Basin and Alkali Subbasin 1998
http://ecos.fws.gov/docs/recovery_plans/1998/980427.pdf

The effects of current land and water use on these fishes are greatly exacerbated by drought, and a prolonged drought could make the recovery of the species more difficult. For example, the drought of 1987 to 1994 reduced stream habitat and desiccated the Warner Lakes, extirpating the lake-resident Warner sucker population. (56)

The recovery strategy for the Warner sucker therefore includes reducing the threats that originally led to the listing of the species. These activities would include protection and rehabilitation of populations and habitat, conservation of genetic diversity of the populations, controlling introduced exotic fishes, securing adequate water supplies for the continued survival of the species, monitoring populations and habitat conditions, and evaluation of long-term effects of climatic trends on the recovery of listed fish. (39, 56, 72)

Cushenbury buckwheat *Eriogonum ovalifolium* var. *vineum*
San Bernardino Mountains Carbonate Plants Draft Recovery Plan 1997
http://ecos.fws.gov/docs/recovery_plans/1997/970930e.pdf

At a minimum, habitat reserves should be designed to contain contiguous, buffered habitat, take into account long-term sustainability, potential geographic distributional shifts in response to climate change, and include the possibility of reintroduction/expansion of carbonate plant populations. (28)

Cushenbury milk-vetch *Astragalus albens*
San Bernardino Mountains Carbonate Plants Draft Recovery Plan 1997
http://ecos.fws.gov/docs/recovery_plans/1997/970930e.pdf

At a minimum, habitat reserves should be designed to contain contiguous, buffered habitat, take into account long-term sustainability, potential geographic distributional shifts in response to climate change, and include the possibility of reintroduction/expansion of carbonate plant populations. (28)

Cushenbury oxytheca *Oxytheca parishii* var. *goodmaniana*
San Bernardino Mountains Carbonate Plants Draft Recovery Plan 1997
http://ecos.fws.gov/docs/recovery_plans/1997/970930e.pdf

At a minimum, habitat reserves should be designed to contain contiguous, buffered habitat, take into account long-term sustainability, potential geographic distributional shifts in response to climate change, and include the possibility of reintroduction/expansion of carbonate plant populations. (28)

Florida salt marsh vole *Microtus pennsylvanicus dukecampbelli*
Recovery Plan for the Florida Salt Marsh Vole (Microtus pennsylvanicus dukecampbelli) 1997
http://ecos.fws.gov/docs/recovery_plans/1997/970930d.pdf

The decline of the species appears natural, due to climatic changes and an associated rise in sea level. (4)

Marbled murrelet (OR, WA, CA DPS) *Brachyramphus marmoratus marmoratus* (OR, WA, CA DPS)
Recovery Plan for the Threatened Marbled Murrelet (Brachyramphus marmoratus) in Washington, Oregon, and California 1997
http://ecos.fws.gov/docs/recovery_plans/1997/970924.pdf

3. 2. 1. 2 Protect recruitment nesting habitat to buffer and enlarge existing stands, reduce fragmentation, and provide replacement habitat for current suitable nesting habitat lost to disturbance events. Stands (currently 80 years old or older) that will produce suitable habitat within the next few decades are the most immediate source of new habitat and may be the only replacement for existing habitat lost to disturbance (e. g. , timber harvest, fires, etc.) over the next century. Such stands are particularly important because of the vulnerability of many existing habitat fragments to fire and wind and the possibility that climate change will increase the effects of the frequency and severity of natural disturbances. (143)

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Parish's daisy *Erigeron parishii*
San Bernardino Mountains Carbonate Plants Draft Recovery Plan 1997
http://ecos.fws.gov/docs/recovery_plans/1997/970930e.pdf
At a minimum, habitat reserves should be designed to contain contiguous, buffered habitat, take into account long-term sustainability, potential geographic distributional shifts in response to climate change, and include the possibility of reintroduction/expansion of carbonate plant populations. (28)

San Bernardino Mountains bladderpod *Lesquerella kingii* ssp. *bernardina*
San Bernardino Mountains Carbonate Plants Draft Recovery Plan 1997
http://ecos.fws.gov/docs/recovery_plans/1997/970930e.pdf

At a minimum, habitat reserves should be designed to contain contiguous, buffered habitat, take into account long-term sustainability, potential geographic distributional shifts in response to climate change, and include the possibility of reintroduction/expansion of carbonate plant populations. (28)

Delta smelt *Hypomesus transpacificus*
Sacramento-San Joaquin Delta Native Fishes Recovery Plan 1996
http://ecos.fws.gov/docs/recovery_plans/1996/961126.pdf

Climate change. In the past decade (1984-1994), California experienced more variability in precipitation than had occurred in the previous century. The result was an extended drought interrupted by a record flood (1993), another dry year (1994), and then an exceptionally wet year (1995). Tree ring records indicate that droughts of 20-50 years or longer were common in the past, yet California's water management system is based on the assumption that such extended droughts do not occur. A lengthy drought will severely test society's willingness to continue to provide water for environmental purposes, especially in the Delta, when the agricultural and urban economies are severely stressed because of inadequate water supplies. (11)

3. Climatic variation. The climatic conditions that the estuary has experienced since 1982 have been some of the most extreme since the arrival of Europeans. The years 1985 1992 were ones of continuous drought, broken only by the record outflows of February 1986. The prolonged drought had two major interacting effects: a natural decrease in outflow and an increase in the proportion of inflowing water being diverted. A natural decline in longfin smelt numbers would be expected from the reduced outflow, because of the reduced availability of brackish water habitat for larvae and juveniles. However, the increase in diversions most likely exacerbated the decline in longfin smelt survival through a combination of further reduction in brackish water habitat and increased entrainment of larvae, juveniles, and adults. It is important to recognize that extreme floods and droughts have occurred in the past and longfin smelt have managed to persist through them. However, unlike today, longfin smelt historically did not experience the extreme conditions caused by increased diversion of water. (54)

Sacramento splittail *Pogonichthys macrolepidotus*
Sacramento-San Joaquin Delta Native Fishes Recovery Plan 1996
http://ecos.fws.gov/docs/recovery_plans/1996/961126.pdf

Climate change. In the past decade (1984-1994), California experienced more variability in precipitation than had occurred in the previous century. The result was an extended drought interrupted by a record flood (1993), another dry year (1994), and then an exceptionally wet year (1995). Tree ring records indicate that droughts of20-50 years or longer were common in the past, yet California's water management system is based on the assumption that such extended droughts do not occur. A lengthy drought will severely test society's willingness to continue to provide water for environmental purposes, especially in the Delta, when the agricultural and urban economies are severely stressed because of inadequate water supplies. (11)

Seabeach amaranth *Amaranthus pumilus*
Recovery Plan for Seabeach Amaranth (Amaranthus pumilus) 1996
http://ecos.fws.gov/docs/recovery_plans/1996/961112b.pdf

The 1990 surveys revealed that the effects of these climatic events (series of hurricanes and nor-easters) were substantial. (13)

If data and hypotheses suggesting future increases in sea level are correct, beach erosion will accelerate and put further pressure on seabeach amaranth, especially on the barrier beaches that can no longer respond naturally to such change because of beach armoring and other hard stabilization structures.... This amaranth has certainly survived other episodes of sea level rise, which have occurred naturally and episodically in the past. (12)

Water howellia *Howellia aquatilis*
Water Howellia (Howellia aquatilis) Recovery Plan, Public and Agency Review Draft 1996
http://ecos.fws.gov/docs/recovery_plans/1996/960924.pdf

Short- and long-term climatic changes could affect H. aquatilis by influencing the seasonal flooding and drying patterns of wetlands...climatic change, whether it results in excessive drying or water retention in the wetlands, might ultimately lead to extinction of the species. Alternatively, climate change could create ideal conditions for H. aquatilis in ponds that currently are unable to support H. aquatilis. (25-26)

...the maintenance of as many occurrences of H. aquatilis as possible within each geographic area will best insure the ability of the individual metapopulations to persist in the face of future natural environmental changes and land use effects (i. e. , global climate warming...(27)

Sensitive joint-vetch *Aeschynomene virginica*
Sensitive Joint-Vetch (Aeschynomene virginica) Recovery Plan 1995
http://ecos.fws.gov/docs/recovery_plans/1995/950929b.pdf

Natural threats are often identified with disturbances, such as wave and ice action associated with severe storm events, competition, herbivory, channel migration, sea level rise (see previous discussion), and natural sedimentation processes. (29)

Desert tortoise (Mojave DPS) *Gopherus agassizii* pop. 1
Desert tortoise (Mojave population) Recovery Plan 1994
http://ecos.fws.gov/docs/recovery_plans/1994/940628.pdf

...the (population viability) simulations point to the extremely potent effect that climate change could have if new conditions resulted in abandoning reproduction altogether in numerous bad years interspersed among somewhat better years for production of food resources. (C-3) Another group of impacts which can be categorized as potential impacts includes air pollution, acid rain, acid precipitation, electromagnetic fields, electromagnetism, global warming, and greenhouse effects. (D-40, C-3)

Diamond Head schiedea *Schiedea adamantis*
Recovery plan for Schiedea adamantis 1994
http://ecos.fws.gov/docs/recovery_plans/1994/940202a.pdf

Climatic changes. Extended drought over a several-year period, whether because of normal variation in weather patterns or because of long-term climatic changes such as global warming, could result in high mortality and extinction of Schiedea adamantis in spite of its being adapted to dry lowland conditions. Seedlings are very vulnerable to desiccation, and adults may also suffer high mortality with a sequence of dry years. (12)

Hawaiian Island Violet *Viola helenae*
Recovery Plan for the Wahiawa Plant Cluster: Cyanea undulata Dubautia pauciflorula, Hesperomannia lvdgatei, Labordia lvdgatei and Viola helenae. 1994
http://ecos.fws.gov/docs/recovery_plans/1994/940531.pdf

54. Determine if hypothesized human-induced changes in climate will affect populations Hypothesized human-induced changes in global climate may also impact on local climates and thus plant distributions. It would be prudent to hypothesize how these global climate changes might affect the long-term survivability of existing populations. (42, 51)

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Kamakahala *Labordia lydgatei*
Recovery Plan for the Wahiawa Plant Cluster: Cyanea undulata Dubautia pauciflorula, Hesperomannia lvdgatei, Labordia lvdgatei and Viola helenae. 1994
http://ecos.fws.gov/docs/recovery_plans/1994/940531.pdf

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Kauai hesperomannia *Hesperomannia lydgatei*
Recovery Plan for the Wahiawa Plant Cluster: Cyanea undulata Dubautia pauciflorula, Hesperomannia lvdgatei, Labordia lvdgatei and Viola helenae. 1994
http://ecos.fws.gov/docs/recovery_plans/1994/940531.pdf

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Koki`o *Kokia drynarioides*
Recovery Plan for Kokia drynarioides and Caesalpinia kavaiensis 1994
http://ecos.fws.gov/docs/recovery_plans/1994/940506a.pdf

54. Determine if hypothesized human-induced changes in climate will affect populations Human-induced changes in global climate may also impact on local climates and thus plant distributions. How these global climate changes might affect the long-term survivability of existing Caesalpinia kavaiensis and Kokia drynarioides populations should be studied. (62, 65)

Na`ena`e *Dubautia pauciflorula*
Recovery Plan for the Wahiawa Plant Cluster: Cyanea undulata Dubautia pauciflorula, Hesperomannia lvdgatei, Labordia lvdgatei and Viola helenae. 1994
http://ecos.fws.gov/docs/recovery_plans/1994/940531.pdf

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Uhiuhi *Caesalpinia kavaiensis*
Recovery Plan for Kokia drynarioides and Caesalpinia kavaiensis 1994
http://ecos.fws.gov/docs/recovery_plans/1994/940506a.pdf

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Wavy cyanea *Cyanea undulata*
Recovery Plan for the Wahiawa Plant Cluster: Cyanea undulata Dubautia pauciflorula, Hesperomannia lvdgatei, Labordia lvdgatei and Viola helenae. 1994
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Black-spored quillwort *Isoetes melanospora*
Recovery Plan for Three Granite Outcrop Plant Species 1993
http://ecos.fws.gov/docs/recovery_plans/1993/930707.pdf

The effects of widespread environmental changes, such as acid rain and possible global warming, are unclear. For example, both the buffering capacity of outcrop soil and the tolerance of these species to lowered pH are unknown. (11)

Chisos Mountains hedgehog cactus *Echinocereus chisoensis* var. *chisoensis*
Chisos Mountain Hedgehog Cactus (Echinocereus chisoensis var. chisoensis) Recovery Plan 1993
http://ecos.fws.gov/docs/recovery_plans/1993/931208c.pdf

3111. Study geology and hydrology.... The study should include an assessment of any alteration in site conditions resulting from past land uses or climatic changes over the last two centuries. (27)

3141. Study the status of the variety in the community.... Changes in community composition over the last two centuries should be evaluated in terms of causal factors (grazing and/or climatic change) and potential for restoration. (28)

Grizzly bear (Lower 48 Outside Yellowstone DPS) *Ursus arctos* (Lower 48 Outside Yellowstone DPS)
Revised grizzly bear recovery plan 1993
http://ecos.fws.gov/docs/recovery_plans/2006/060224.pdf

...if predicted global climate changes eventually occur, already marginal grizzly habitat in areas such as Yellowstone National Park may be rendered unsuitable for grizzly occupancy. (2-23)

It is crucial that this information on the grizzly bears' biological requirements be correlated with habitat conditions. Of particular relevance are habitat factors relating to ecosystem dynamics that may limit the range or food availability of bears. These factors can include climate change...Detailed information on these factors should be gathered as soon as possible and annual recording of patterns should be initiated in order to recognize habitat dynamics changes as they might occur. (3-53, 3-74, 3-92, 3-111)

Grizzly bear (Yellowstone DPS) *Ursus arctos* (Yellowstone DPS)
Revised grizzly bear recovery plan 1993
http://ecos.fws.gov/docs/recovery_plans/2006/060224.pdf

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Honohono *Haplostachys haplostachya*
Draft Recovery Plan for Haplostachys haplostachya and Stenogyne angustifolia 1993
http://ecos.fws.gov/docs/recovery_plans/1993/930920.pdf

94. Determine whether the hypothesized human-induced changes in climate will affect the populations. Hypothesized human-induced changes in global climate may also impact on local climates and, thus, plant distributions. It would be prudent to hypothesize how these global climate changes might affect the long-term survival of existing H. haplostachya and S. angustifolia populations. (94, 28)

Little amphianthus *Amphianthus pusillus*
Recovery Plan for Three Granite Outcrop Plant Species 1993
http://ecos.fws.gov/docs/recovery_plans/1993/930707.pdf

The effects of widespread environmental changes, such as acid rain and possible global warming, are unclear. For example, both the buffering capacity of outcrop soil and the tolerance of these species to lowered pH are unknown. (11)

Mat-forming quillwort *Isoetes tegetiformans*
Recovery Plan for Three Granite Outcrop Plant Species 1993
http://ecos.fws.gov/docs/recovery_plans/1993/930707.pdf

The effects of widespread environmental changes, such as acid rain and possible global warming, are unclear. For example, both the buffering capacity of outcrop soil and the tolerance of these species to lowered pH are unknown. (11)

Mt. Graham red squirrel *Tamiasciurus hudsonicus grahamensis*
Mount Graham Red Squirrel Recovery Plan 1993
http://ecos.fws.gov/docs/recovery_plans/1993/930503.pdf

...natural succession will also increase the habitat capability. However, natural or human-caused catastrophes such as insect outbreaks, fires, and possible climatic shifts due to global warming, may alter and affect habitat. (5)

Global Warming: The Pinalenos contain relict montane conifer and spruce—fir associations that have retreated up the mountain in elevation since the Pleistocene glacial period. Global warming might cause a further retreat of the forests up the mountain greatly reducing or eliminating red squirrel habitat. (22)

Natural or man-caused catastrophes could cause extinction. Catastrophic fire (both natural and human caused) and human development projects within the habitat are the most immediate threats that will likely affect suitable habitat. Global warming could cause retreat of the Pleistocene relict forest and reduce the squirrels' chances for survival over the long-term. Insect or tree disease outbreaks are also significant treats to suitable habitat. (22)

The recovery plan uses catastrophe to describe events that eliminate significant portions of the available habitat of the red squirrel. Major fires and long-term droughts are specifically mentioned. The FWS must look at events or conditions that may preclude recovery of the species. Restoration of some forested areas may take 200 to 300 or more years. If global warming is occurring and continues, then there may be effects to the forests of the Pinalenos. We recognize there is little we can do about global warming, but it has a reasonable probability of occurring so should be mentioned. (166)

Nanu *Gardenia brighamii*
Recovery Plan for the Hawaiian Gardenia (Gardenia brighamii) 1993
http://ecos.fws.gov/docs/recovery_plans/1993/930930b.pdf

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would be prudent to hypothesize how these global climate changes might affect the long-term survivability of existing Gardenia brighamii populations. (45, 68)

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Narrow-leaved stenogyne *Stenogyne angustifolia* var. *angustifolia*
Draft Recovery Plan for Haplostachys haplostachya and Stenogyne angustifolia 1993
http://ecos.fws.gov/docs/recovery_plans/1993/930920.pdf

94. Determine whether the hypothesized human-induced changes in climate will affect the populations. Hypothesized human-induced changes in global climate may also impact on local climates and, thus, plant distributions. It would be prudent to hypothesize how these global climate changes might affect the long-term survival of existing H. haplostachya and S. angustifolia populations. (94, 28)

Utah prairie dog *Cynomys parvidens*
Utah Prairie Dog Recovery Plan 1991
http://ecos.fws.gov/docs/recovery_plans/1991/910930b.pdf

Climatological changes also have resulted in a constriction of the species distribution. The western portion of the species' historical range has become less favorable to prairie dogs due to the higher temperatures, drier climate, and gradual replacement of tall grasses with salt-shrub vegetation. (11)

Carolina northern flying squirrel *Glaucomys sabrinus coloratus*
Appalachian Northern Flying Squirrels (Glaucomys sabrinus fuscus) (Glaucomys sabrinus coloratus) Recovery Plan 1990
http://ecos.fws.gov/docs/recovery_plans/1990/900924c.pdf

Even without human intervention, small, relict populations might suffer disproportionately from genetic constraints (e.g., increased homozygosity) as well as from climatic and vegetational processes associated with post-Wisconsin changes in mountain environments. However, habitat destruction, fragmentation, or alteration associated with clearing of forests, introduced insect pests, mineral extraction, recreational or other development, pollution (heavy metals, pesticides, acid rain), and the potential for global warming outweigh any known natural threats to the species or its habitat. (12)

West Virginia northern flying squirrel *Glaucomys sabrinus fuscus*
Appalachian Northern Flying Squirrels (Glaucomys sabrinus fuscus) (Glaucomys sabrinus coloratus) Recovery Plan 1990
http://ecos.fws.gov/docs/recovery_plans/1990/900924c.pdf

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Acc. No. 0572.3 – EPA Rule Regulating Greenhouse Gas Emissions and copyrighted attachments can be viewed on the docket:
http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0565 – Social Cost of Carbon: A Closer Look at Uncertainty can be viewed on the docket:
http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Title	When will Summer Arctic Sea Ice Disappear?
Author(s)	Maslowski, Wieslaw
Citation	地球温暖化による劇変を解明する. 平成20年6月24日. 札幌市
Issue Date	2008-06-24
Type	presentation
URL	http://hdl.handle.net/2115/34395
Right	

When will Summer Arctic Sea Ice Disappear?

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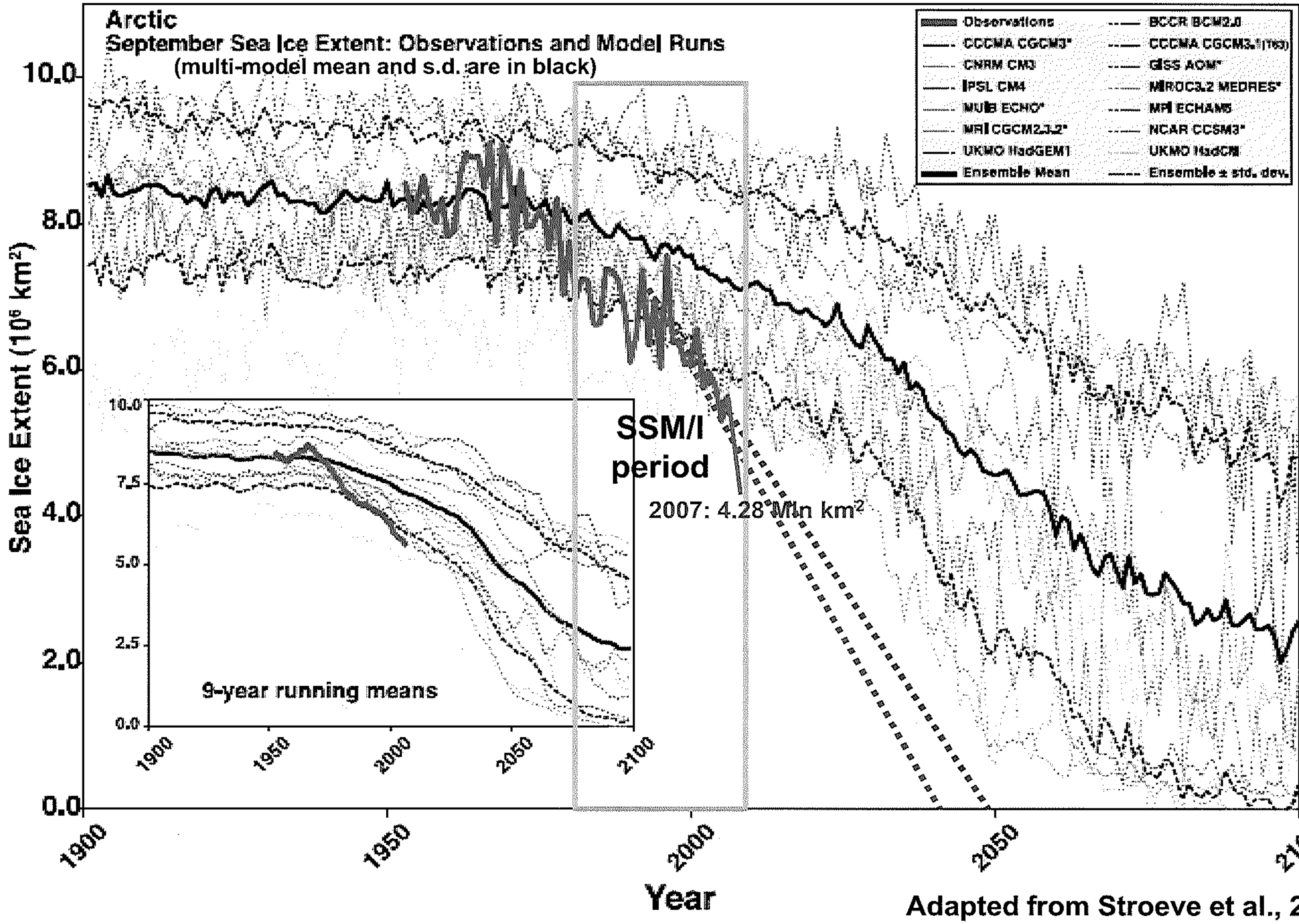
Jay Zwally	- NASA / GSFC
Jaromir Jakacki, Waldemar Walczowski	- Institute of Oceanology, PAS
Agnieszka Beszczynska-Möller	- AWI
Ron Kwok	- NASA / JPL
Marika Holland	- NCAR

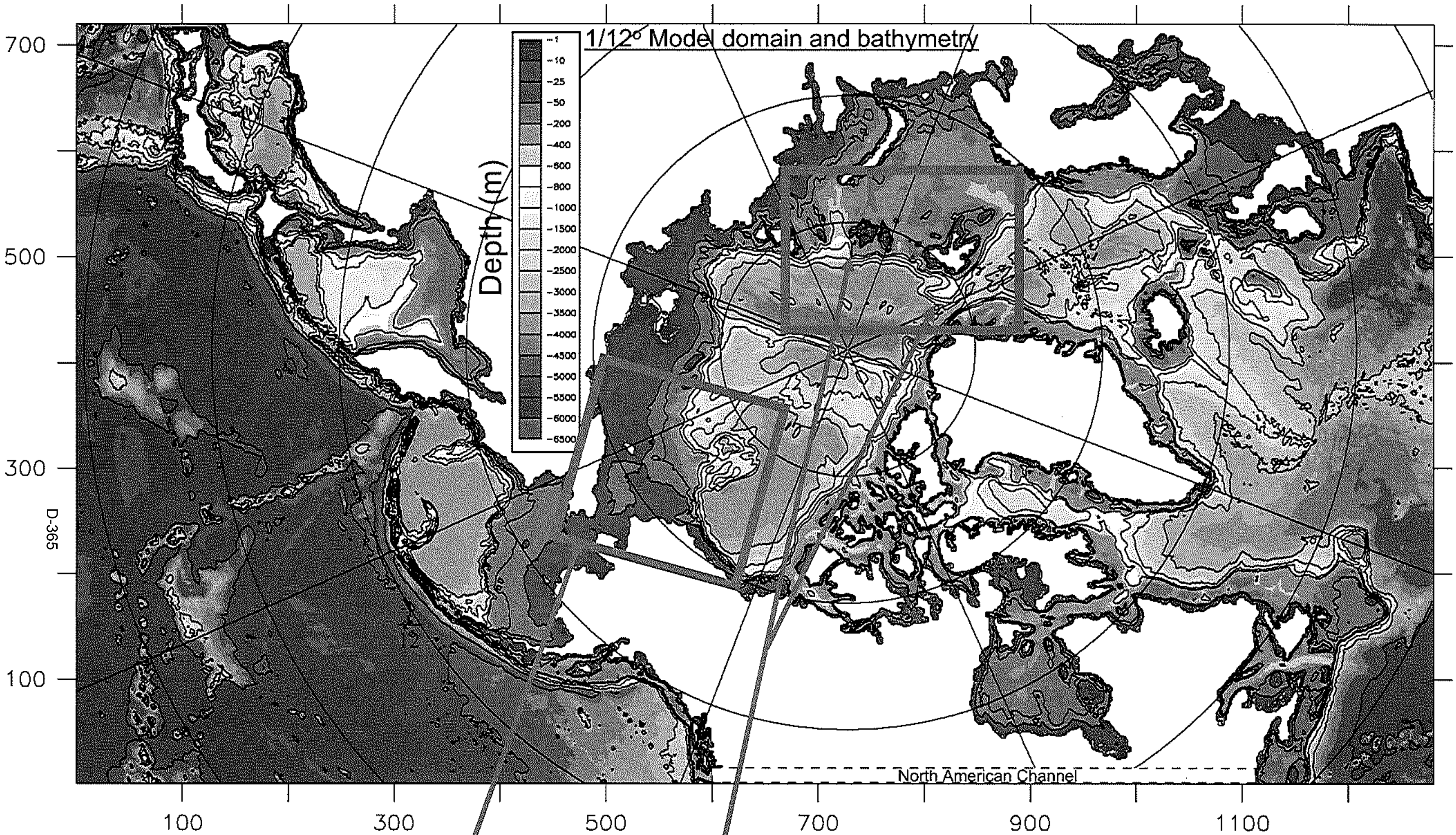
Revolutionary Research . . . Relevant Results

Sustainability Weeks 2008 – Symposium on Drastic Change in the Earth System during Global Warming
Sapporo, Japan, 24 June 2008

Observed rate of loss of Arctic ice extent is faster than IPCC AR4 predictions



Adapted from Stroeve et al., 2007

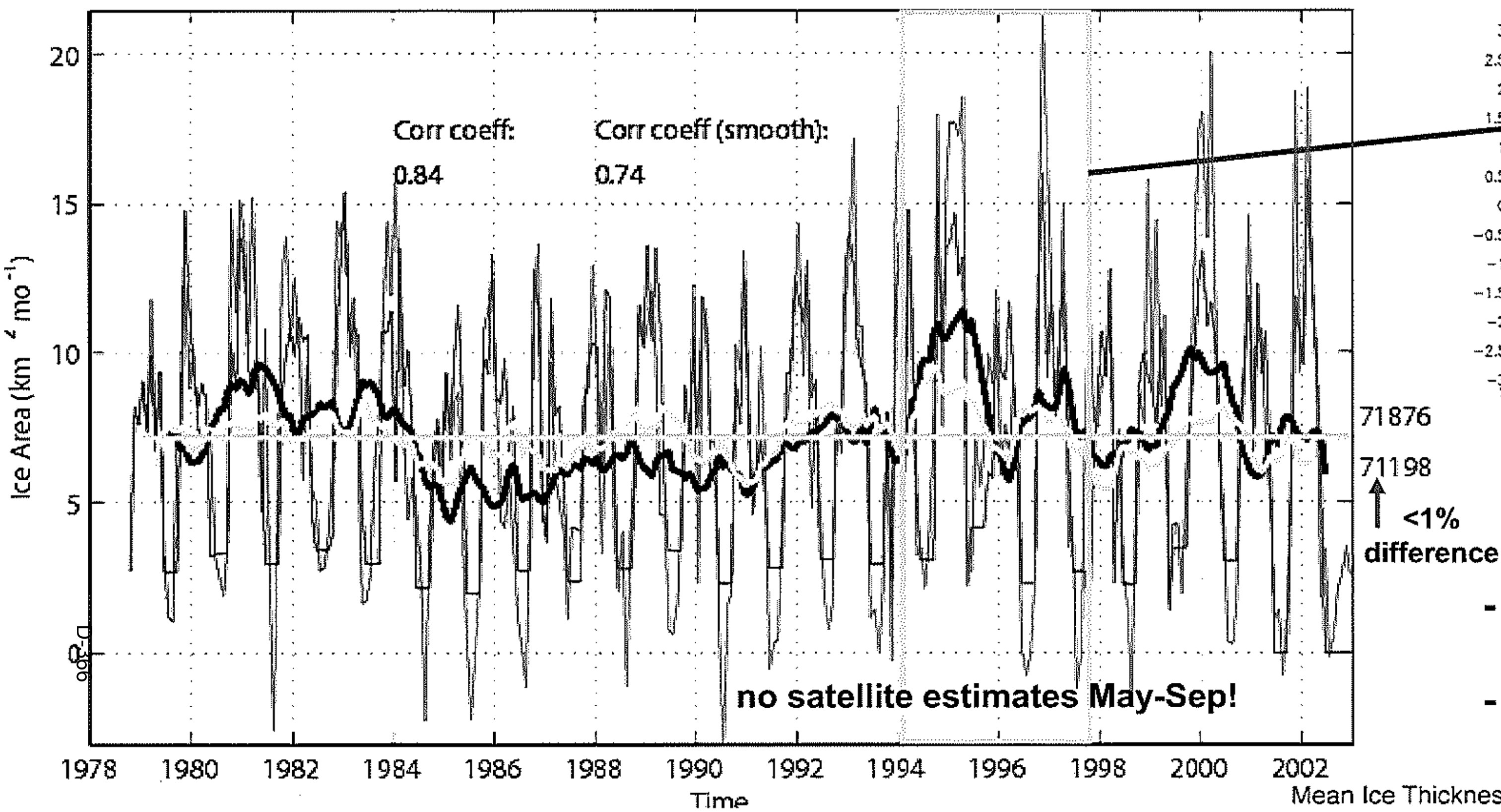


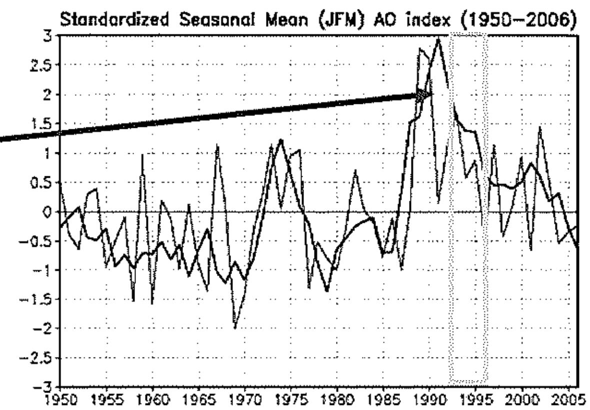
Gateways/Margins of Pacific Water and Atlantic Water Inflow into the Arctic Ocean

<u>Main uncertainties of importance to global climate</u>

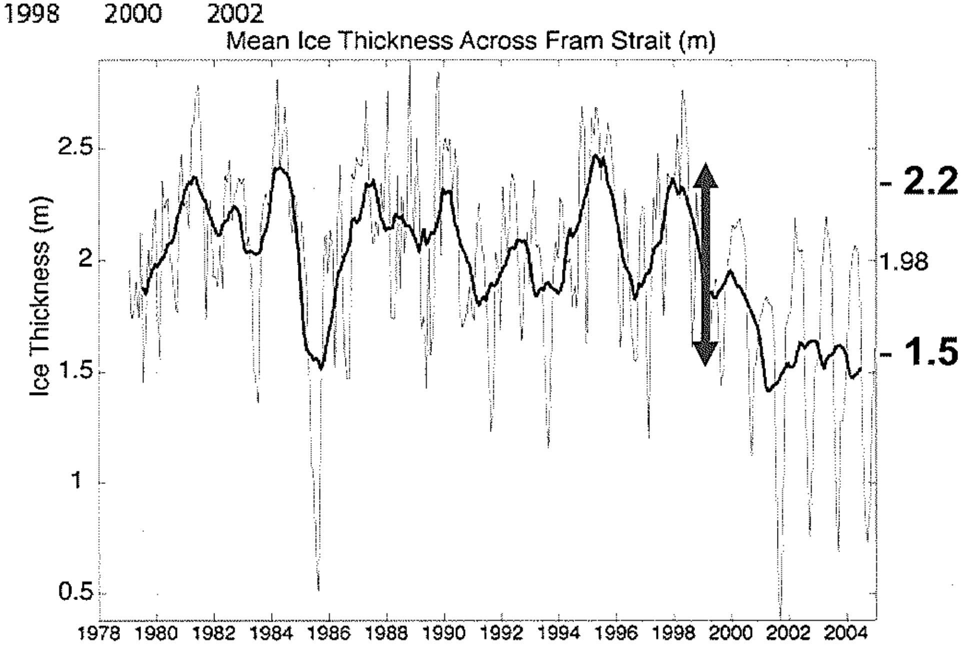
1. Northward heat transport from the N. Atlantic/Pacific to Arctic Ocean *
2. Arctic sea ice thickness and volume *
3. Freshwater export from the Arctic to North Atlantic

Sea Ice Export through Fram Strait (wind-driven)



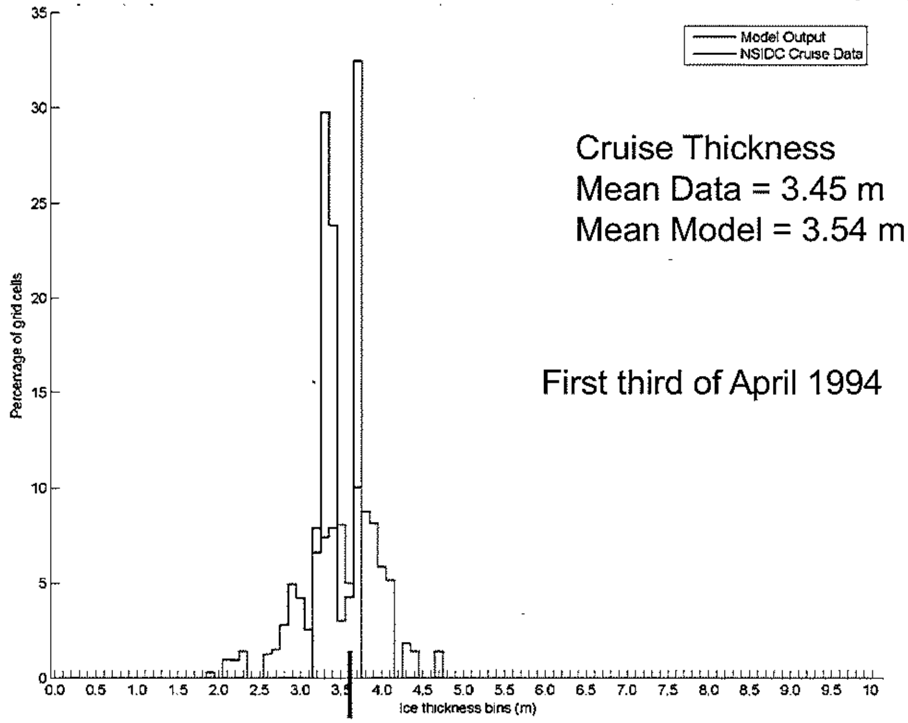


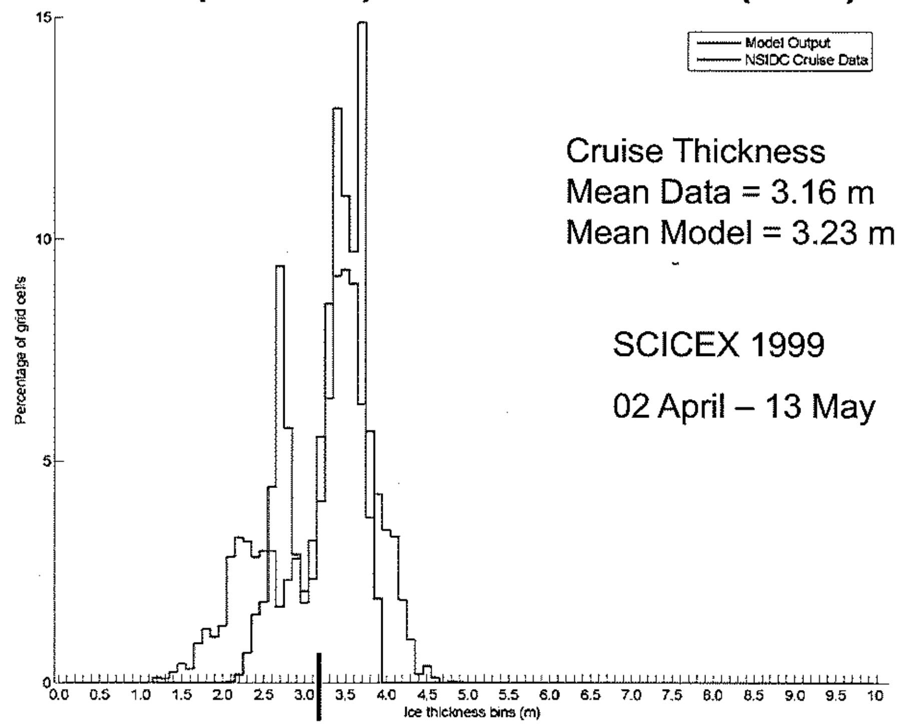
Mean area flux [km²/mo]
Estimates from:
- **satellite (Kwok et al., 2004 blue/cyan/yellow)**
- **model (red/black/green)**

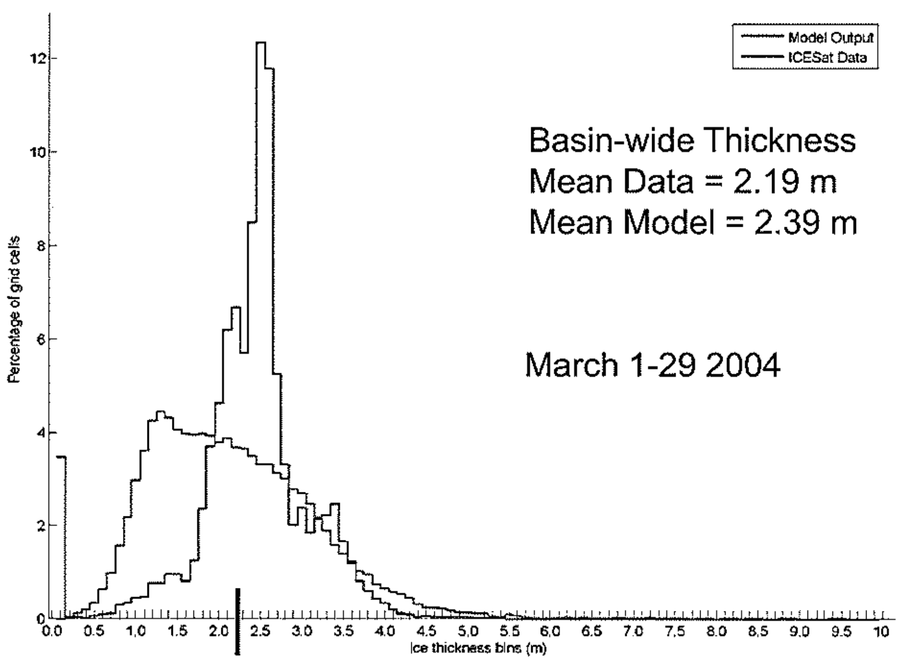


High export of thick sea ice from the Artic Ocean in the mid-1990s:
- in response to high positive AO/NAO
- mean thickness of sea ice across Fram Strait decreased by ~70 cm (or ~1/3)
- less multi-year ice in the Arctic Ocean
- warming more pronounced on thinner ice
- thinner ice less stable to perturbations

PDFs of ice thickness from submarines (top) / ICESat (bottom) and NPS model (blue)

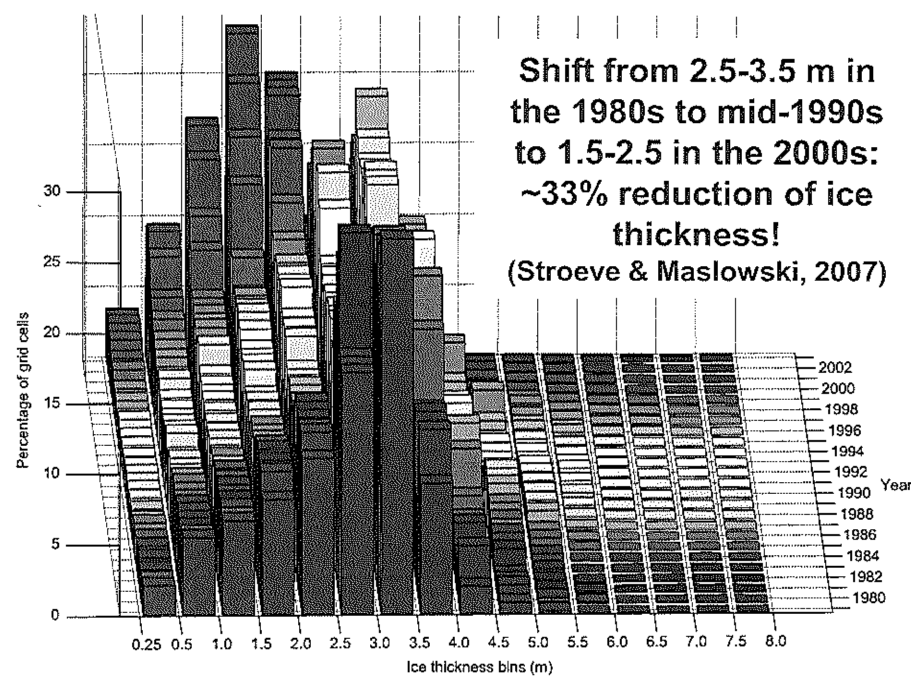




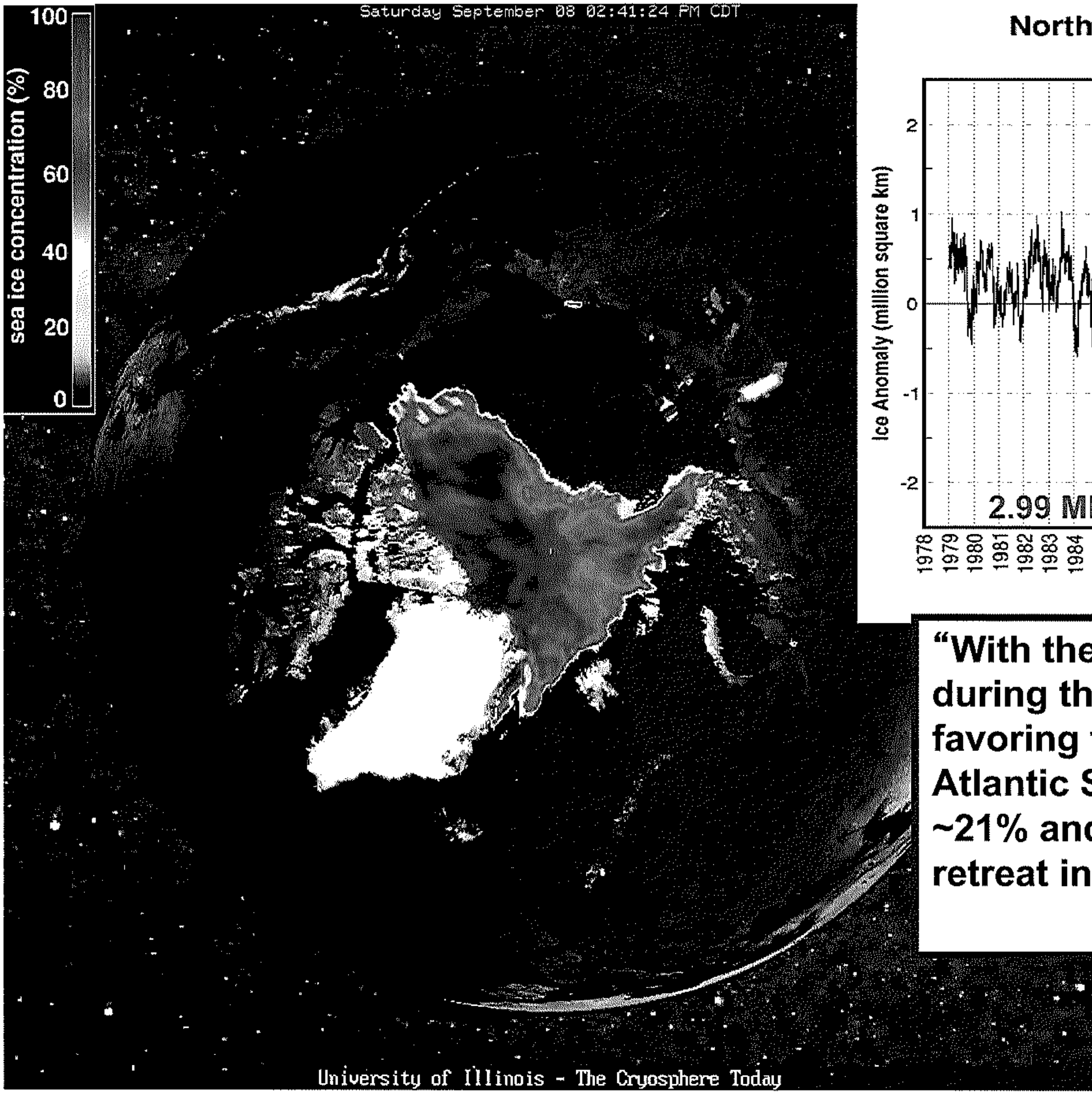


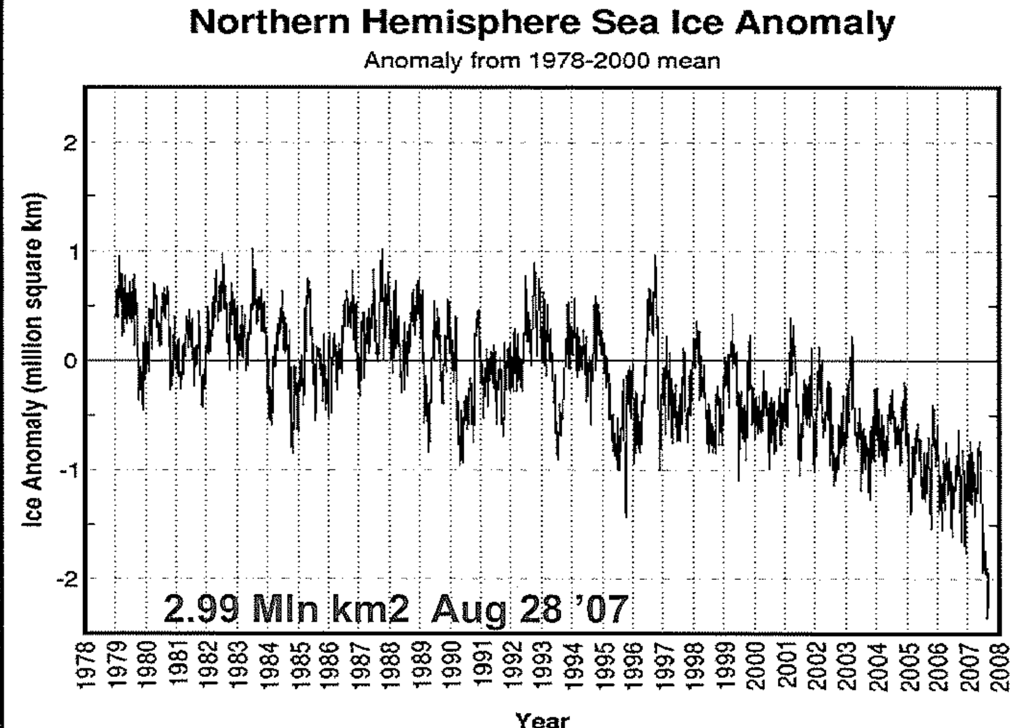
(from McNamara, 2006 and Whelan, 2007)

PDF of Model 1979-2003 Annual Sea Ice Thickness



Atmospheric forcing of the 2007 summer ice minimum?



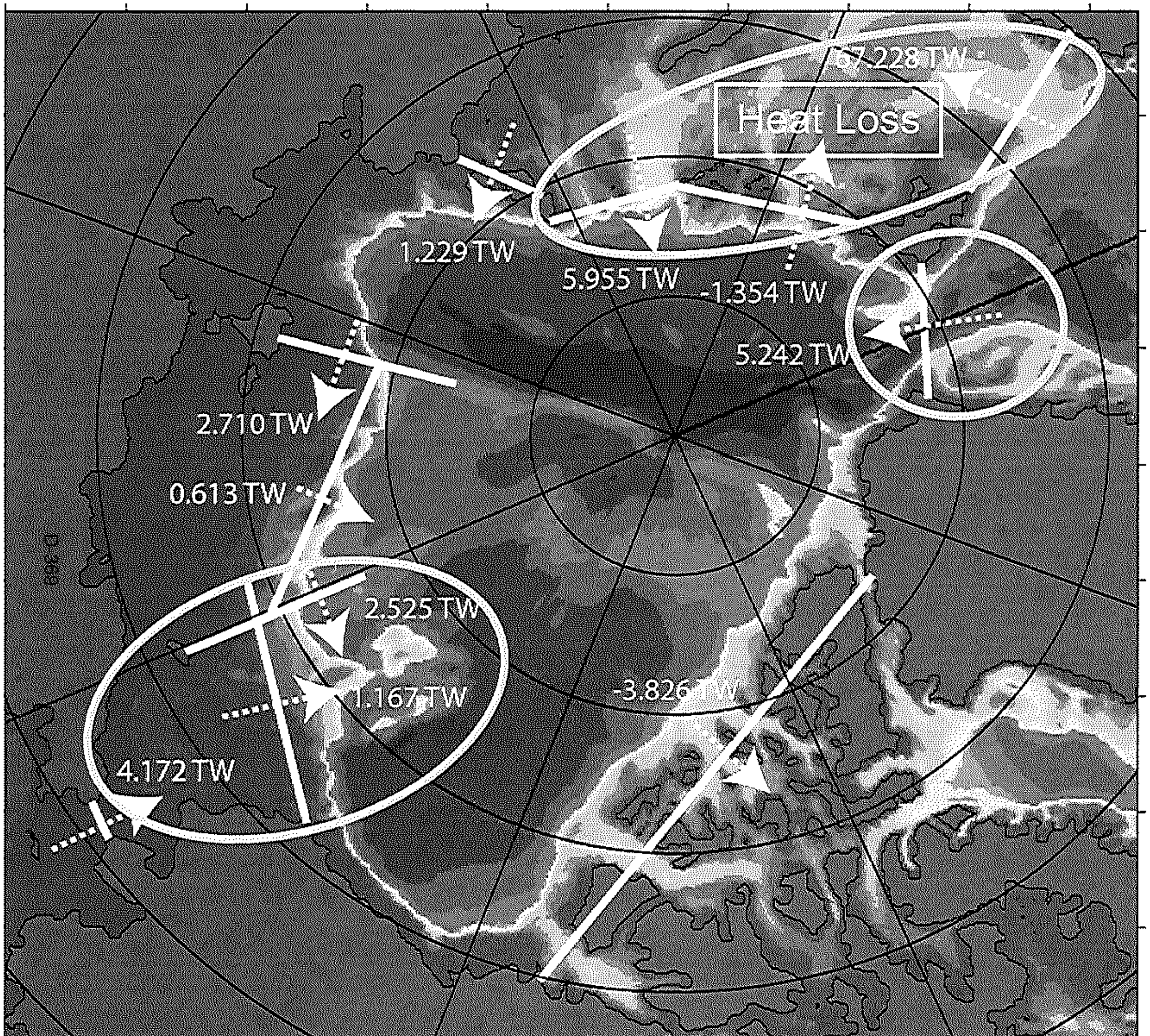


"With the sea-level pressure patterns during the summer of 2006 and 2007 favoring the export of sea ice into the Atlantic Sector, the regional outflow is ~21% and ~15% of the total sea ice retreat in the Pacific sector. "

Kwok GRL 2008

Why no record minimum in 2006?

1979-2004 Mean Oceanic Heat Convergence: 0-120 m; $T_{ref} = T_{freezing}$



Modeling Challenges: Inflow of Pacific / Atlantic Water into the Arctic Ocean and impacts on the sea ice

- Pacific Water entering via narrow (~60mi) Bering Strait and across Chukchi shelf

  (Clement et al., DSR II 2005)

- outflow through Fram Strait vs. Atlantic Water inflow (FSBW/BSBW)

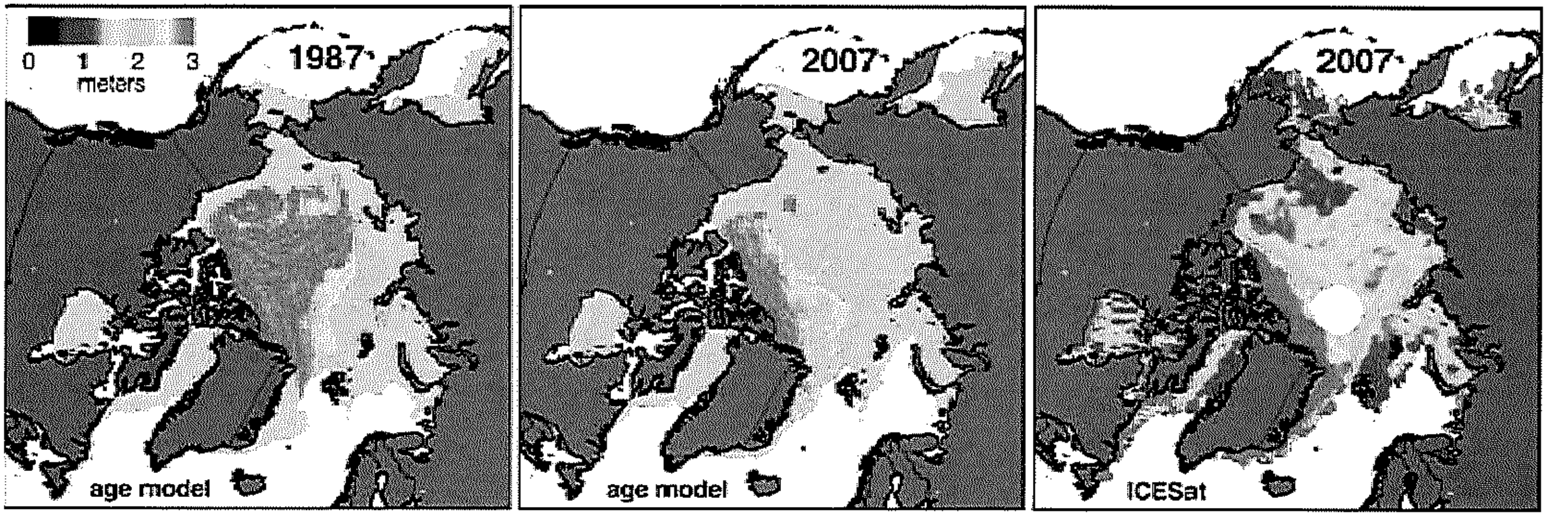
  (Maslowski et al., JGR 2004; Stroeve and Maslowski, 2007)

- Atlantic (BSBW) and Pacific Water each losses majority of heat to the atmosphere before entering Arctic Basin

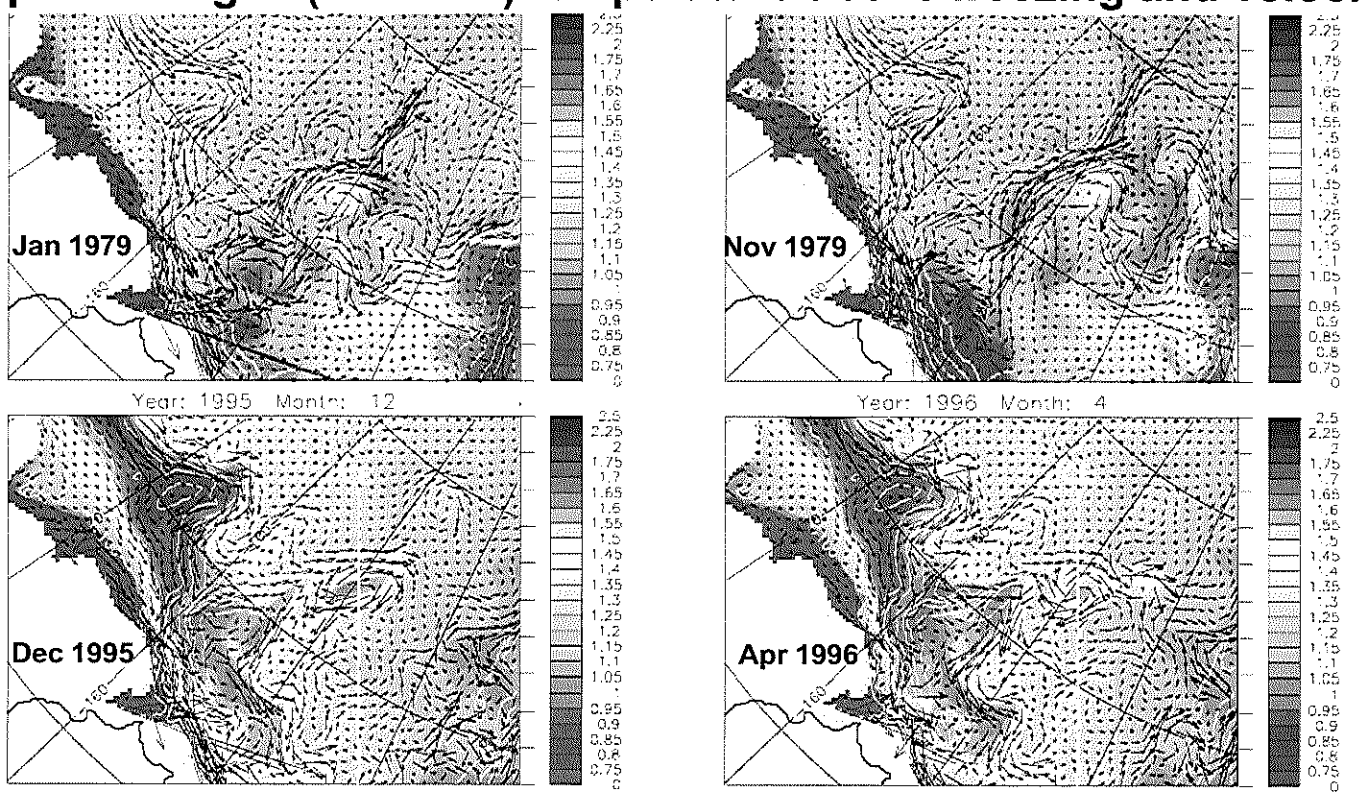
High resolution is one of the top requirements for advanced modeling of Arctic climate

(Maslowski et al., 2008)

Ice Thickness estimates based on age (a) 1987, (b) 2007, and ICESat freeboard (c) 2007

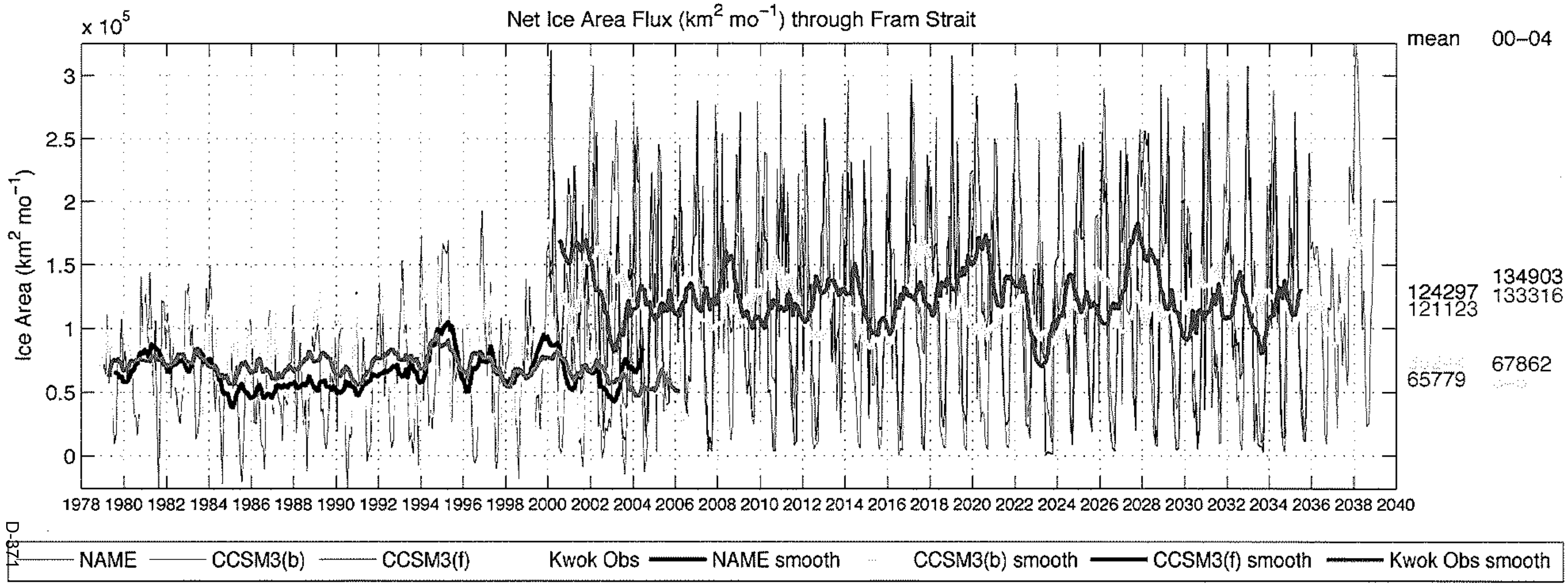


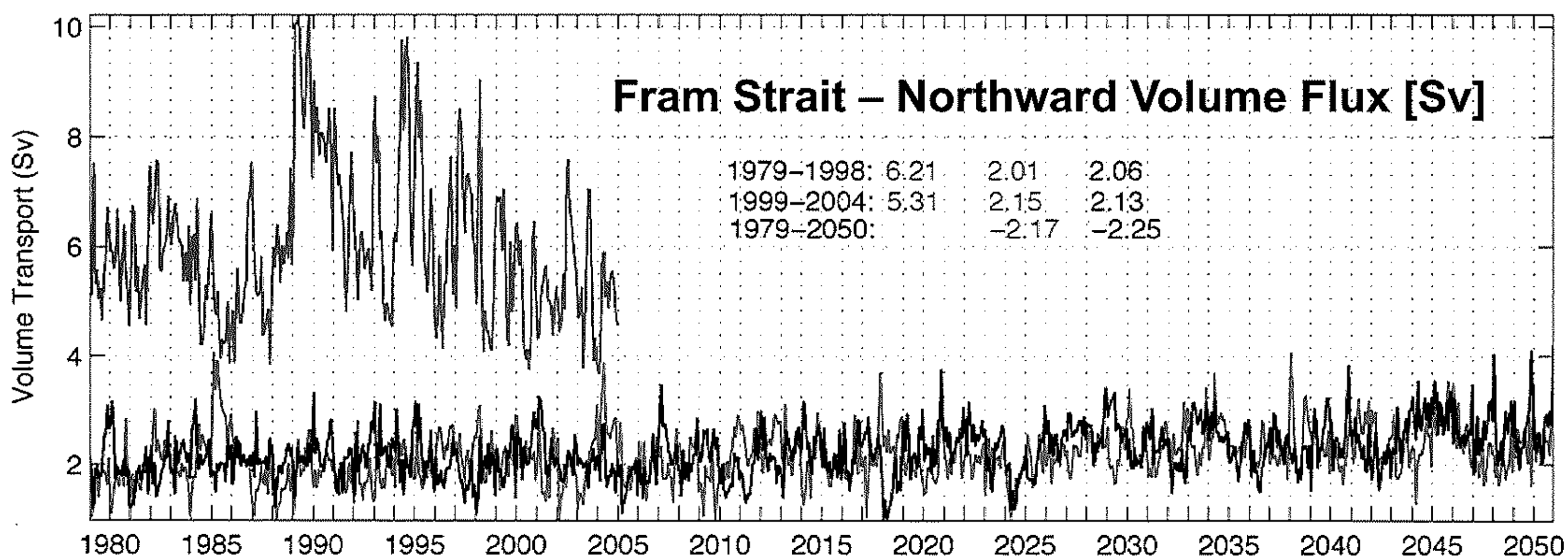
Depth-averaged (65-120m) temperature above freezing and velocity



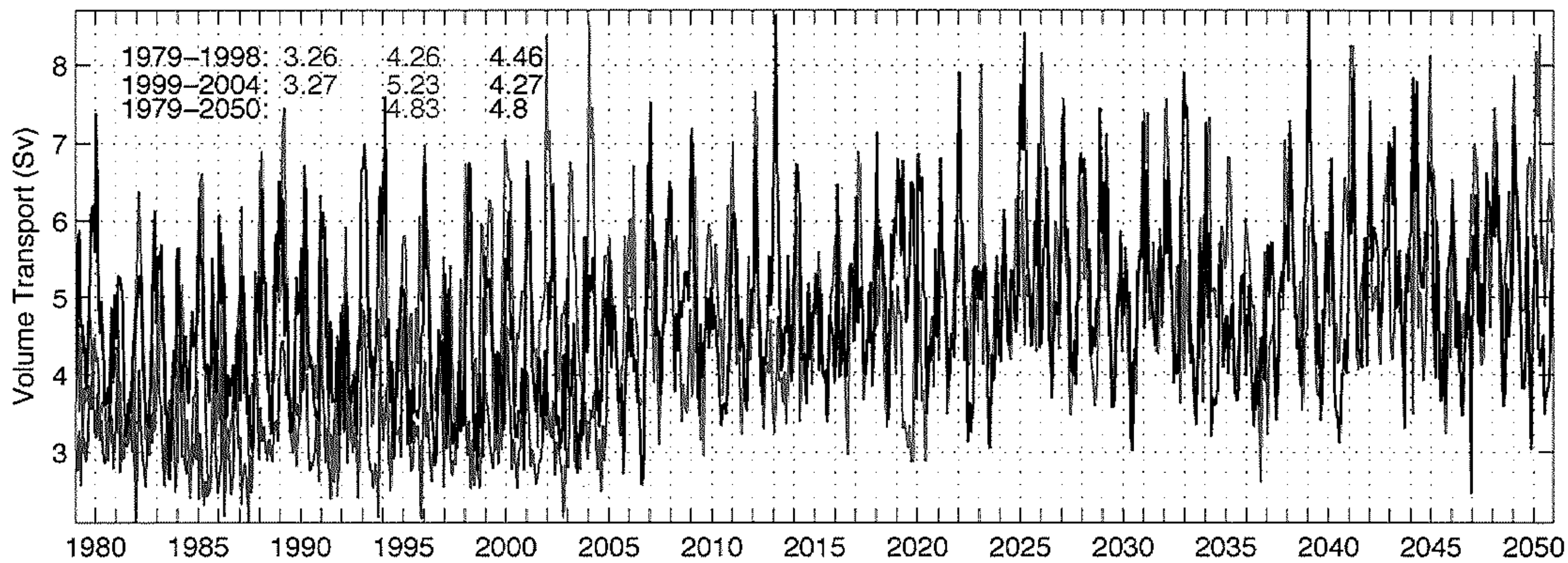
Increasing impact of eddy-driven oceanic heat advection in the western Arctic

Comparison of areal sea ice export via Fram Strait

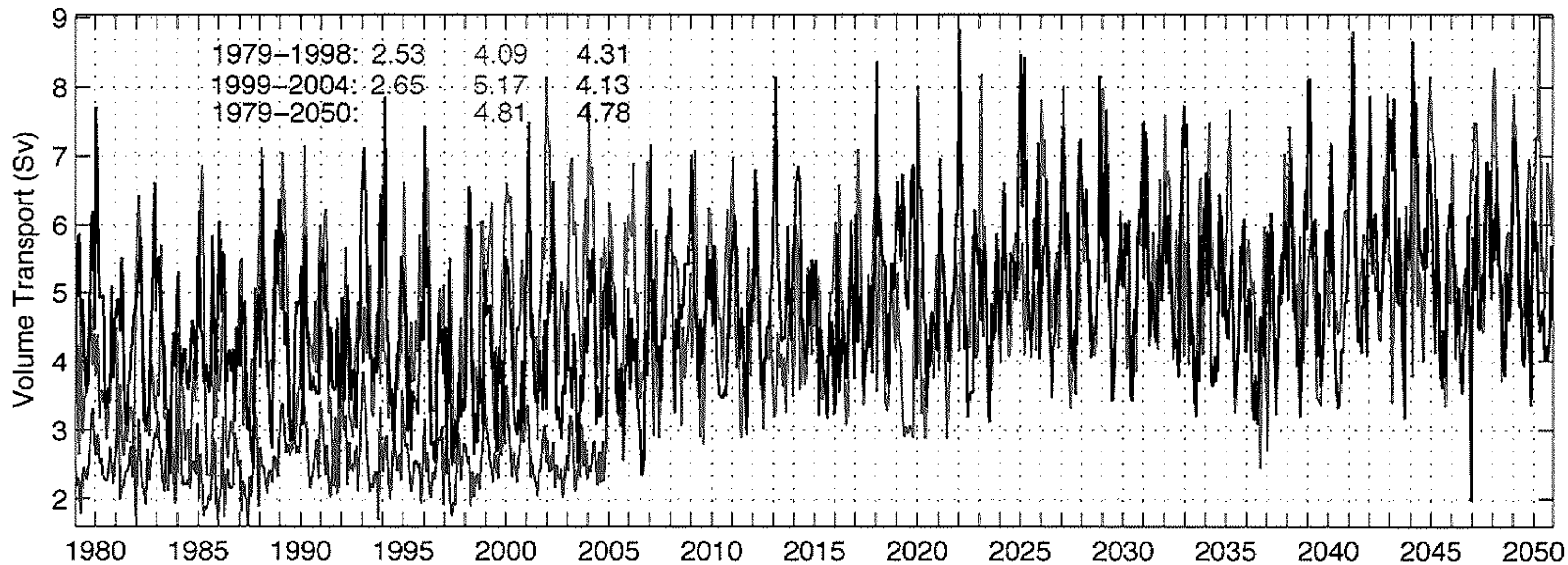




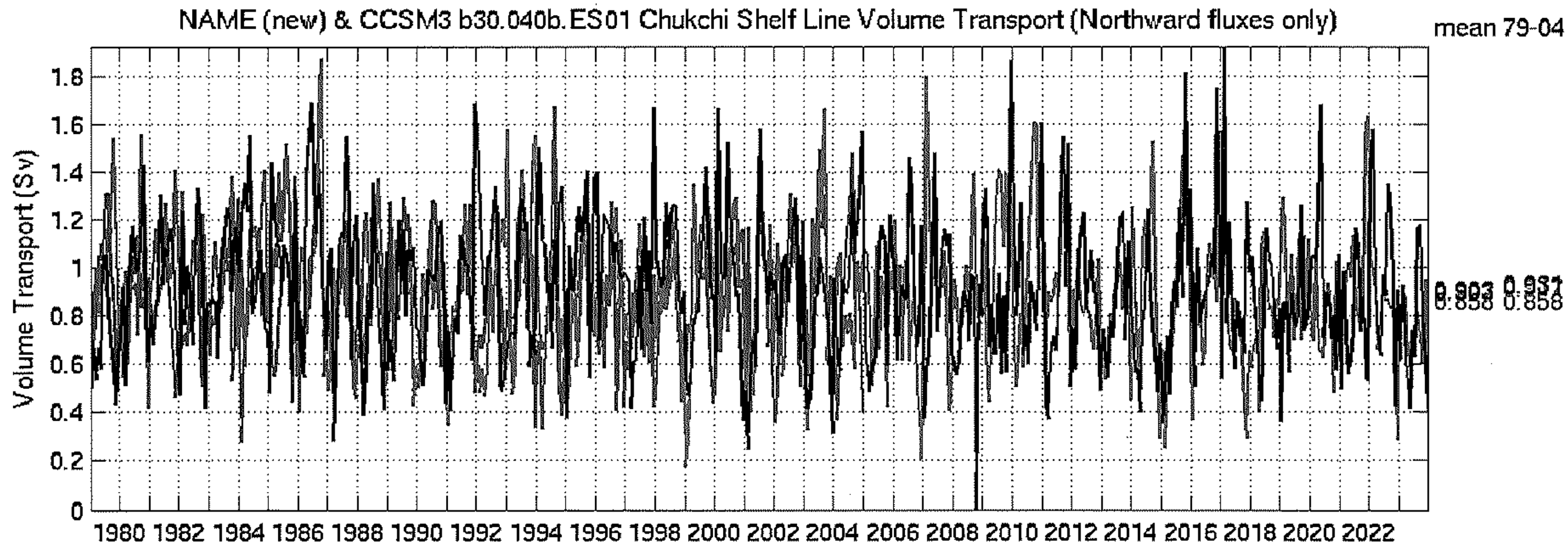
BSO – Net Volume Flux [Sv] – positive east

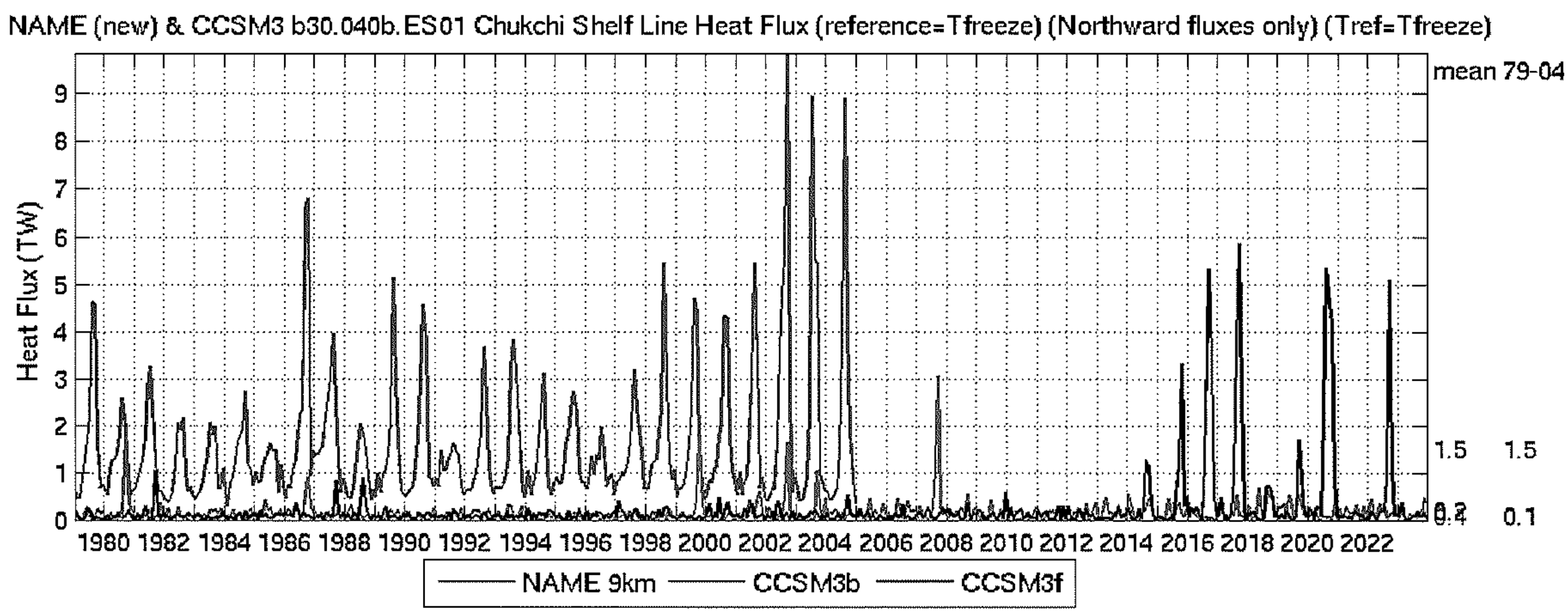


FJL-NZ – Net Volume Flux [Sv] – positive east



Volume and Heat Fluxes from the Chukchi Shelf into the Western Arctic

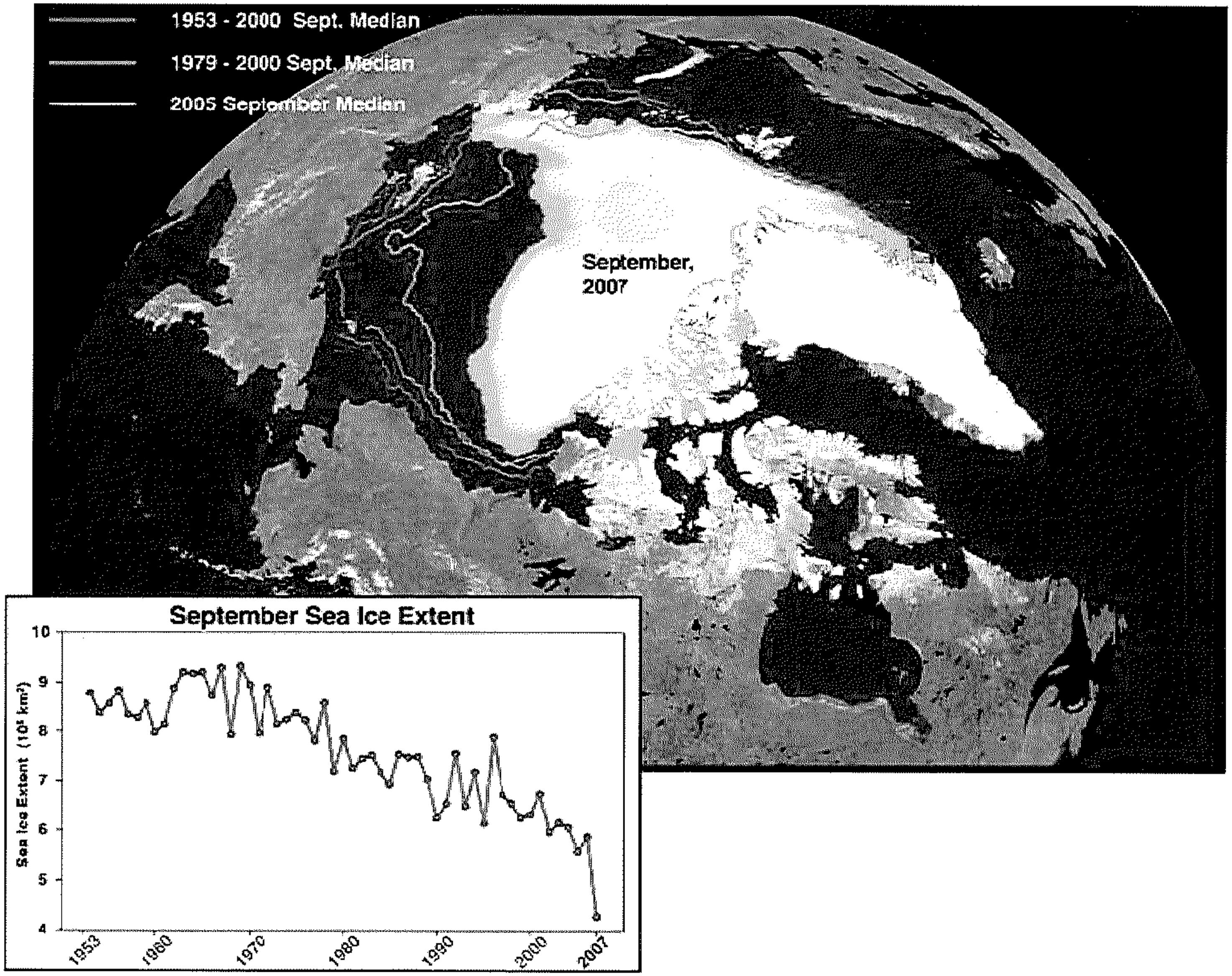




25-year mean volume transport (Sv) / heat trasnsport (TW)

	CCSM(b)			NPS		
	In	Out	Net	In	Out	Net
Fram Strait	2.0/17	-6.9/ -23	-4.9/-6	6.0/45	-8.4/-36	-2.4/+9
Barents Sea Opening	4.8/115.	-0.3/-5	4.5/110	5.0/107	-1.8/-28	3.2/79
FJL-NZ	4.7/32	-0.35/-1	4.35/31	3.4/2.9	-0.8/-0.7	2.6/2.2

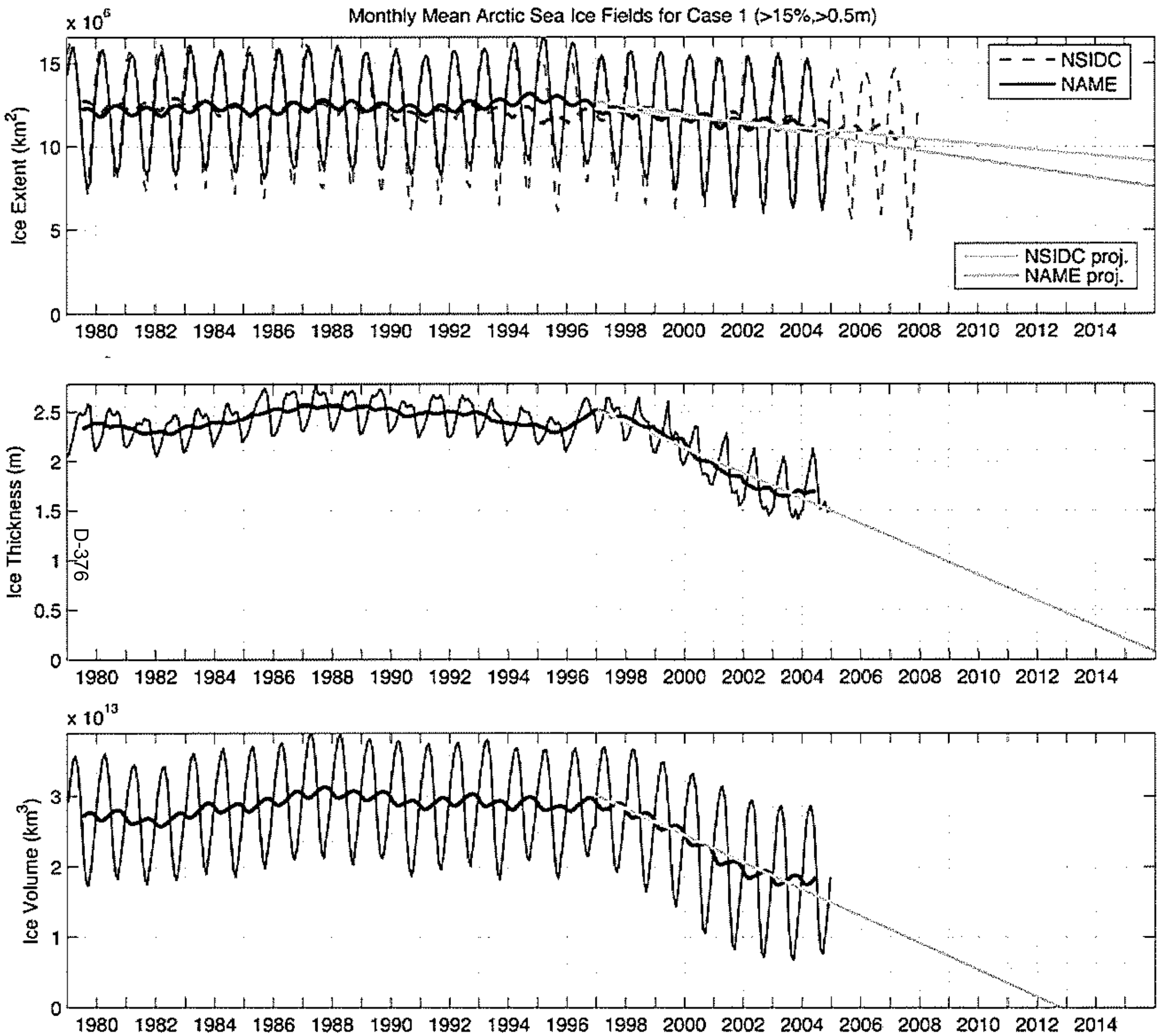
'NPS' TRANSPORTS (Maslowski et al., JGR, 2004)
Fram Strait 'in' obs estimates: 7.0 Sv / 50 TW - Courtesy of A. Beszczynska-Möller, AWI
FJL-NZ: near-zero heat transport (Gammelsrod et al., JMS submitted)



"Given these conservative model results, along with the remarkable events of 2007, our view is that a seasonally ice-free Arctic Ocean might be realized as early as 2030."

Stroeve et al., EOS 01/082008

79-04 time series of Ice Extent, Thickness, and Volume



Between 1997-2004:

- **annual mean sea ice concentration has decreased by ~17%**
- **mean ice thickness has decreased by ~0.9 m or ~36%**
- **ice volume decreased by 40%, which is >2x the rate of ice area decrease**

<u>If this trend persists the Arctic Ocean will become ice-free by ~2013!</u>

Conclusions

1. The rate of decrease of sea ice thickness and volume possibly about 2x greater than that of sea ice extent
2. Anomalous export of sea ice through Fram Strait during the mid-1990s a precursor of sea ice decline
3. Oceanic heat advection has contributed significant forcing (>60%) to sea ice melt during the last decade
4. CCSM3/HadGEM1 (and potentially many other GCMs) simulations compared to NPS and observational estimates:
   a) have too weak northward heat fluxes through Bering / Chukchi seas, which explains why they have too much ice in the western Arctic
   b) have too weak northward and recirculating fluxes at Fram Strait, which allow too much ice in the Greenland Sea
   c) simulate too much volume and heat flux through the Barents Sea and try to melt the sea ice cover from the eastern side

   which is why their predictions are too conservative

5. Ice thickness and ocean heat flux data critical for model validation
6. Dedicated computer resources needed to advance Arctic and global climate modeling and prediction

"A linear increase in heat in the Arctic Ocean will result in a non-linear, and accelerating, loss of sea ice."

– Norbert Untersteiner, Professor Emeritus,

University of Washington, July 2006

Climate Change 2007: Synthesis Report

Summary for Policymakers

An Assessment of the Intergovernmental Panel on Climate Change

This summary, approved in detail at IPCC Plenary XXVII (Valencia, Spain, 12-17 November 2007), represents the formally agreed statement of the IPCC concerning key findings and uncertainties contained in the Working Group contributions to the Fourth Assessment Report.

Based on a draft prepared by:

Lenny Bernstein, Peter Bosch, Osvaldo Canziani, Zhenlin Chen, Renate Christ, Ogunlade Davidson, William Hare, Saleemul Huq, David Karoly, Vladimir Kattsov, Zbigniew Kundzewicz, Jian Liu, Ulrike Lohmann, Martin Manning, Taroh Matsuno, Bettina Menne, Bert Metz, Monirul Mirza, Neville Nicholls, Leonard Nurse, Rajendra Pachauri, Jean Palutikof, Martin Parry, Dahe Qin, Nijavalli Ravindranath, Andy Reisinger, Jiawen Ren, Keywan Riahi, Cynthia Rosenzweig, Matilde Rusticucci, Stephen Schneider, Youba Sokona, Susan Solomon, Peter Stott, Ronald Stouffer, Taishi Sugiyama, Rob Swart, Dennis Tirpak, Coleen Vogel, Gary Yohe

Introduction

This Synthesis Report is based on the assessment carried out by the three Working Groups of the Intergovernmental Panel on Climate Change (IPCC). It provides an integrated view of climate change as the final part of the IPCC's Fourth Assessment Report (AR4).

A complete elaboration of the Topics covered in this summary can be found in this Synthesis Report and in the underlying reports of the three Working Groups.

1. Observed changes in climate and their effects

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (Figure SPM.1). *{1.1}*

Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850). The 100-year linear trend (1906-2005) of 0.74 [0.56 to 0.92]°C[1] is larger than the corresponding trend of 0.6 [0.4 to 0.8]°C (1901-2000) given in the Third Assessment Report (TAR) (Figure SPM.1). The temperature increase is widespread over the globe and is greater at higher northern latitudes. Land regions have warmed faster than the oceans (Figures SPM.2, SPM.4). *{1.1, 1.2}*

Rising sea level is consistent with warming (Figure SPM.1). Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3] mm/yr and since 1993 at 3.1 [2.4 to 3.8] mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets. Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer-term trend is unclear. *{1.1}*

Observed decreases in snow and ice extent are also consistent with warming (Figure SPM.1). Satellite data since 1978 show that annual average Arctic sea ice extent has shrunk by 2.7 [2.1 to 3.3]% per decade, with larger decreases in summer of 7.4 [5.0 to 9.8]% per decade. Mountain glaciers and snow cover on average have declined in both hemispheres. *{1.1}*

From 1900 to 2005, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia but declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally, the area affected by drought has *likely*[2] increased since the 1970s. *{1.1}*

It is *very likely* that over the past 50 years: cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent. It is *likely* that: heat waves have become more frequent over most land areas, the frequency of heavy precipitation events has increased over most areas, and since 1975 the incidence of extreme high sea level[3] has increased worldwide. *{1.1}*

There is observational evidence of an increase in intense tropical cyclone activity in the North Atlantic since about 1970, with limited evidence of increases elsewhere. There is no clear trend in the annual numbers of tropical cyclones. It is difficult to ascertain longer-term trends in cyclone activity, particularly prior to 1970. *{1.1}*

Average Northern Hemisphere temperatures during the second half of the 20th century were *very likely* higher than during any other 50-year period in the last 500 years and *likely* the highest in at least the past 1300 years. *{1.1}*

Observational evidence[4] from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. *{1.2}*

Changes in snow, ice and frozen ground have with *high confidence* increased the number and size of glacial lakes, increased ground instability in mountain and other permafrost regions and led to changes in some Arctic and Antarctic ecosystems. *{1.2}*

There is *high confidence* that some hydrological systems have also been affected through increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers and through effects on thermal structure and water quality of warming rivers and lakes. *{1.2}*

In terrestrial ecosystems, earlier timing of spring events and poleward and upward shifts in plant and animal ranges are with *very high confidence* linked to recent warming. In some marine and freshwater systems, shifts in ranges and changes in algal, plankton and fish abundance are with *high confidence* associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation. *{1.2}*

Of the more than 29,000 observational data series, from 75 studies, that show significant change in many physical and biological systems, more than 89% are consistent with the direction of change expected as a response to warming (Fig-

[1] Numbers in square brackets indicate a 90% uncertainty interval around a best estimate, i.e. there is an estimated 5% likelihood that the value could be above the range given in square brackets and 5% likelihood that the value could be below that range. Uncertainty intervals are not necessarily symmetric around the corresponding best estimate.

[2] Words in italics represent calibrated expressions of uncertainty and confidence. Relevant terms are explained in the Box 'Treatment of uncertainty' in the Introduction of this Synthesis Report.

[3] Excluding tsunamis, which are not due to climate change. Extreme high sea level depends on average sea level and on regional weather systems. It is defined here as the highest 1% of hourly values of observed sea level at a station for a given reference period.

[4] Based largely on data sets that cover the period since 1970.

Changes in temperature, sea level and Northern Hemisphere snow cover

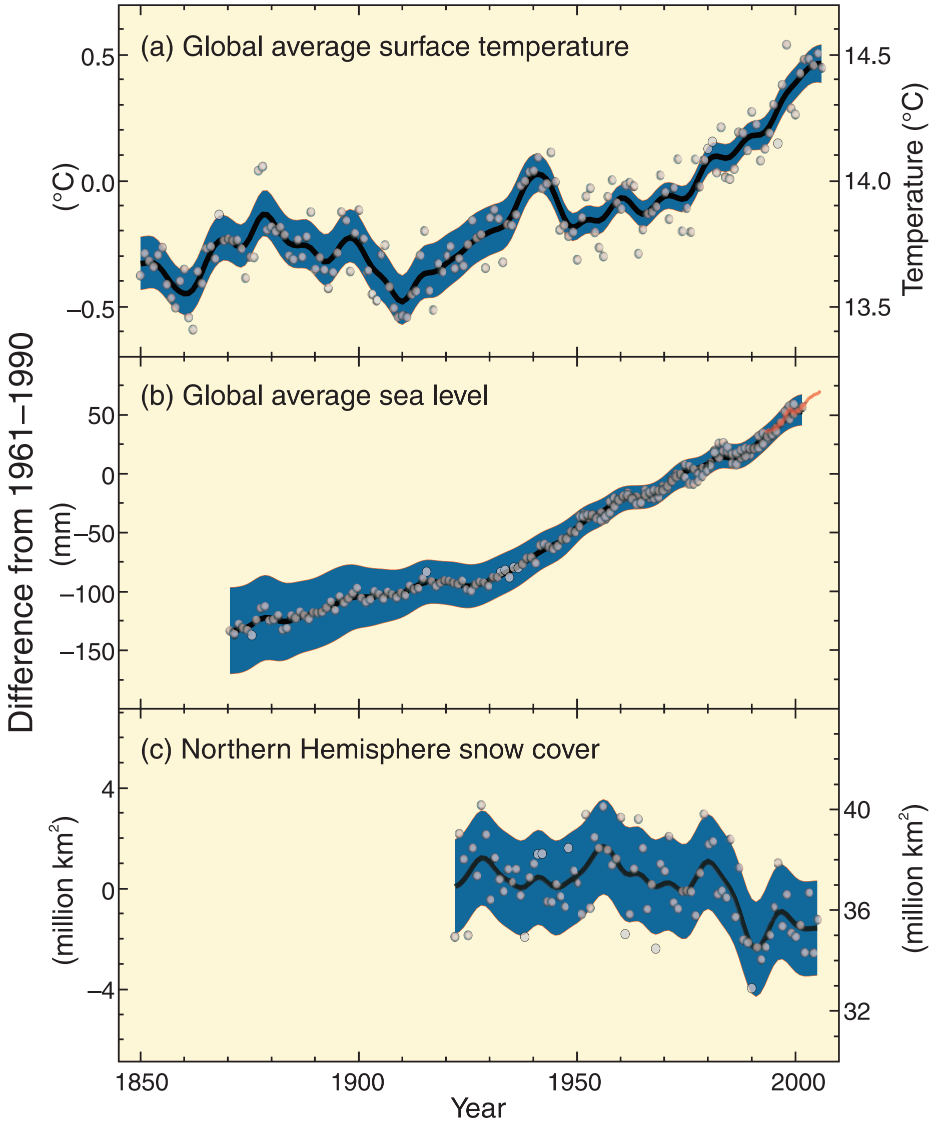


Figure SPM.1. *Observed changes in (a) global average surface temperature; (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All differences are relative to corresponding averages for the period 1961-1990. Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c). {Figure 1.1}*

ure SPM.2). However, there is a notable lack of geographic balance in data and literature on observed changes, with marked scarcity in developing countries. *{1.2, 1.3}*

There is *medium confidence* that other effects of regional climate change on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers. *{1.2}*

They include effects of temperature increases on: *{1.2}*

- agricultural and forestry management at Northern Hemisphere higher latitudes, such as earlier spring planting of crops, and alterations in disturbance regimes of forests due to fires and pests
- some aspects of human health, such as heat-related mortality in Europe, changes in infectious disease vectors in some areas, and allergenic pollen in Northern Hemisphere high and mid-latitudes
- some human activities in the Arctic (e.g. hunting and travel over snow and ice) and in lower-elevation alpine areas (such as mountain sports).

Changes in physical and biological systems and surface temperature 1970-2004

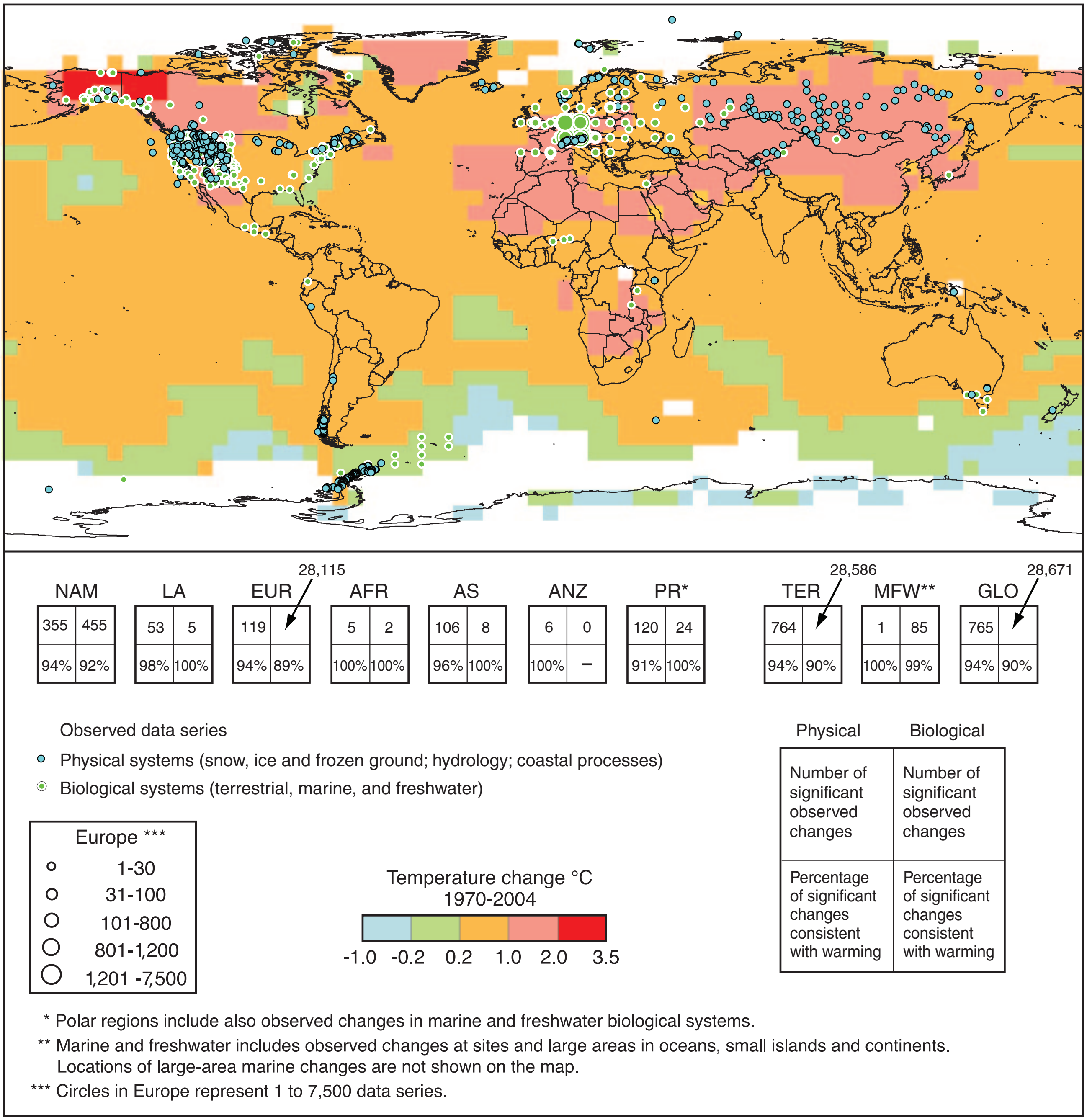


***Figure SPM.2.** Locations of significant changes in data series of physical systems (snow, ice and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine and freshwater biological systems), are shown together with surface air temperature changes over the period 1970-2004. A subset of about 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: (1) ending in 1990 or later; (2) spanning a period of at least 20 years; and (3) showing a significant change in either direction, as assessed in individual studies. These data series are from about 75 studies (of which about 70 are new since the TAR) and contain about 29,000 data series, of which about 28,000 are from European studies. White areas do not contain sufficient observational climate data to estimate a temperature trend. The 2 × 2 boxes show the total number of data series with significant changes (top row) and the percentage of those consistent with warming (bottom row) for (i) continental regions: North America (NAM), Latin America (LA), Europe (EUR), Africa (AFR), Asia (AS), Australia and New Zealand (ANZ), and Polar Regions (PR) and (ii) global-scale: Terrestrial (TER), Marine and Freshwater (MFW), and Global (GLO). The numbers of studies from the seven regional boxes (NAM, EUR, AFR, AS, ANZ, PR) do not add up to the global (GLO) totals because numbers from regions except Polar do not include the numbers related to Marine and Freshwater (MFW) systems. Locations of large-area marine changes are not shown on the map. {Figure 1.2}*

2. Causes of change

Changes in atmospheric concentrations of greenhouse gases (GHGs) and aerosols, land cover and solar radiation alter the energy balance of the climate system. *{2.2}*

Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (Figure SPM.3).[5] *{2.1}*

Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions grew by about 80% between 1970 and 2004. The long-term trend of declining CO_2 emissions per unit of energy supplied reversed after 2000. *{2.1}*

Global atmospheric concentrations of CO_2, methane (CH_4) and nitrous oxide (N_2O) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. *{2.2}*

Atmospheric concentrations of CO_2 (379ppm) and CH_4 (1774ppb) in 2005 exceed by far the natural range over the last 650,000 years. Global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution. It is *very likely* that the observed increase in CH_4 concentration is predominantly due to agriculture and fossil fuel use. CH_4 growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. The increase in N_2O concentration is primarily due to agriculture. *{2.2}*

There is *very high confidence* that the net effect of human activities since 1750 has been one of warming.[6] *{2.2}*

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations.[7] It is *likely* that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica) (Figure SPM.4). *{2.4}*

During the past 50 years, the sum of solar and volcanic forcings would *likely* have produced cooling. Observed patterns of warming and their changes are simulated only by models that include anthropogenic forcings. Difficulties remain in simulating and attributing observed temperature changes at smaller than continental scales. *{2.4}*

Global anthropogenic GHG emissions

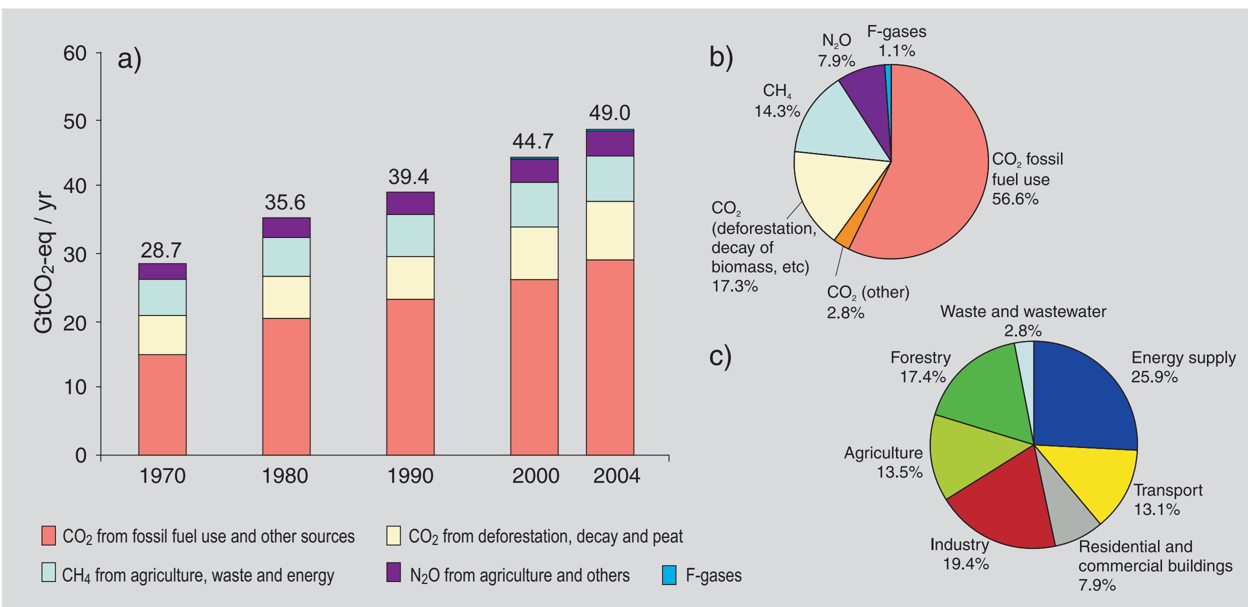


Figure SPM.3. *(a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.[5] (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of carbon dioxide equivalents (CO_2-eq). (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO_2-eq. (Forestry includes deforestation.) {Figure 2.1}*

[5] Includes only carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphurhexafluoride (SF_6), whose emissions are covered by the United Nations Framework Convention on Climate Change (UNFCCC). These GHGs are weighted by their 100-year Global Warming Potentials, using values consistent with reporting under the UNFCCC.

[6] Increases in GHGs tend to warm the surface while the net effect of increases in aerosols tends to cool it. The net effect due to human activities since the pre-industrial era is one of warming (+1.6 [+0.6 to +2.4] W/m²). In comparison, changes in solar irradiance are estimated to have caused a small warming effect (+0.12 [+0.06 to +0.30] W/m²).

[7] Consideration of remaining uncertainty is based on current methodologies.

Global and continental temperature change

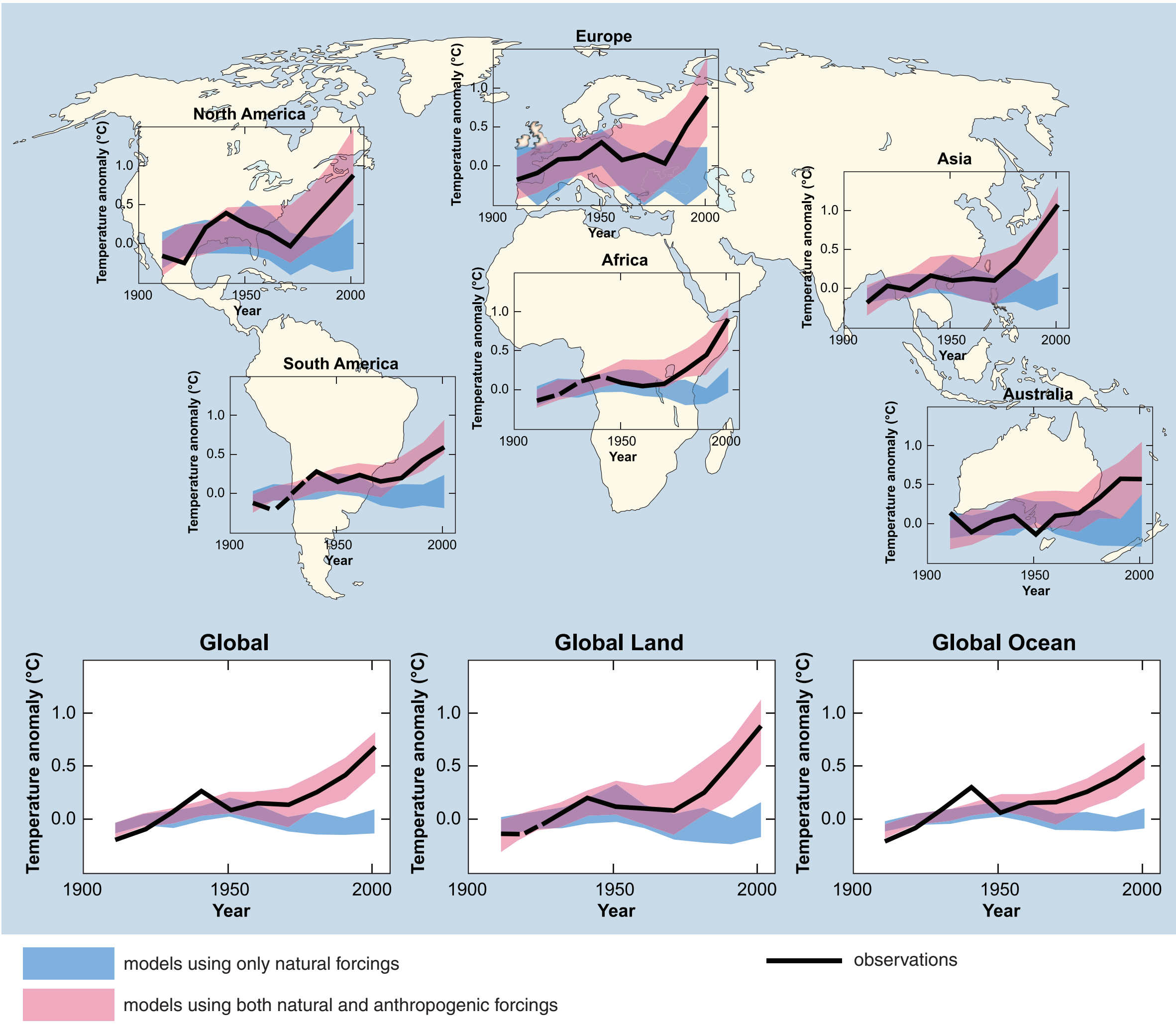


Figure SPM.4. *Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using either natural or both natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906-2005 (black line) plotted against the centre of the decade and relative to the corresponding average for the period 1901-1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5 to 95% range for 19 simulations from five climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5 to 95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. {Figure 2.5}*

Advances since the TAR show that discernible human influences extend beyond average temperature to other aspects of climate. *{2.4}*

Human influences have: *{2.4}*

- *very likely* contributed to sea level rise during the latter half of the 20th century
- *likely* contributed to changes in wind patterns, affecting extra-tropical storm tracks and temperature patterns
- *likely* increased temperatures of extreme hot nights, cold nights and cold days
- *more likely than not* increased risk of heat waves, area affected by drought since the 1970s and frequency of heavy precipitation events.

Anthropogenic warming over the last three decades has *likely* had a discernible influence at the global scale on observed changes in many physical and biological systems. *{2.4}*

Spatial agreement between regions of significant warming across the globe and locations of significant observed changes in many systems consistent with warming is *very unlikely* to be due solely to natural variability. Several modelling studies have linked some specific responses in physical and biological systems to anthropogenic warming. *{2.4}*

More complete attribution of observed natural system responses to anthropogenic warming is currently prevented by the short time scales of many impact studies, greater natural climate variability at regional scales, contributions of non-climate factors and limited spatial coverage of studies. *{2.4}*

3. Projected climate change and its impacts

There is *high agreement* and *much evidence* that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. *{3.1}*

The IPCC Special Report on Emissions Scenarios (SRES, 2000) projects an increase of global GHG emissions by 25 to 90% (CO_2-eq) between 2000 and 2030 (Figure SPM.5), with fossil fuels maintaining their dominant position in the global energy mix to 2030 and beyond. More recent scenarios without additional emissions mitigation are comparable in range.[8,9] *{3.1}*

Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century (Table SPM.1, Figure SPM.5). *{3.2.1}*

For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emissions scenarios. Even if the concentrations of all GHGs and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emissions scenarios. *{3.2}*

The range of projections (Table SPM.1) is broadly consistent with the TAR, but uncertainties and upper ranges for temperature are larger mainly because the broader range of available models suggests stronger climate-carbon cycle feedbacks. Warming reduces terrestrial and ocean uptake of atmospheric CO_2, increasing the fraction of anthropogenic emissions remaining in the atmosphere. The strength of this feedback effect varies markedly among models. *{2.3, 3.2.1}*

Because understanding of some important effects driving sea level rise is too limited, this report does not assess the likelihood, nor provide a best estimate or an upper bound for sea level rise. Table SPM.1 shows model-based projections

Scenarios for GHG emissions from 2000 to 2100 (in the absence of additional climate policies) and projections of surface temperatures

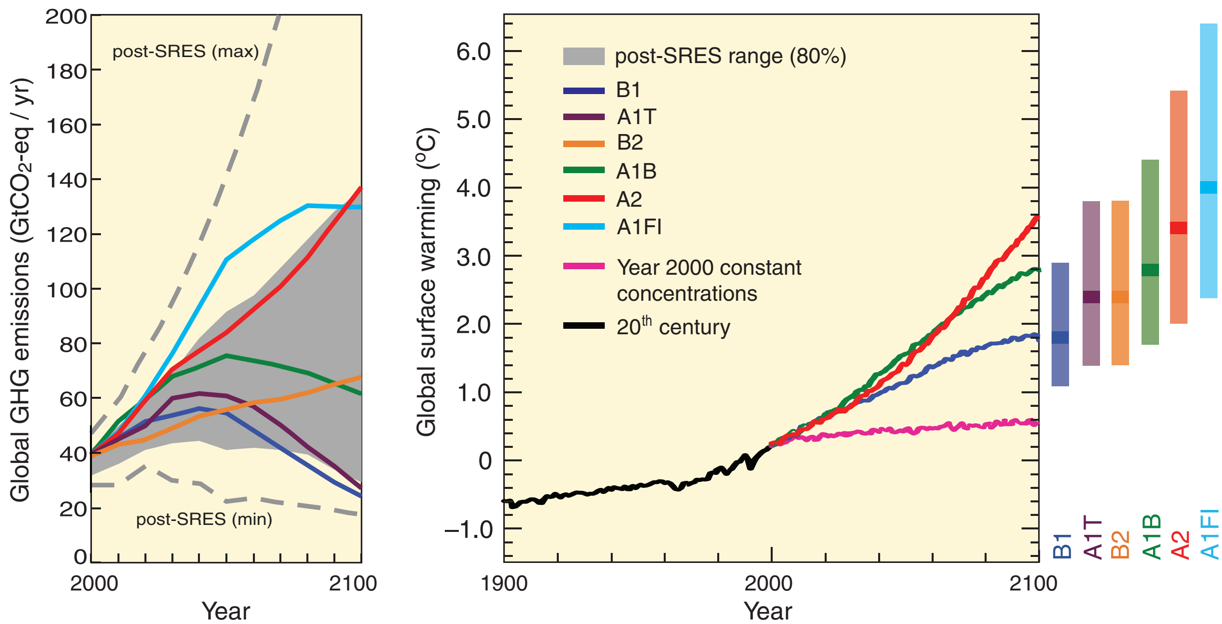


Figure SPM.5. ***Left Panel:*** *Global GHG emissions (in $GtCO_2$-eq) in the absence of climate policies: six illustrative SRES marker scenarios (coloured lines) and the 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases.* ***Right Panel:*** *Solid lines are multi-model global averages of surface warming for scenarios A2, A1B and B1, shown as continuations of the 20th-century simulations. These projections also take into account emissions of short-lived GHGs and aerosols. The pink line is not a scenario, but is for Atmosphere-Ocean General Circulation Model (AOGCM) simulations where atmospheric concentrations are held constant at year 2000 values. The bars at the right of the figure indicate the best estimate (solid line within each bar) and the* likely *range assessed for the six SRES marker scenarios at 2090-2099. All temperatures are relative to the period 1980-1999. {Figures 3.1 and 3.2}*

[8] For an explanation of SRES emissions scenarios, see Box 'SRES scenarios' in Topic 3 of this Synthesis Report. These scenarios do not include additional climate policies above current ones; more recent studies differ with respect to UNFCCC and Kyoto Protocol inclusion.

[9] Emission pathways of mitigation scenarios are discussed in Section 5.

Table SPM.1. Projected global average surface warming and sea level rise at the end of the 21st century. {Table 3.1}

Case	Temperature change (°C at 2090-2099 relative to 1980-1999) [a, d]		Sea level rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant year 2000 concentrations[b]	0.6	0.3 – 0.9	Not available
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Notes:

a) Temperatures are assessed best estimates and *likely* uncertainty ranges from a hierarchy of models of varying complexity as well as observational constraints.

b) Year 2000 constant composition is derived from Atmosphere-Ocean General Circulation Models (AOGCMs) only.

c) All scenarios above are six SRES marker scenarios. Approximate CO_2-eq concentrations corresponding to the computed radiative forcing due to anthropogenic GHGs and aerosols in 2100 (see p. 823 of the Working Group I TAR) for the SRES B1, AIT, B2, A1B, A2 and A1FI illustrative marker scenarios are about 600, 700, 800, 850, 1250 and 1550ppm, respectively.

d) Temperature changes are expressed as the difference from the period 1980-1999. To express the change relative to the period 1850-1899 add 0.5°C.

of global average sea level rise for 2090-2099.[10] The projections do not include uncertainties in climate-carbon cycle feedbacks nor the full effects of changes in ice sheet flow, therefore the upper values of the ranges are not to be considered upper bounds for sea level rise. They include a contribution from increased Greenland and Antarctic ice flow at the rates observed for 1993-2003, but this could increase or decrease in the future.[11] *{3.2.1}*

There is now higher confidence than in the TAR in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation and some aspects of extremes and sea ice. ***{3.2.2}***

Regional-scale changes include: *{3.2.2}*

- warming greatest over land and at most high northern latitudes and least over Southern Ocean and parts of the North Atlantic Ocean, continuing recent observed trends (Figure SPM.6)
- contraction of snow cover area, increases in thaw depth over most permafrost regions and decrease in sea ice extent; in some projections using SRES scenarios, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century
- *very likely* increase in frequency of hot extremes, heat waves and heavy precipitation
- *likely* increase in tropical cyclone intensity; less confidence in global decrease of tropical cyclone numbers
- poleward shift of extra-tropical storm tracks with consequent changes in wind, precipitation and temperature patterns
- *very likely* precipitation increases in high latitudes and *likely* decreases in most subtropical land regions, continuing observed recent trends.

There is *high confidence* that by mid-century, annual river runoff and water availability are projected to increase at high latitudes (and in some tropical wet areas) and decrease in some dry regions in the mid-latitudes and tropics. There is also *high confidence* that many semi-arid areas (e.g. Mediterranean Basin, western United States, southern Africa and north-eastern Brazil) will suffer a decrease in water resources due to climate change. *{3.3.1, Figure 3.5}*

Studies since the TAR have enabled more systematic understanding of the timing and magnitude of impacts related to differing amounts and rates of climate change. ***{3.3.1, 3.3.2}***

Figure SPM.7 presents examples of this new information for systems and sectors. The top panel shows impacts increasing with increasing temperature change. Their estimated magnitude and timing is also affected by development pathway (lower panel). *{3.3.1}*

Examples of some projected impacts for different regions are given in Table SPM.2.

[10] TAR projections were made for 2100, whereas the projections for this report are for 2090-2099. The TAR would have had similar ranges to those in Table SPM.1 if it had treated uncertainties in the same way.

[11] For discussion of the longer term, see material below.

Geographical pattern of surface warming

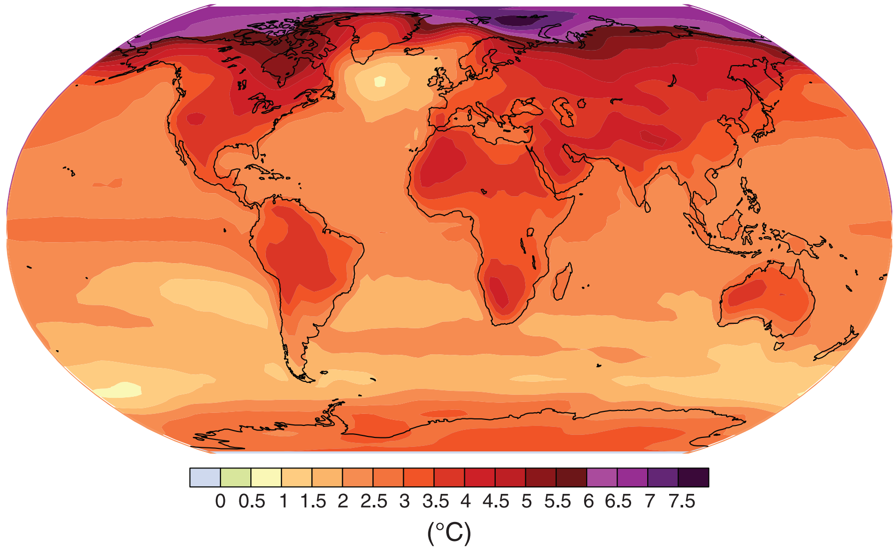


Figure SPM.6. *Projected surface temperature changes for the late 21st century (2090-2099). The map shows the multi-AOGCM average projection for the A1B SRES scenario. Temperatures are relative to the period 1980-1999. {Figure 3.2}*

Some systems, sectors and regions are *likely* to be especially affected by climate change.[12] *{3.3.3}*

Systems and sectors: *{3.3.3}*

- particular ecosystems:
  - terrestrial: tundra, boreal forest and mountain regions because of sensitivity to warming; mediterranean-type ecosystems because of reduction in rainfall; and tropical rainforests where precipitation declines
  - coastal: mangroves and salt marshes, due to multiple stresses
  - marine: coral reefs due to multiple stresses; the sea ice biome because of sensitivity to warming
- water resources in some dry regions at mid-latitudes[13] and in the dry tropics, due to changes in rainfall and evapotranspiration, and in areas dependent on snow and ice melt
- agriculture in low latitudes, due to reduced water availability
- low-lying coastal systems, due to threat of sea level rise and increased risk from extreme weather events
- human health in populations with low adaptive capacity.

Regions: *{3.3.3}*

- the Arctic, because of the impacts of high rates of projected warming on natural systems and human communities
- Africa, because of low adaptive capacity and projected climate change impacts
- small islands, where there is high exposure of population and infrastructure to projected climate change impacts
- Asian and African megadeltas, due to large populations and high exposure to sea level rise, storm surges and river flooding.

Within other areas, even those with high incomes, some people (such as the poor, young children and the elderly) can be particularly at risk, and also some areas and some activities. *{3.3.3}*

Ocean acidification

The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic with an average decrease in pH of 0.1 units. Increasing atmospheric CO_2 concentrations lead to further acidification. Projections based on SRES scenarios give a reduction in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century. While the effects of observed ocean acidification on the marine biosphere are as yet undocumented, the progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms (e.g. corals) and their dependent species. *{3.3.4}*

[12] Identified on the basis of expert judgement of the assessed literature and considering the magnitude, timing and projected rate of climate change, sensitivity and adaptive capacity.

[13] Including arid and semi-arid regions.

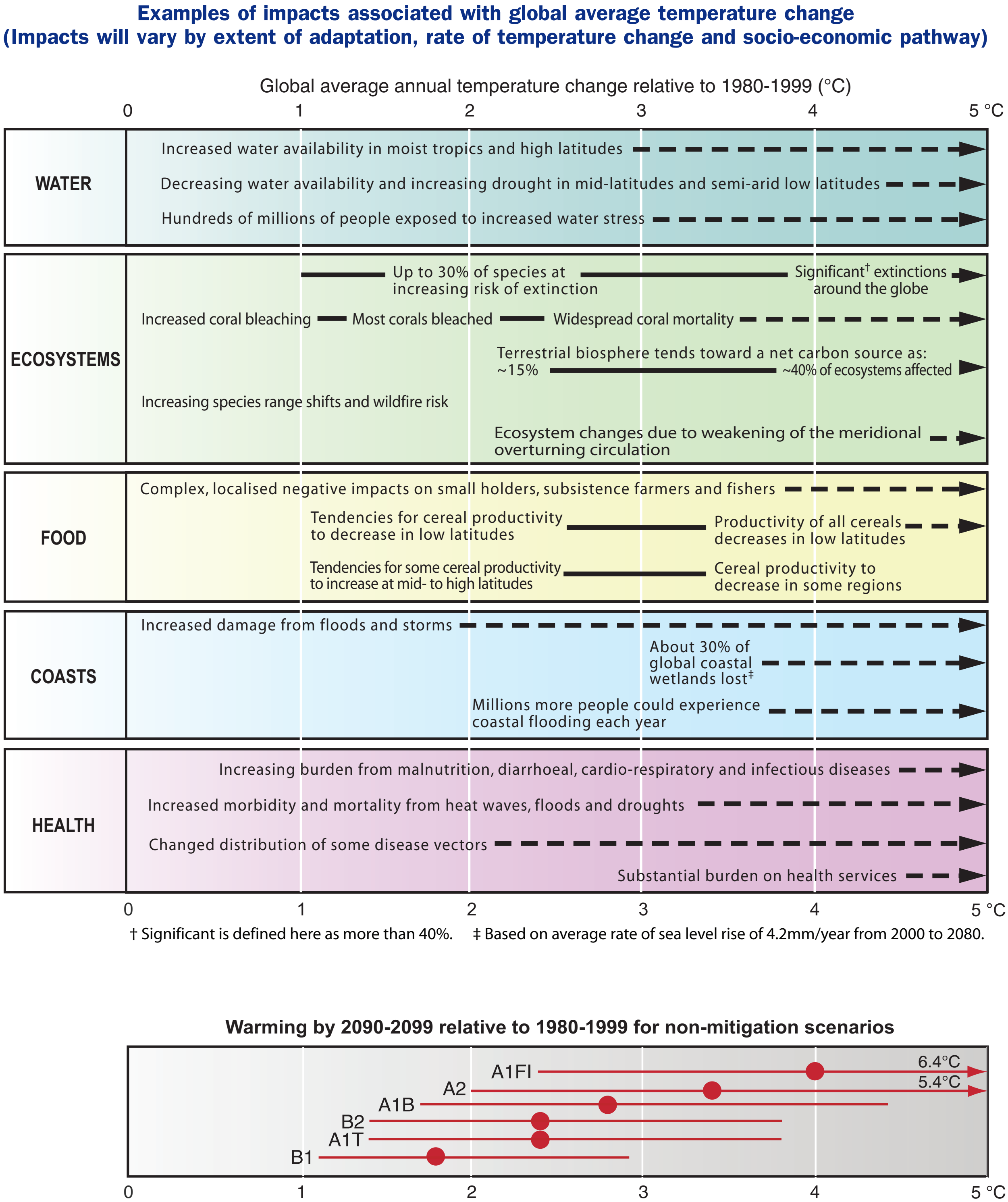


Figure SPM.7. *Examples of impacts associated with projected global average surface warming.* ***Upper panel:*** *Illustrative examples of global impacts projected for climate changes (and sea level and atmospheric* CO_2 *where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. The black lines link impacts; broken-line arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left-hand side of text indicates the approximate level of warming that is associated with the onset of a given impact. Quantitative entries for water scarcity and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES scenarios A1FI, A2, B1 and B2. Adaptation to climate change is not included in these estimations. Confidence levels for all statements are* high. ***Lower panel:*** *Dots and bars indicate the best estimate and* likely *ranges of warming assessed for the six SRES marker scenarios for 2090-2099 relative to 1980-1999. {Figure 3.6}*

Table SPM.2. *Examples of some projected regional impacts. {3.3.2}*

Africa	• By 2020, between 75 and 250 million of people are projected to be exposed to increased water stress due to climate change. • By 2020, in some countries, yields from rain-fed agriculture could be reduced by up to 50%. Agricultural production, including access to food, in many African countries is projected to be severely compromised. This would further adversely affect food security and exacerbate malnutrition. • Towards the end of the 21st century, projected sea level rise will affect low-lying coastal areas with large populations. The cost of adaptation could amount to at least 5 to 10% of Gross Domestic Product (GDP). • By 2080, an increase of 5 to 8% of arid and semi-arid land in Africa is projected under a range of climate scenarios (TS).
Asia	• By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease. • Coastal areas, especially heavily populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers. • Climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation and economic development. • Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle.
Australia and New Zealand	• By 2020, significant loss of biodiversity is projected to occur in some ecologically rich sites, including the Great Barrier Reef and Queensland Wet Tropics. • By 2030, water security problems are projected to intensify in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions. • By 2030, production from agriculture and forestry is projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits are projected in some other regions. • By 2050, ongoing coastal development and population growth in some areas of Australia and New Zealand are projected to exacerbate risks from sea level rise and increases in the severity and frequency of storms and coastal flooding.
Europe	• Climate change is expected to magnify regional differences in Europe's natural resources and assets. Negative impacts will include increased risk of inland flash floods and more frequent coastal flooding and increased erosion (due to storminess and sea level rise). • Mountainous areas will face glacier retreat, reduced snow cover and winter tourism, and extensive species losses (in some areas up to 60% under high emissions scenarios by 2080). • In southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity. • Climate change is also projected to increase the health risks due to heat waves and the frequency of wildfires.
Latin America	• By mid-century, increases in temperature and associated decreases in soil water are projected to lead to gradual replacement of tropical forest by savanna in eastern Amazonia. Semi-arid vegetation will tend to be replaced by arid-land vegetation. • There is a risk of significant biodiversity loss through species extinction in many areas of tropical Latin America. • Productivity of some important crops is projected to decrease and livestock productivity to decline, with adverse consequences for food security. In temperate zones, soybean yields are projected to increase. Overall, the number of people at risk of hunger is projected to increase (TS; *medium confidence*). • Changes in precipitation patterns and the disappearance of glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation.
North America	• Warming in western mountains is projected to cause decreased snowpack, more winter flooding and reduced summer flows, exacerbating competition for over-allocated water resources. • In the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5 to 20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilised water resources. • Cities that currently experience heat waves are expected to be further challenged by an increased number, intensity and duration of heat waves during the course of the century, with potential for adverse health impacts. • Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution.

continued...

Table SPM.2. *continued...*

Polar Regions	• The main projected biophysical effects are reductions in thickness and extent of glaciers, ice sheets and sea ice, and changes in natural ecosystems with detrimental effects on many organisms including migratory birds, mammals and higher predators. • For human communities in the Arctic, impacts, particularly those resulting from changing snow and ice conditions, are projected to be mixed. • Detrimental impacts would include those on infrastructure and traditional indigenous ways of life. • In both polar regions, specific ecosystems and habitats are projected to be vulnerable, as climatic barriers to species invasions are lowered.
Small Islands	• Sea level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities. • Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected to affect local resources. • By mid-century, climate change is expected to reduce water resources in many small islands, e.g. in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low-rainfall periods. • With higher temperatures, increased invasion by non-native species is expected to occur, particularly on mid- and high-latitude islands.

Note:
Unless stated explicitly, all entries are from Working Group II SPM text, and are either *very high confidence* or *high confidence* statements, reflecting different sectors (agriculture, ecosystems, water, coasts, health, industry and settlements). The Working Group II SPM refers to the source of the statements, timelines and temperatures. The magnitude and timing of impacts that will ultimately be realised will vary with the amount and rate of climate change, emissions scenarios, development pathways and adaptation.

Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human systems. *{3.3.5}*

Examples for selected extremes and sectors are shown in Table SPM.3.

Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if GHG concentrations were to be stabilised. *{3.2.3}*

Estimated long-term (multi-century) warming corresponding to the six AR4 Working Group III stabilisation categories is shown in Figure SPM.8.

Contraction of the Greenland ice sheet is projected to continue to contribute to sea level rise after 2100. Current models suggest virtually complete elimination of the Greenland ice sheet and a resulting contribution to sea level rise of about 7m if global average warming were sustained for millennia in excess of 1.9 to 4.6°C relative to pre-industrial values. The corresponding future temperatures in Greenland are comparable to those inferred for the last interglacial period 125,000 years ago, when palaeoclimatic information suggests reductions of polar land ice extent and 4 to 6m of sea level rise. *{3.2.3}*

Current global model studies project that the Antarctic ice sheet will remain too cold for widespread surface melting and gain mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance. *{3.2.3}*

Estimated multi-century warming relative to 1980-1999 for AR4 stabilisation categories

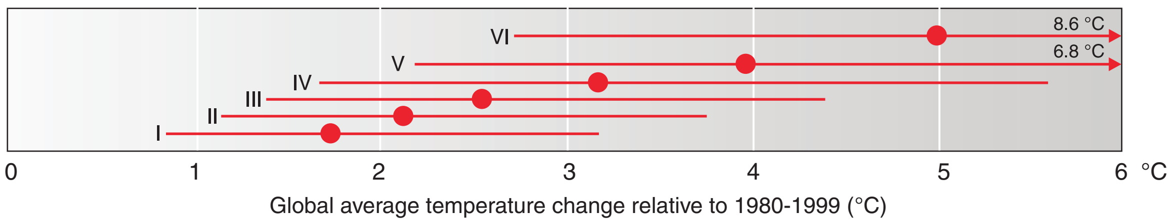


Figure SPM.8. *Estimated long-term (multi-century) warming corresponding to the six AR4 Working Group III stabilisation categories (Table SPM.6). The temperature scale has been shifted by -0.5°C compared to Table SPM.6 to account approximately for the warming between pre-industrial and 1980-1999. For most stabilisation levels global average temperature is approaching the equilibrium level over a few centuries. For GHG emissions scenarios that lead to stabilisation at levels comparable to SRES B1 and A1B by 2100 (600 and 850ppm CO_2-eq; category IV and V), assessed models project that about 65 to 70% of the estimated global equilibrium temperature increase, assuming a climate sensitivity of 3°C, would be realised at the time of stabilisation. For the much lower stabilisation scenarios (category I and II, Figure SPM.11), the equilibrium temperature may be reached earlier. {Figure 3.4}*

Table SPM.3. *Examples of possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid- to late 21st century. These do not take into account any changes or developments in adaptive capacity. The likelihood estimates in column two relate to the phenomena listed in column one. {Table 3.2}*

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems	Water resources	Human health	Industry, settlement and society
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	*Virtually certain*[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	*Very likely*	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	*Very likely*	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding: pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	*Likely*	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	*Likely*	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migrations; loss of property
Increased incidence of extreme high sea level (excludes tsunamis)[c]	*Likely*[d]	Salinisation of irrigation water, estuaries and fresh-water systems	Decreased fresh-water availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

Notes:
a) See Working Group I Table 3.7 for further details regarding definitions.
b) Warming of the most extreme days and nights each year.
c) Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
d) In all scenarios, the projected global average sea level at 2100 is higher than in the reference period. The effect of changes in regional weather systems on sea level extremes has not been assessed.

Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change. *{3.4}*

Partial loss of ice sheets on polar land could imply metres of sea level rise, major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands. Such changes are projected to occur over millennial time scales, but more rapid sea level rise on century time scales cannot be excluded. *{3.4}*

Climate change is *likely* to lead to some irreversible impacts. There is *medium confidence* that approximately 20 to 30% of species assessed so far are *likely* to be at increased risk of extinction if increases in global average warming exceed 1.5 to 2.5°C (relative to 1980-1999). As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40 to 70% of species assessed) around the globe. *{3.4}*

Based on current model simulations, the meridional overturning circulation (MOC) of the Atlantic Ocean will *very likely* slow down during the 21st century; nevertheless temperatures over the Atlantic and Europe are projected to increase. The MOC is *very unlikely* to undergo a large abrupt transition during the 21st century. Longer-term MOC changes cannot be assessed with confidence. Impacts of large-scale and persistent changes in the MOC are *likely* to include changes in marine ecosystem productivity, fisheries, ocean CO_2 uptake, oceanic oxygen concentrations and terrestrial vegetation. Changes in terrestrial and ocean CO_2 uptake may feed back on the climate system. *{3.4}*

4. Adaptation and mitigation options[14]

A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change. There are barriers, limits and costs, which are not fully understood. ***{4.2}***

Societies have a long record of managing the impacts of weather- and climate-related events. Nevertheless, additional adaptation measures will be required to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation undertaken over the next two to three decades. Moreover, vulnerability to climate change can be exacerbated by other stresses. These arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict and incidence of diseases such as HIV/AIDS. *{4.2}*

Some planned adaptation to climate change is already occurring on a limited basis. Adaptation can reduce vulnerability, especially when it is embedded within broader sectoral initiatives (Table SPM.4). There is *high confidence* that there are viable adaptation options that can be implemented in some sectors at low cost, and/or with high benefit-cost ratios. However, comprehensive estimates of global costs and benefits of adaptation are limited. *{4.2, Table 4.1}*

Adaptive capacity is intimately connected to social and economic development but is unevenly distributed across and within societies. ***{4.2}***

A range of barriers limits both the implementation and effectiveness of adaptation measures. The capacity to adapt is dynamic and is influenced by a society's productive base, including natural and man-made capital assets, social networks and entitlements, human capital and institutions, governance, national income, health and technology. Even societies with high adaptive capacity remain vulnerable to climate change, variability and extremes. *{4.2}*

Both bottom-up and top-down studies indicate that there is *high agreement* and *much evidence* of substantial economic potential for the mitigation of global GHG emissions over the coming decades that could offset the projected growth of global emissions or reduce emissions below current levels (Figures SPM.9, SPM.10).[15] While top-down and bottom-up studies are in line at the global level (Figure SPM.9) there are considerable differences at the sectoral level. ***{4.3}***

No single technology can provide all of the mitigation potential in any sector. The economic mitigation potential, which is generally greater than the market mitigation potential, can only be achieved when adequate policies are in place and barriers removed (Table SPM.5). *{4.3}*

Bottom-up studies suggest that mitigation opportunities with net negative costs have the potential to reduce emissions by around 6 $GtCO_2$-eq/yr in 2030, realising which requires dealing with implementation barriers. *{4.3}*

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[14] While this Section deals with adaptation and mitigation separately, these responses can be complementary. This theme is discussed in Section 5.

[15] The concept of '**mitigation potential**' has been developed to assess the scale of GHG reductions that could be made, relative to emission baselines, for a given level of carbon price (expressed in cost per unit of carbon dioxide equivalent emissions avoided or reduced). Mitigation potential is further differentiated in terms of 'market mitigation potential' and 'economic mitigation potential'.

Market mitigation potential is the mitigation potential based on private costs and private discount rates (reflecting the perspective of private consumers and companies), which might be expected to occur under forecast market conditions, including policies and measures currently in place, noting that barriers limit actual uptake.

Economic mitigation potential is the mitigation potential that takes into account social costs and benefits and social discount rates (reflecting the perspective of society; social discount rates are lower than those used by private investors), assuming that market efficiency is improved by policies and measures and barriers are removed.

Mitigation potential is estimated using different types of approaches. ***Bottom-up studies*** are based on assessment of mitigation options, emphasising specific technologies and regulations. They are typically sectoral studies taking the macro-economy as unchanged. ***Top-down studies*** assess the economy-wide potential of mitigation options. They use globally consistent frameworks and aggregated information about mitigation options and capture macro-economic and market feedbacks.

Table SPM.4. *Selected examples of planned adaptation by sector. {Table 4.1}*

Sector	Adaptation option/strategy	Underlying policy framework	Key constraints and opportunities to implementation (Normal font = constraints; *italics = opportunities*)
Water	Expanded rainwater harvesting; water storage and conservation techniques; water re-use; desalination; water-use and irrigation efficiency	National water policies and integrated water resources management; water-related hazards management	Financial, human resources and physical barriers; *integrated water resources management; synergies with other sectors*
Agriculture	Adjustment of planting dates and crop variety; crop relocation; improved land management, e.g. erosion control and soil protection through tree planting	R&D policies; institutional reform; land tenure and land reform; training; capacity building; crop insurance; financial incentives, e.g. subsidies and tax credits	Technological and financial constraints; access to new varieties; markets; *longer growing season in higher latitudes; revenues from 'new' products*
Infrastructure/ settlement (including coastal zones)	Relocation; seawalls and storm surge barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea level rise and flooding; protection of existing natural barriers	Standards and regulations that integrate climate change considerations into design; land-use policies; building codes; insurance	Financial and technological barriers; availability of relocation space; *integrated policies and management; synergies with sustainable development goals*
Human health	Heat-health action plans; emergency medical services; improved climate-sensitive disease surveillance and control; safe water and improved sanitation	Public health policies that recognise climate risk; strengthened health services; regional and international cooperation	Limits to human tolerance (vulnerable groups); knowledge limitations; financial capacity; *upgraded health services; improved quality of life*
Tourism	Diversification of tourism attractions and revenues; shifting ski slopes to higher altitudes and glaciers; artificial snow-making	Integrated planning (e.g. carrying capacity; linkages with other sectors); financial incentives, e.g. subsidies and tax credits	Appeal/marketing of new attractions; financial and logistical challenges; potential adverse impact on other sectors (e.g. artificial snow-making may increase energy use); *revenues from 'new' attractions; involvement of wider group of stakeholders*
Transport	Realignment/relocation; design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Integrating climate change considerations into national transport policy; investment in R&D for special situations, e.g. permafrost areas	Financial and technological barriers; availability of less vulnerable routes; *improved technologies and integration with key sectors (e.g. energy)*
Energy	Strengthening of overhead transmission and distribution infrastructure; underground cabling for utilities; energy efficiency; use of renewable sources; reduced dependence on single sources of energy	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources; incorporating climate change in design standards	Access to viable alternatives; financial and technological barriers; acceptance of new technologies; *stimulation of new technologies; use of local resources*

Note:
Other examples from many sectors would include early warning systems.

Future energy infrastructure investment decisions, expected to exceed US$20 trillion[16] between 2005 and 2030, will have long-term impacts on GHG emissions, because of the long lifetimes of energy plants and other infrastructure capital stock. The widespread diffusion of low-carbon technologies may take many decades, even if early investments in these technologies are made attractive. Initial estimates show that returning global energy-related CO_2 emissions to 2005 levels by 2030 would require a large shift in investment patterns, although the net additional investment required ranges from negligible to 5 to 10%. *{4.3}*

[16] 20 trillion = 20,000 billion = 20×10^{12}

Comparison between global economic mitigation potential and projected emissions increase in 2030

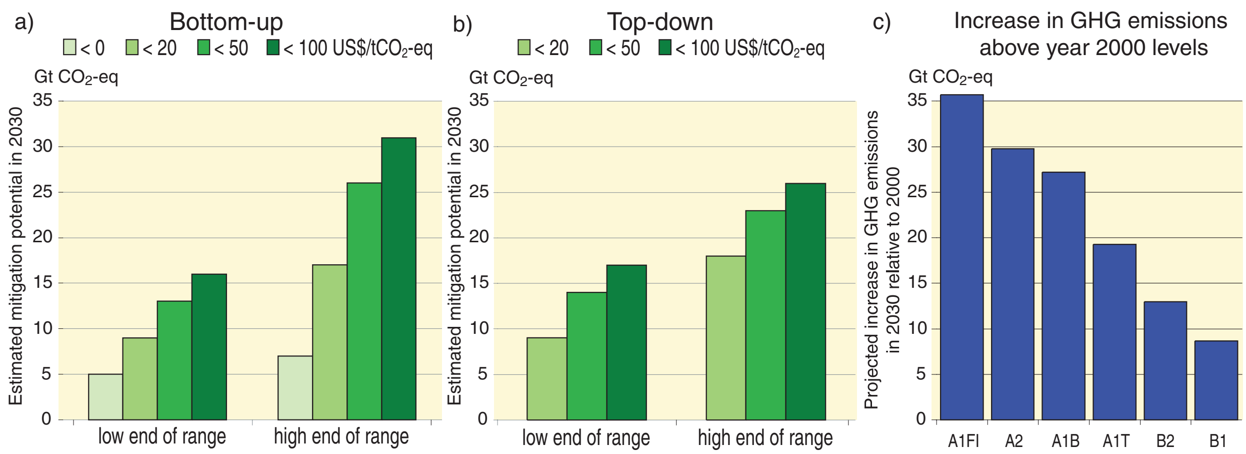

__Figure SPM.9.__ Global economic mitigation potential in 2030 estimated from bottom-up (Panel a) and top-down (Panel b) studies, compared with the projected emissions increases from SRES scenarios relative to year 2000 GHG emissions of 40.8 $GtCO_2$-eq (Panel c). Note: GHG emissions in 2000 are exclusive of emissions of decay of above ground biomass that remains after logging and deforestation and from peat fires and drained peat soils, to ensure consistency with the SRES emission results. {Figure 4.1}

Economic mitigation potentials by sector in 2030 estimated from bottom-up studies

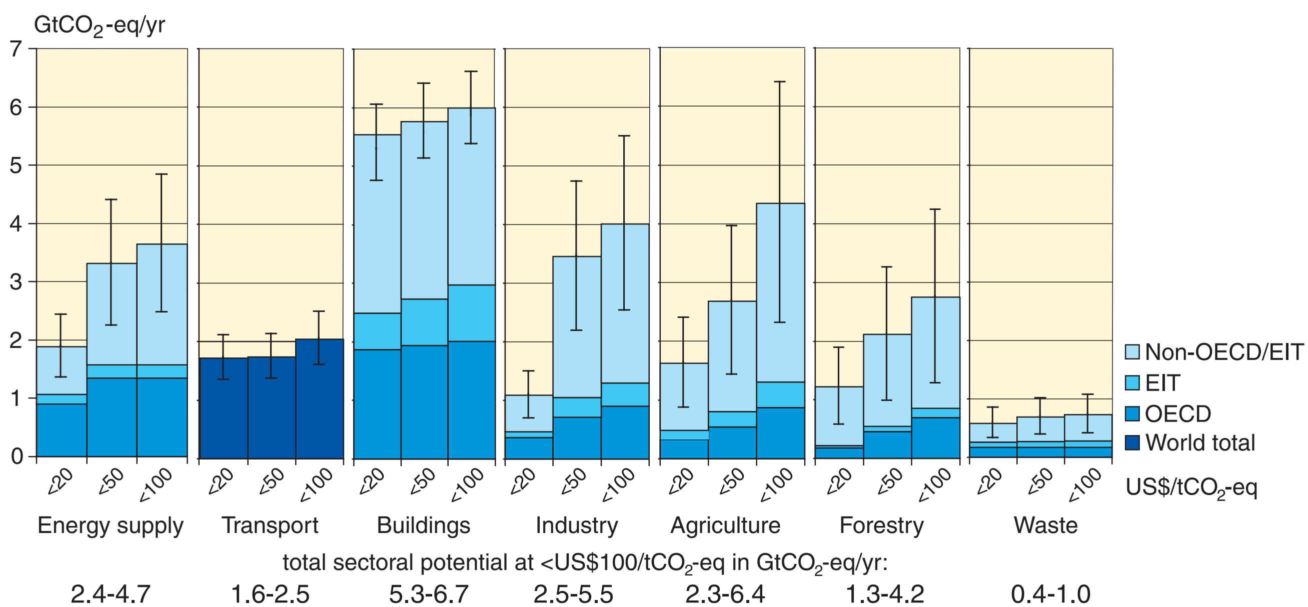

__Figure SPM.10.__ Estimated economic mitigation potential by sector in 2030 from bottom-up studies, compared to the respective baselines assumed in the sector assessments. The potentials do not include non-technical options such as lifestyle changes. {Figure 4.2}

Notes:

a) The ranges for global economic potentials as assessed in each sector are shown by vertical lines. The ranges are based on end-use allocations of emissions, meaning that emissions of electricity use are counted towards the end-use sectors and not to the energy supply sector.

b) The estimated potentials have been constrained by the availability of studies particularly at high carbon price levels.

c) Sectors used different baselines. For industry, the SRES B2 baseline was taken, for energy supply and transport, the World Energy Outlook (WEO) 2004 baseline was used; the building sector is based on a baseline in between SRES B2 and A1B; for waste, SRES A1B driving forces were used to construct a waste-specific baseline; agriculture and forestry used baselines that mostly used B2 driving forces.

d) Only global totals for transport are shown because international aviation is included.

e) Categories excluded are: non-CO_2 emissions in buildings and transport, part of material efficiency options, heat production and co-generation in energy supply, heavy duty vehicles, shipping and high-occupancy passenger transport, most high-cost options for buildings, wastewater treatment, emission reduction from coal mines and gas pipelines, and fluorinated gases from energy supply and transport. The underestimation of the total economic potential from these emissions is of the order of 10 to 15%.

Table SPM.5 *Selected examples of key sectoral mitigation technologies, policies and measures, constraints and opportunities. {Table 4.2}*

Sector	Key mitigation technologies and practices currently commercially available. ***Key mitigation technologies and practices projected to be commercialised before 2030 shown in italics.***	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities (Normal font = constraints; *italics = opportunities*)
Energy supply	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas); *CCS for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics*	Reduction of fossil fuel subsidies; taxes or carbon charges on fossil fuels	Resistance by vested interests may make them difficult to implement
		Feed-in tariffs for renewable energy technologies; renewable energy obligations; producer subsidies	*May be appropriate to create markets for low-emissions technologies*
Transport	More fuel-efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning; *second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries*	Mandatory fuel economy; biofuel blending and CO_2 standards for road transport	Partial coverage of vehicle fleet may limit effectiveness
		Taxes on vehicle purchase, registration, use and motor fuels; road and parking pricing	Effectiveness may drop with higher incomes
		Influence mobility needs through land-use regulations and infrastructure planning; investment in attractive public transport facilities and non-motorised forms of transport	*Particularly appropriate for countries that are building up their transportation systems*
Buildings	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycling of fluorinated gases; *integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar photovoltaics integrated in buildings*	Appliance standards and labelling	Periodic revision of standards needed
		Building codes and certification	*Attractive for new buildings.* Enforcement can be difficult
		Demand-side management programmes	Need for regulations so that utilities may profit
		Public sector leadership programmes, including procurement	*Government purchasing can expand demand for energy-efficient products*
		Incentives for energy service companies (ESCOs)	*Success factor: Access to third party financing*
Industry	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions; and a wide array of process-specific technologies; *advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture*	Provision of benchmark information; performance standards; subsidies; tax credits	*May be appropriate to stimulate technology uptake.* Stability of national policy important in view of international competitiveness
		Tradable permits	Predictable allocation mechanisms and stable price signals important for investments
		Voluntary agreements	Success factors include: clear targets, a baseline scenario, third-party involvement in design and review and formal provisions of monitoring, close cooperation between government and industry
Agriculture	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertiliser application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency; *improvements of crop yields*	Financial incentives and regulations for improved land management; maintaining soil carbon content; efficient use of fertilisers and irrigation	*May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation*
Forestry/ forests	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use; *tree species improvement to increase biomass productivity and carbon sequestration; improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change*	Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests; land-use regulation and enforcement	Constraints include lack of investment capital and land tenure issues. *Can help poverty alleviation*
Waste	Landfill CH_4 recovery; waste incineration with energy recovery; composting of organic waste; controlled wastewater treatment; recycling and waste minimisation; *biocovers and biofilters to optimise CH_4 oxidation*	Financial incentives for improved waste and wastewater management	*May stimulate technology diffusion*
		Renewable energy incentives or obligations	Local availability of low-cost fuel
		Waste management regulations	Most effectively applied at national level with enforcement strategies

A wide variety of policies and instruments are available to governments to create the incentives for mitigation action. Their applicability depends on national circumstances and sectoral context (Table SPM.5). *{4.3}*

They include integrating climate policies in wider development policies, regulations and standards, taxes and charges, tradable permits, financial incentives, voluntary agreements, information instruments, and research, development and demonstration (RD&D). *{4.3}*

An effective carbon-price signal could realise significant mitigation potential in all sectors. Modelling studies show that global carbon prices rising to US$20-80/t$CO_2$-eq by 2030 are consistent with stabilisation at around 550ppm CO_2-eq by 2100. For the same stabilisation level, induced technological change may lower these price ranges to US$5-65/t$CO_2$-eq in 2030.[17] *{4.3}*

There is *high agreement* and *much evidence* that mitigation actions can result in near-term co-benefits (e.g. improved health due to reduced air pollution) that may offset a substantial fraction of mitigation costs. *{4.3}*

There is *high agreement* and *medium evidence* that Annex I countries' actions may affect the global economy and global emissions, although the scale of carbon leakage remains uncertain.[18] *{4.3}*

Fossil fuel exporting nations (in both Annex I and non-Annex I countries) may expect, as indicated in the TAR, lower demand and prices and lower GDP growth due to mitigation policies. The extent of this spillover depends strongly on assumptions related to policy decisions and oil market conditions. *{4.3}*

There is also *high agreement* and *medium evidence* that changes in lifestyle, behaviour patterns and management practices can contribute to climate change mitigation across all sectors. *{4.3}*

Many options for reducing global GHG emissions through international cooperation exist. There is *high agreement* and *much evidence* that notable achievements of the UNFCCC and its Kyoto Protocol are the establishment of a global response to climate change, stimulation of an array of national policies, and the creation of an international carbon market and new institutional mechanisms that may provide the foundation for future mitigation efforts. Progress has also been made in addressing adaptation within the UNFCCC and additional international initiatives have been suggested. *{4.5}*

Greater cooperative efforts and expansion of market mechanisms will help to reduce global costs for achieving a given level of mitigation, or will improve environmental effectiveness. Efforts can include diverse elements such as emissions targets; sectoral, local, sub-national and regional actions; RD&D programmes; adopting common policies; implementing development-oriented actions; or expanding financing instruments. *{4.5}*

In several sectors, climate response options can be implemented to realise synergies and avoid conflicts with other dimensions of sustainable development. Decisions about macroeconomic and other non-climate policies can significantly affect emissions, adaptive capacity and vulnerability. *{4.4, 5.8}*

Making development more sustainable can enhance mitigative and adaptive capacities, reduce emissions and reduce vulnerability, but there may be barriers to implementation. On the other hand, it is *very likely* that climate change can slow the pace of progress towards sustainable development. Over the next half-century, climate change could impede achievement of the Millennium Development Goals. *{5.8}*

5. The long-term perspective

Determining what constitutes "dangerous anthropogenic interference with the climate system" in relation to Article 2 of the UNFCCC involves value judgements. Science can support informed decisions on this issue, including by providing criteria for judging which vulnerabilities might be labelled 'key'. *{Box 'Key Vulnerabilities and Article 2 of the UNFCCC', Topic 5}*

Key vulnerabilities[19] may be associated with many climate-sensitive systems, including food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets and modes of oceanic and atmospheric circulation. *{Box 'Key Vulnerabilities and Article 2 of the UNFCCC', Topic 5}*

[17] Studies on mitigation portfolios and macro-economic costs assessed in this report are based on top-down modelling. Most models use a global least-cost approach to mitigation portfolios, with universal emissions trading, assuming transparent markets, no transaction cost, and thus perfect implementation of mitigation measures throughout the 21st century. Costs are given for a specific point in time. Global modelled costs will increase if some regions, sectors (e.g. land use), options or gases are excluded. Global modelled costs will decrease with lower baselines, use of revenues from carbon taxes and auctioned permits, and if induced technological learning is included. These models do not consider climate benefits and generally also co-benefits of mitigation measures, or equity issues. Significant progress has been achieved in applying approaches based on induced technological change to stabilisation studies; however, conceptual issues remain. In the models that consider induced technological change, projected costs for a given stabilisation level are reduced; the reductions are greater at lower stabilisation level.

[18] Further details may be found in Topic 4 of this Synthesis Report.

[19] Key vulnerabilities can be identified based on a number of criteria in the literature, including magnitude, timing, persistence/reversibility, the potential for adaptation, distributional aspects, likelihood and 'importance' of the impacts.

The five 'reasons for concern' identified in the TAR remain a viable framework to consider key vulnerabilities. These 'reasons' are assessed here to be stronger than in the TAR. Many risks are identified with higher confidence. Some risks are projected to be larger or to occur at lower increases in temperature. Understanding about the relationship between impacts (the basis for 'reasons for concern' in the TAR) and vulnerability (that includes the ability to adapt to impacts) has improved. *{5.2}*

This is due to more precise identification of the circumstances that make systems, sectors and regions especially vulnerable and growing evidence of the risks of very large impacts on multiple-century time scales. *{5.2}*

- ***Risks to unique and threatened systems.*** There is new and stronger evidence of observed impacts of climate change on unique and vulnerable systems (such as polar and high mountain communities and ecosystems), with increasing levels of adverse impacts as temperatures increase further. An increasing risk of species extinction and coral reef damage is projected with higher confidence than in the TAR as warming proceeds. There is *medium confidence* that approximately 20 to 30% of plant and animal species assessed so far are *likely* to be at increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5°C over 1980-1999 levels. Confidence has increased that a 1 to 2°C increase in global mean temperature above 1990 levels (about 1.5 to 2.5°C above pre-industrial) poses significant risks to many unique and threatened systems including many biodiversity hotspots. Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1 to 3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals. Increasing vulnerability of indigenous communities in the Arctic and small island communities to warming is projected. *{5.2}*
- ***Risks of extreme weather events.*** Responses to some recent extreme events reveal higher levels of vulnerability than the TAR. There is now higher confidence in the projected increases in droughts, heat waves and floods, as well as their adverse impacts. *{5.2}*
- ***Distribution of impacts and vulnerabilities.*** There are sharp differences across regions and those in the weakest economic position are often the most vulnerable to climate change. There is increasing evidence of greater vulnerability of specific groups such as the poor and elderly not only in developing but also in developed countries. Moreover, there is increased evidence that low-latitude and less developed areas generally face greater risk, for example in dry areas and megadeltas. *{5.2}*
- ***Aggregate impacts.*** Compared to the TAR, initial net market-based benefits from climate change are projected to peak at a lower magnitude of warming, while damages would be higher for larger magnitudes of warming. The net costs of impacts of increased warming are projected to increase over time. *{5.2}*
- ***Risks of large-scale singularities.*** There is *high confidence* that global warming over many centuries would lead to a sea level rise contribution from thermal expansion alone that is projected to be much larger than observed over the 20th century, with loss of coastal area and associated impacts. There is better understanding than in the TAR that the risk of additional contributions to sea level rise from both the Greenland and possibly Antarctic ice sheets may be larger than projected by ice sheet models and could occur on century time scales. This is because ice dynamical processes seen in recent observations but not fully included in ice sheet models assessed in the AR4 could increase the rate of ice loss. *{5.2}*

There is *high confidence* that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change. *{5.3}*

Adaptation is necessary in the short and longer term to address impacts resulting from the warming that would occur even for the lowest stabilisation scenarios assessed. There are barriers, limits and costs, but these are not fully understood. Unmitigated climate change would, in the long term, be *likely* to exceed the capacity of natural, managed and human systems to adapt. The time at which such limits could be reached will vary between sectors and regions. Early mitigation actions would avoid further locking in carbon intensive infrastructure and reduce climate change and associated adaptation needs. *{5.2, 5.3}*

Many impacts can be reduced, delayed or avoided by mitigation. Mitigation efforts and investments over the next two to three decades will have a large impact on opportunities to achieve lower stabilisation levels. Delayed emission reductions significantly constrain the opportunities to achieve lower stabilisation levels and increase the risk of more severe climate change impacts. *{5.3, 5.4, 5.7}*

In order to stabilise the concentration of GHGs in the atmosphere, emissions would need to peak and decline thereafter. The lower the stabilisation level, the more quickly this peak and decline would need to occur.[20] *{5.4}*

Table SPM.6 and Figure SPM.11 summarise the required emission levels for different groups of stabilisation concentrations and the resulting equilibrium global warming and long-

[20] For the lowest mitigation scenario category assessed, emissions would need to peak by 2015, and for the highest, by 2090 (see Table SPM.6). Scenarios that use alternative emission pathways show substantial differences in the rate of global climate change.

term sea level rise due to thermal expansion only.[21] The timing and level of mitigation to reach a given temperature stabilisation level is earlier and more stringent if climate sensitivity is high than if it is low. *{5.4, 5.7}*

Sea level rise under warming is inevitable. Thermal expansion would continue for many centuries after GHG concentrations have stabilised, for any of the stabilisation levels assessed, causing an eventual sea level rise much larger than projected for the 21st century. The eventual contributions from Greenland ice sheet loss could be several metres, and larger than from thermal expansion, should warming in excess of 1.9 to 4.6°C above pre-industrial be sustained over many centuries. The long time scales of thermal expansion and ice sheet response to warming imply that stabilisation of GHG concentrations at or above present levels would not stabilise sea level for many centuries. *{5.3, 5.4}*

There is *high agreement* and *much evidence* that all stabilisation levels assessed can be achieved by deployment of a portfolio of technologies that are either currently available or expected to be commercialised in coming decades, assuming appropriate and effective incentives are in place for their development, acquisition, deployment and diffusion and addressing related barriers. *{5.5}*

All assessed stabilisation scenarios indicate that 60 to 80% of the reductions would come from energy supply and use and industrial processes, with energy efficiency playing a key role in many scenarios. Including non-CO_2 and CO_2 land-use and forestry mitigation options provides greater flexibility and cost-effectiveness. Low stabilisation levels require early investments and substantially more rapid diffusion and commercialisation of advanced low-emissions technologies. *{5.5}*

Without substantial investment flows and effective technology transfer, it may be difficult to achieve emission reduction at a significant scale. Mobilising financing of incremental costs of low-carbon technologies is important. *{5.5}*

Table SPM.6. *Characteristics of post-TAR stabilisation scenarios and resulting long-term equilibrium global average temperature and the sea level rise component from thermal expansion only.[a] {Table 5.1}*

Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d, e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes:

a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).

b) Atmospheric CO_2 concentrations were 379ppm in 2005. The best estimate of total CO_2-eq concentration in 2005 for all long-lived GHGs is about 455ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375ppm CO_2-eq.

c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios (see Figure SPM.3).

d) The best estimate of climate sensitivity is 3°C.

e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilisation of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150 (see also Footnote 21).

f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

[21] Estimates for the evolution of temperature over the course of this century are not available in the AR4 for the stabilisation scenarios. For most stabilisation levels, global average temperature is approaching the equilibrium level over a few centuries. For the much lower stabilisation scenarios (category I and II, Figure SPM.11), the equilibrium temperature may be reached earlier.

CO_2 emissions and equilibrium temperature increases for a range of stabilisation levels

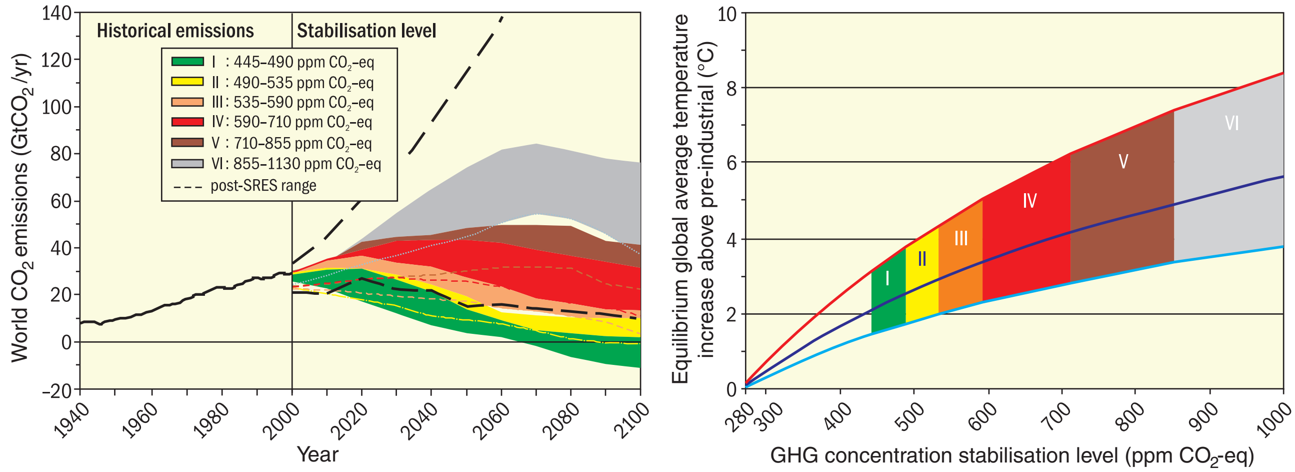

Figure SPM.11. *Global CO_2 emissions for 1940 to 2000 and emissions ranges for categories of stabilisation scenarios from 2000 to 2100 (left-hand panel); and the corresponding relationship between the stabilisation target and the* likely *equilibrium global average temperature increase above pre-industrial (right-hand panel). Approaching equilibrium can take several centuries, especially for scenarios with higher levels of stabilisation. Coloured shadings show stabilisation scenarios grouped according to different targets (stabilisation category I to VI). The right-hand panel shows ranges of global average temperature change above pre-industrial, using (i) 'best estimate' climate sensitivity of 3°C (black line in middle of shaded area), (ii) upper bound of* likely *range of climate sensitivity of 4.5°C (red line at top of shaded area) (iii) lower bound of* likely *range of climate sensitivity of 2°C (blue line at bottom of shaded area). Black dashed lines in the left panel give the emissions range of recent baseline scenarios published since the SRES (2000). Emissions ranges of the stabilisation scenarios comprise CO_2-only and multigas scenarios and correspond to the 10^{th} to 90^{th} percentile of the full scenario distribution. Note: CO_2 emissions in most models do not include emissions from decay of above ground biomass that remains after logging and deforestation, and from peat fires and drained peat soils. {Figure 5.1}*

The macro-economic costs of mitigation generally rise with the stringency of the stabilisation target (Table SPM.7). For specific countries and sectors, costs vary considerably from the global average.[22] *{5.6}*

In 2050, global average macro-economic costs for mitigation towards stabilisation between 710 and 445ppm CO_2-eq are between a 1% gain and 5.5% decrease of global GDP (Table SPM.7). This corresponds to slowing average annual global GDP growth by less than 0.12 percentage points. *{5.6}*

Table SPM.7. *Estimated global macro-economic costs in 2030 and 2050. Costs are relative to the baseline for least-cost trajectories towards different long-term stabilisation levels. {Table 5.2}*

Stabilisation levels (ppm CO_2-eq)	Median GDP reduction[a] (%)		Range of GDP reduction[b] (%)		Reduction of average annual GDP growth rates (percentage points) [c,e]	
	2030	2050	2030	2050	2030	2050
445 – 535[d]	Not available		< 3	< 5.5	< 0.12	< 0.12
535 – 590	0.6	1.3	0.2 to 2.5	slightly negative to 4	< 0.1	< 0.1
590 – 710	0.2	0.5	-0.6 to 1.2	-1 to 2	< 0.06	< 0.05

Notes:
Values given in this table correspond to the full literature across all baselines and mitigation scenarios that provide GDP numbers.
a) Global GDP based on market exchange rates.
b) The 10^{th} and 90^{th} percentile range of the analysed data are given where applicable. Negative values indicate GDP gain. The first row (445-535ppm CO_2-eq) gives the upper bound estimate of the literature only.
c) The calculation of the reduction of the annual growth rate is based on the average reduction during the assessed period that would result in the indicated GDP decrease by 2030 and 2050 respectively.
d) The number of studies is relatively small and they generally use low baselines. High emissions baselines generally lead to higher costs.
e) The values correspond to the highest estimate for GDP reduction shown in column three.

[22] See Footnote 17 for more detail on cost estimates and model assumptions.

Responding to climate change involves an iterative risk management process that includes both adaptation and mitigation and takes into account climate change damages, co-benefits, sustainability, equity and attitudes to risk. *{5.1}*

Impacts of climate change are *very likely* to impose net annual costs, which will increase over time as global temperatures increase. Peer-reviewed estimates of the social cost of carbon[23] in 2005 average US$12 per tonne of CO_2, but the range from 100 estimates is large (-$3 to $95/t$CO_2$). This is due in large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses and discount rates. Aggregate estimates of costs mask significant differences in impacts across sectors, regions and populations and *very likely* underestimate damage costs because they cannot include many non-quantifiable impacts. *{5.7}*

Limited and early analytical results from integrated analyses of the costs and benefits of mitigation indicate that they are broadly comparable in magnitude, but do not as yet permit an unambiguous determination of an emissions pathway or stabilisation level where benefits exceed costs. *{5.7}*

Climate sensitivity is a key uncertainty for mitigation scenarios for specific temperature levels. *{5.4}*

Choices about the scale and timing of GHG mitigation involve balancing the economic costs of more rapid emission reductions now against the corresponding medium-term and long-term climate risks of delay. *{5.7}*

[23] Net economic costs of damages from climate change aggregated across the globe and discounted to the specified year.

A report of Working Group I of the Intergovernmental Panel on Climate Change

Summary for Policymakers

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This Summary for Policymakers should be cited as:

IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Introduction

The Working Group I contribution to the IPCC Fourth Assessment Report describes progress in understanding of the human and natural drivers of climate change,[1] observed climate change, climate processes and attribution, and estimates of projected future climate change. It builds upon past IPCC assessments and incorporates new findings from the past six years of research. Scientific progress since the Third Assessment Report (TAR) is based upon large amounts of new and more comprehensive data, more sophisticated analyses of data, improvements in understanding of processes and their simulation in models and more extensive exploration of uncertainty ranges.

The basis for substantive paragraphs in this Summary for Policymakers can be found in the chapter sections specified in curly brackets.

Human and Natural Drivers of Climate Change

Changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties alter the energy balance of the climate system. These changes are expressed in terms of radiative forcing,[2] which is used to compare how a range of human and natural factors drive warming or cooling influences on global climate. Since the TAR, new observations and related modelling of greenhouse gases, solar activity, land surface properties and some aspects of aerosols have led to improvements in the quantitative estimates of radiative forcing.

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years (see Figure SPM.1). The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture. {2.3, 6.4, 7.3}

- Carbon dioxide is the most important anthropogenic greenhouse gas (see Figure SPM.2). The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm[3] in 2005. The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores. The annual carbon dioxide concentration growth rate was larger during the last 10 years (1995–2005 average: 1.9 ppm per year), than it has been since the beginning of continuous direct atmospheric measurements (1960–2005 average: 1.4 ppm per year) although there is year-to-year variability in growth rates. {2.3, 7.3}

- The primary source of the increased atmospheric concentration of carbon dioxide since the pre-industrial period results from fossil fuel use, with land-use change providing another significant but smaller contribution. Annual fossil carbon dioxide emissions[4] increased from an average of 6.4 [6.0 to 6.8][5] GtC (23.5 [22.0 to 25.0] $GtCO_2$) per year in the 1990s to 7.2 [6.9 to 7.5] GtC (26.4 [25.3 to 27.5] $GtCO_2$) per year in 2000–2005 (2004 and 2005 data are interim estimates). Carbon dioxide emissions associated with land-use change

[1] *Climate change* in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change, where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

[2] *Radiative forcing* is a measure of the influence that a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. Positive forcing tends to warm the surface while negative forcing tends to cool it. In this report, radiative forcing values are for 2005 relative to pre-industrial conditions defined at 1750 and are expressed in watts per square metre ($W\ m^{-2}$). See Glossary and Section 2.2 for further details.

[3] ppm (parts per million) or ppb (parts per billion, 1 billion = 1,000 million) is the ratio of the number of greenhouse gas molecules to the total number of molecules of dry air. For example, 300 ppm means 300 molecules of a greenhouse gas per million molecules of dry air.

[4] Fossil carbon dioxide emissions include those from the production, distribution and consumption of fossil fuels and as a by-product from cement production. An emission of 1 GtC corresponds to 3.67 $GtCO_2$.

[5] In general, uncertainty ranges for results given in this Summary for Policymakers are 90% uncertainty intervals unless stated otherwise, that is, there is an estimated 5% likelihood that the value could be above the range given in square brackets and 5% likelihood that the value could be below that range. Best estimates are given where available. Assessed uncertainty intervals are not always symmetric about the corresponding best estimate. Note that a number of uncertainty ranges in the Working Group I TAR corresponded to 2 standard deviations (95%), often using expert judgement.

Changes in Greenhouse Gases from Ice Core and Modern Data

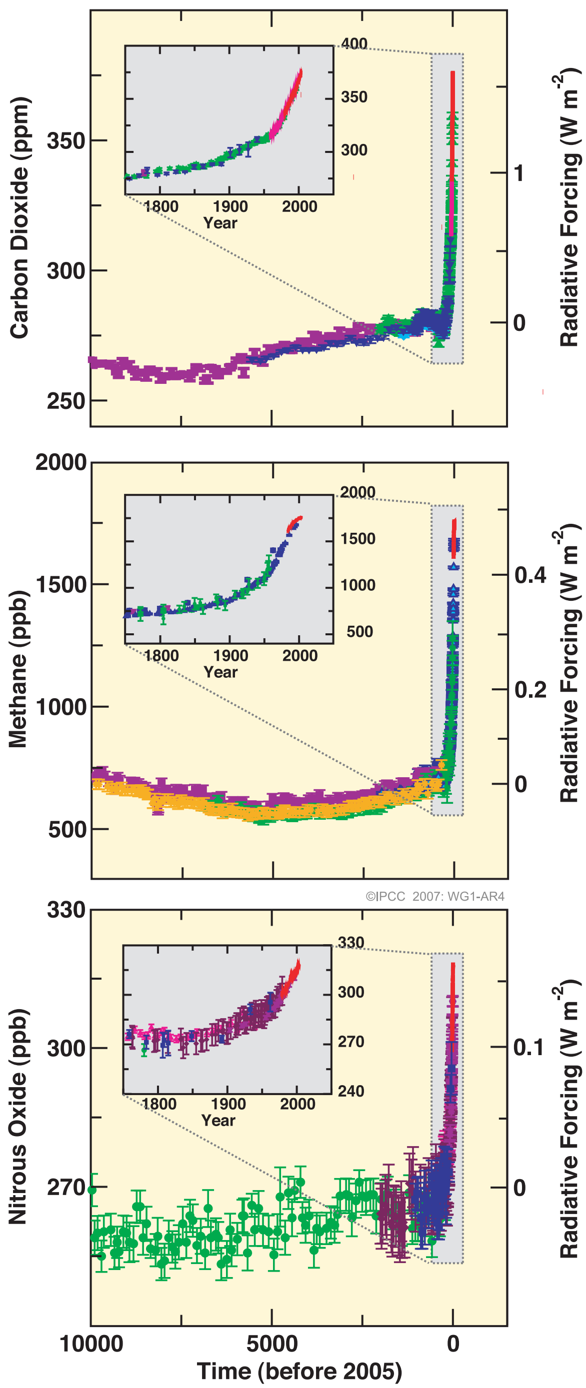

Figure SPM.1. *Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right hand axes of the large panels. {Figure 6.4}*

are estimated to be 1.6 [0.5 to 2.7] GtC (5.9 [1.8 to 9.9] $GtCO_2$) per year over the 1990s, although these estimates have a large uncertainty. {7.3}

- The global atmospheric concentration of methane has increased from a pre-industrial value of about 715 ppb to 1732 ppb in the early 1990s, and was 1774 ppb in 2005. The atmospheric concentration of methane in 2005 exceeds by far the natural range of the last 650,000 years (320 to 790 ppb) as determined from ice cores. Growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. It is *very likely*[6] that the observed increase in methane concentration is due to anthropogenic activities, predominantly agriculture and fossil fuel use, but relative contributions from different source types are not well determined. {2.3, 7.4}

- The global atmospheric nitrous oxide concentration increased from a pre-industrial value of about 270 ppb to 319 ppb in 2005. The growth rate has been approximately constant since 1980. More than a third of all nitrous oxide emissions are anthropogenic and are primarily due to agriculture. {2.3, 7.4}

The understanding of anthropogenic warming and cooling influences on climate has improved since the TAR, leading to *very high confidence*[7] that the global average net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m^{-2} (see Figure SPM.2). {2.3., 6.5, 2.9}

- The combined radiative forcing due to increases in carbon dioxide, methane, and nitrous oxide is +2.30 [+2.07 to +2.53] W m^{-2}, and its rate of increase during the industrial era is *very likely* to have been unprecedented in more than 10,000 years (see Figures

[6] In this Summary for Policymakers, the following terms have been used to indicate the assessed likelihood, using expert judgement, of an outcome or a result: *Virtually certain* > 99% probability of occurrence, *Extremely likely* > 95%, *Very likely* > 90%, *Likely* > 66%, *More likely than not* > 50%, *Unlikely* < 33%, *Very unlikely* < 10%, *Extremely unlikely* < 5% (see Box TS.1 for more details).

[7] In this Summary for Policymakers the following levels of confidence have been used to express expert judgements on the correctness of the underlying science: *very high confidence* represents at least a 9 out of 10 chance of being correct; *high confidence* represents about an 8 out of 10 chance of being correct (see Box TS.1)

SPM.1 and SPM.2). The carbon dioxide radiative forcing increased by 20% from 1995 to 2005, the largest change for any decade in at least the last 200 years. {2.3, 6.4}

- Anthropogenic contributions to aerosols (primarily sulphate, organic carbon, black carbon, nitrate and dust) together produce a cooling effect, with a total direct radiative forcing of –0.5 [–0.9 to –0.1] W m^{-2} and an indirect cloud albedo forcing of –0.7 [–1.8 to –0.3] W m^{-2}. These forcings are now better understood than at the time of the TAR due to improved *in situ*, satellite and ground-based measurements and more comprehensive modelling, but remain the dominant uncertainty in radiative forcing. Aerosols also influence cloud lifetime and precipitation. {2.4, 2.9, 7.5}

- Significant anthropogenic contributions to radiative forcing come from several other sources. Tropospheric ozone changes due to emissions of ozone-forming chemicals (nitrogen oxides, carbon monoxide, and hydrocarbons) contribute +0.35 [+0.25 to +0.65] W m^{-2}. The direct radiative forcing due to changes in halocarbons[8] is +0.34 [+0.31 to +0.37] W m^{-2}. Changes in surface albedo, due to land cover changes and deposition of black carbon aerosols on snow, exert

Radiative Forcing Components

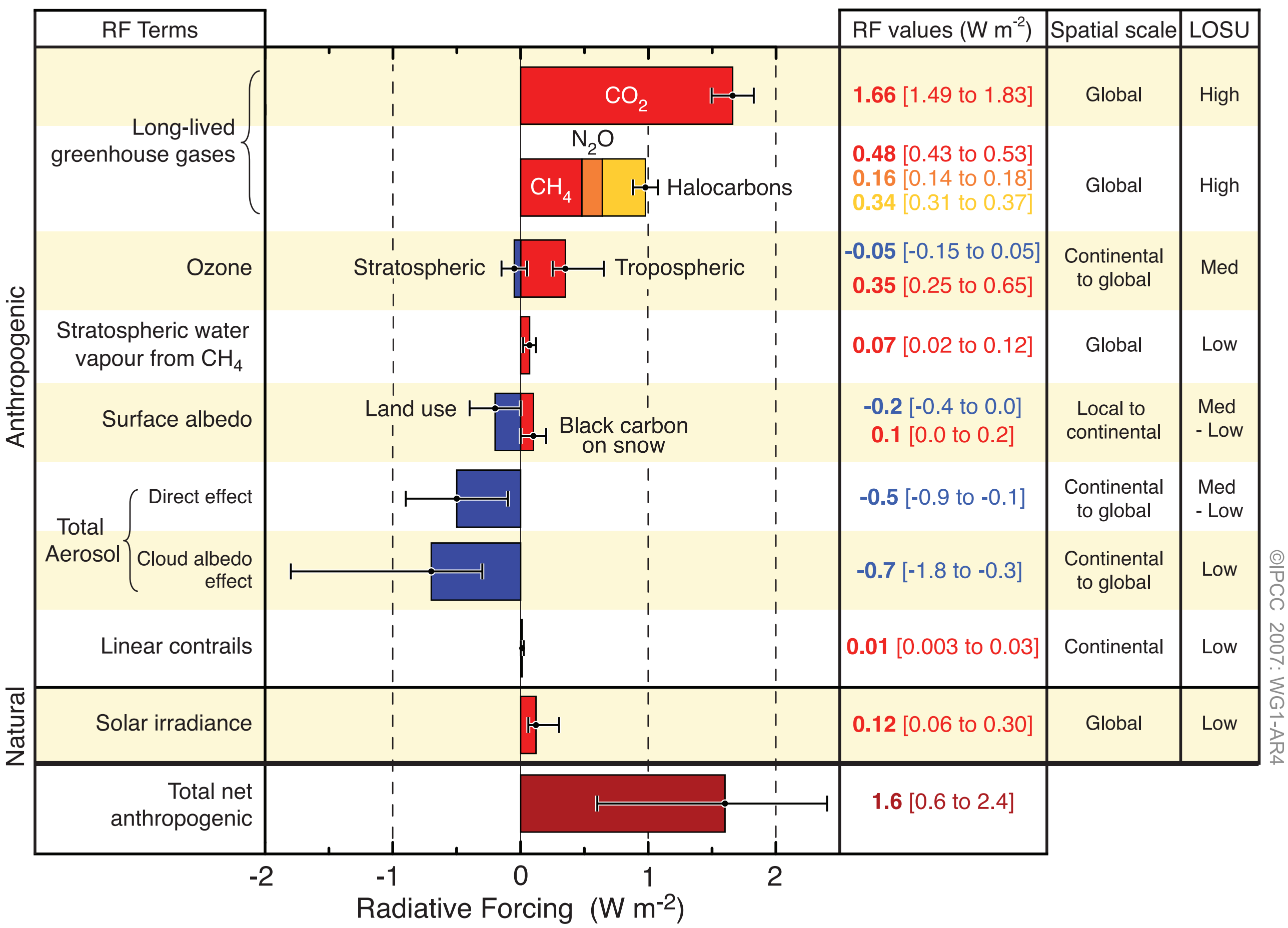

Figure SPM.2. *Global average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. The range for linear contrails does not include other possible effects of aviation on cloudiness. {2.9, Figure 2.20}*

[8] Halocarbon radiative forcing has been recently assessed in detail in *IPCC's Special Report on Safeguarding the Ozone Layer and the Global Climate System* (2005).

respective forcings of –0.2 [–0.4 to 0.0] and +0.1 [0.0 to +0.2] W m^{-2}. Additional terms smaller than ±0.1 W m^{-2} are shown in Figure SPM.2. {2.3, 2.5, 7.2}

- Changes in solar irradiance since 1750 are estimated to cause a radiative forcing of +0.12 [+0.06 to +0.30] W m^{-2}, which is less than half the estimate given in the TAR. {2.7}

Direct Observations of Recent Climate Change

Since the TAR, progress in understanding how climate is changing in space and in time has been gained through improvements and extensions of numerous datasets and data analyses, broader geographical coverage, better understanding of uncertainties, and a wider variety of measurements. Increasingly comprehensive observations are available for glaciers and snow cover since the 1960s, and for sea level and ice sheets since about the past decade. However, data coverage remains limited in some regions.

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (see Figure SPM.3). {3.2, 4.2, 5.5}

- Eleven of the last twelve years (1995–2006) rank among the 12 warmest years in the instrumental record of global surface temperature[9] (since 1850). The updated 100-year linear trend (1906 to 2005) of 0.74°C [0.56°C to 0.92°C] is therefore larger than the corresponding trend for 1901 to 2000 given in the TAR of 0.6°C [0.4°C to 0.8°C]. The linear warming trend over the last 50 years (0.13°C [0.10°C to 0.16°C] per decade) is nearly twice that for the last 100 years. The total temperature increase from 1850–1899 to 2001–2005 is 0.76°C [0.57°C to 0.95°C]. Urban heat island effects are real but local, and have a negligible influence (less than 0.006°C per decade over land and zero over the oceans) on these values. {3.2}

- New analyses of balloon-borne and satellite measurements of lower- and mid-tropospheric temperature show warming rates that are similar to those of the surface temperature record and are consistent within their respective uncertainties, largely reconciling a discrepancy noted in the TAR. {3.2, 3.4}

- The average atmospheric water vapour content has increased since at least the 1980s over land and ocean as well as in the upper troposphere. The increase is broadly consistent with the extra water vapour that warmer air can hold. {3.4}

- Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system. Such warming causes seawater to expand, contributing to sea level rise (see Table SPM.1). {5.2, 5.5}

- Mountain glaciers and snow cover have declined on average in both hemispheres. Widespread decreases in glaciers and ice caps have contributed to sea level rise (ice caps do not include contributions from the Greenland and Antarctic Ice Sheets). (See Table SPM.1.) {4.6, 4.7, 4.8, 5.5}

- New data since the TAR now show that losses from the ice sheets of Greenland and Antarctica have *very likely* contributed to sea level rise over 1993 to 2003 (see Table SPM.1). Flow speed has increased for some Greenland and Antarctic outlet glaciers, which drain ice from the interior of the ice sheets. The corresponding increased ice sheet mass loss has often followed thinning, reduction or loss of ice shelves or loss of floating glacier tongues. Such dynamical ice loss is sufficient to explain most of the Antarctic net mass loss and approximately half of the Greenland net mass loss. The remainder of the ice loss from Greenland has occurred because losses due to melting have exceeded accumulation due to snowfall. {4.6, 4.8, 5.5}

- Global average sea level rose at an average rate of 1.8 [1.3 to 2.3] mm per year over 1961 to 2003. The rate was faster over 1993 to 2003: about 3.1 [2.4 to 3.8] mm per year. Whether the faster rate for 1993 to 2003 reflects decadal variability or an increase in the longer-term trend is unclear. There is *high confidence* that

[9] The average of near-surface air temperature over land and sea surface temperature.

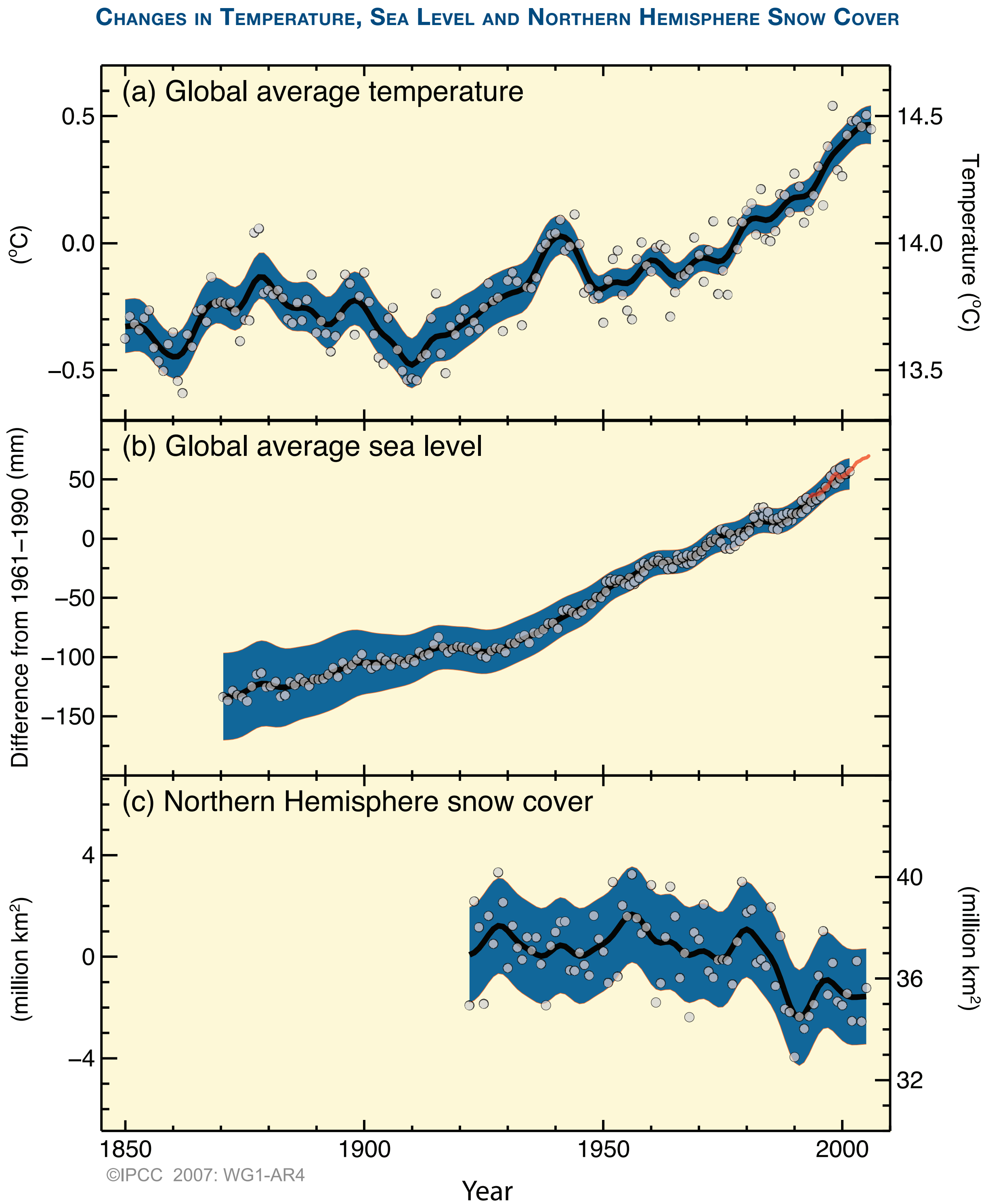

Figure SPM.3. *Observed changes in (a) global average surface temperature, (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All changes are relative to corresponding averages for the period 1961–1990. Smoothed curves represent decadal average values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c). {FAQ 3.1, Figure 1, Figure 4.2, Figure 5.13}* the rate of observed sea level rise increased from the 19th to the 20th century. The total 20th-century rise is estimated to be 0.17 [0.12 to 0.22] m. {5.5}

- For 1993 to 2003, the sum of the climate contributions is consistent within uncertainties with the total sea level rise that is directly observed (see Table SPM.1). These estimates are based on improved satellite and *in situ* data now available. For the period 1961 to 2003, the sum of climate contributions is estimated to be smaller than the observed sea level rise. The TAR reported a similar discrepancy for 1910 to 1990. {5.5}

At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones.[10] {3.2, 3.3, 3.4, 3.5, 3.6, 5.2}

- Average arctic temperatures increased at almost twice the global average rate in the past 100 years. Arctic temperatures have high decadal variability, and a warm period was also observed from 1925 to 1945. {3.2}

- Satellite data since 1978 show that annual average arctic sea ice extent has shrunk by 2.7 [2.1 to 3.3]% per decade, with larger decreases in summer of 7.4 [5.0 to 9.8]% per decade. These values are consistent with those reported in the TAR. {4.4}

- Temperatures at the top of the permafrost layer have generally increased since the 1980s in the Arctic (by up to 3°C). The maximum area covered by seasonally frozen ground has decreased by about 7% in the Northern Hemisphere since 1900, with a decrease in spring of up to 15%. {4.7}

- Long-term trends from 1900 to 2005 have been observed in precipitation amount over many large regions.[11] Significantly increased precipitation has been observed in eastern parts of North and South America, northern Europe and northern and central Asia. Drying has been observed in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Precipitation is highly variable spatially and temporally, and data are limited in some regions. Long-term trends have not been observed for the other large regions assessed.[11] {3.3, 3.9}

- Changes in precipitation and evaporation over the oceans are suggested by freshening of mid- and high-latitude waters together with increased salinity in low-latitude waters. {5.2}

Table SPM.1. *Observed rate of sea level rise and estimated contributions from different sources. {5.5, Table 5.3}*

Source of sea level rise	Rate of sea level rise (mm per year) 1961–2003	1993–2003
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22
Greenland Ice Sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic Ice Sheet	0.14 ± 0.41	0.21 ± 0.35
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	2.8 ± 0.7
Observed total sea level rise	1.8 ± 0.5[a]	3.1 ± 0.7[a]
Difference (Observed minus sum of estimated climate contributions)	0.7 ± 0.7	0.3 ± 1.0

Table note:
[a] Data prior to 1993 are from tide gauges and after 1993 are from satellite altimetry.

[10] Tropical cyclones include hurricanes and typhoons.

[11] The assessed regions are those considered in the regional projections chapter of the TAR and in Chapter 11 of this report.

- Mid-latitude westerly winds have strengthened in both hemispheres since the 1960s. {3.5}

- More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics. Increased drying linked with higher temperatures and decreased precipitation has contributed to changes in drought. Changes in sea surface temperatures, wind patterns and decreased snowpack and snow cover have also been linked to droughts. {3.3}

- The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapour. {3.8, 3.9}

- Widespread changes in extreme temperatures have been observed over the last 50 years. Cold days, cold nights and frost have become less frequent, while hot days, hot nights and heat waves have become more frequent (see Table SPM.2). {3.8}

Table SPM.2. *Recent trends, assessment of human influence on the trend and projections for extreme weather events for which there is an observed late-20th century trend. {Tables 3.7, 3.8, 9.4; Sections 3.8, 5.5, 9.7, 11.2–11.9}*

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend[b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]	*Virtually certain*[d]
Warm spells/heat waves. Frequency increases over most land areas	*Likely*	*More likely than not*[f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*[f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[f,h]	*Likely*[i]

Table notes:

[a] See Table 3.7 for further details regarding definitions.
[b] See Table TS.4, Box TS.5 and Table 9.4.
[c] Decreased frequency of cold days and nights (coldest 10%).
[d] Warming of the most extreme days and nights each year.
[e] Increased frequency of hot days and nights (hottest 10%).
[f] Magnitude of anthropogenic contributions not assessed. Attribution for these phenomena based on expert judgement rather than formal attribution studies.
[g] Extreme high sea level depends on average sea level and on regional weather systems. It is defined here as the highest 1% of hourly values of observed sea level at a station for a given reference period.
[h] Changes in observed extreme high sea level closely follow the changes in average sea level. {5.5} It is *very likely* that anthropogenic activity contributed to a rise in average sea level. {9.5}
[i] In all scenarios, the projected global average sea level at 2100 is higher than in the reference period. {10.6} The effect of changes in regional weather systems on sea level extremes has not been assessed.

- There is observational evidence for an increase in intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures. There are also suggestions of increased intense tropical cyclone activity in some other regions where concerns over data quality are greater. Multi-decadal variability and the quality of the tropical cyclone records prior to routine satellite observations in about 1970 complicate the detection of long-term trends in tropical cyclone activity. There is no clear trend in the annual numbers of tropical cyclones. {3.8}

Some aspects of climate have not been observed to change. {3.2, 3.8, 4.4, 5.3}

- A decrease in diurnal temperature range (DTR) was reported in the TAR, but the data available then extended only from 1950 to 1993. Updated observations reveal that DTR has not changed from 1979 to 2004 as both day- and night-time temperature have risen at about the same rate. The trends are highly variable from one region to another. {3.2}

- Antarctic sea ice extent continues to show interannual variability and localised changes but no statistically significant average trends, consistent with the lack of warming reflected in atmospheric temperatures averaged across the region. {3.2, 4.4}

- There is insufficient evidence to determine whether trends exist in the meridional overturning circulation (MOC) of the global ocean or in small-scale phenomena such as tornadoes, hail, lightning and dust-storms. {3.8, 5.3}

A Palaeoclimatic Perspective

Palaeoclimatic studies use changes in climatically sensitive indicators to infer past changes in global climate on time scales ranging from decades to millions of years. Such proxy data (e.g., tree ring width) may be influenced by both local temperature and other factors such as precipitation, and are often representative of particular seasons rather than full years. Studies since the TAR draw increased confidence from additional data showing coherent behaviour across multiple indicators in different parts of the world. However, uncertainties generally increase with time into the past due to increasingly limited spatial coverage.

Palaeoclimatic information supports the interpretation that the warmth of the last half century is unusual in at least the previous 1,300 years. The last time the polar regions were significantly warmer than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 m of sea level rise. {6.4, 6.6}

- Average Northern Hemisphere temperatures during the second half of the 20th century were *very likely* higher than during any other 50-year period in the last 500 years and *likely* the highest in at least the past 1,300 years. Some recent studies indicate greater variability in Northern Hemisphere temperatures than suggested in the TAR, particularly finding that cooler periods existed in the 12th to 14th, 17th and 19th centuries. Warmer periods prior to the 20th century are within the uncertainty range given in the TAR. {6.6}

- Global average sea level in the last interglacial period (about 125,000 years ago) was *likely* 4 to 6 m higher than during the 20th century, mainly due to the retreat of polar ice. Ice core data indicate that average polar temperatures at that time were 3°C to 5°C higher than present, because of differences in the Earth's orbit. The Greenland Ice Sheet and other arctic ice fields *likely* contributed no more than 4 m of the observed sea level rise. There may also have been a contribution from Antarctica. {6.4}

Understanding and Attributing Climate Change

This assessment considers longer and improved records, an expanded range of observations and improvements in the simulation of many aspects of climate and its variability based on studies since the TAR. It also considers the results of new attribution studies that have evaluated whether observed changes are quantitatively consistent with the expected response to external forcings and inconsistent with alternative physically plausible explanations.

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.[12] This is an advance since the TAR's conclusion that "most of the observed warming over the last 50 years is *likely* to have been due to the increase in greenhouse gas concentrations". Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns (see Figure SPM.4 and Table SPM.2). {9.4, 9.5}

- It is *likely* that increases in greenhouse gas concentrations alone would have caused more warming than observed because volcanic and anthropogenic aerosols have offset some warming that would otherwise have taken place. {2.9, 7.5, 9.4}

- The observed widespread warming of the atmosphere and ocean, together with ice mass loss, support the conclusion that it is *extremely unlikely* that global climate change of the past 50 years can be explained without external forcing, and *very likely* that it is not due to known natural causes alone. {4.8, 5.2, 9.4, 9.5, 9.7}

- Warming of the climate system has been detected in changes of surface and atmospheric temperatures in the upper several hundred metres of the ocean, and in contributions to sea level rise. Attribution studies have established anthropogenic contributions to all of these changes. The observed pattern of tropospheric warming and stratospheric cooling is *very likely* due to the combined influences of greenhouse gas increases and stratospheric ozone depletion. {3.2, 3.4, 9.4, 9.5}

- It is *likely* that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica (see Figure SPM.4). The observed patterns of warming, including greater warming over land than over the ocean, and their changes over time, are only simulated by models that include anthropogenic forcing. The ability of coupled climate models to simulate the observed temperature evolution on each of six continents provides stronger evidence of human influence on climate than was available in the TAR. {3.2, 9.4}

- Difficulties remain in reliably simulating and attributing observed temperature changes at smaller scales. On these scales, natural climate variability is relatively larger, making it harder to distinguish changes expected due to external forcings. Uncertainties in local forcings and feedbacks also make it difficult to estimate the contribution of greenhouse gas increases to observed small-scale temperature changes. {8.3, 9.4}

- Anthropogenic forcing is *likely* to have contributed to changes in wind patterns,[13] affecting extra-tropical storm tracks and temperature patterns in both hemispheres. However, the observed changes in the Northern Hemisphere circulation are larger than simulated in response to 20th-century forcing change. {3.5, 3.6, 9.5, 10.3}

- Temperatures of the most extreme hot nights, cold nights and cold days are *likely* to have increased due to anthropogenic forcing. It is *more likely than not* that anthropogenic forcing has increased the risk of heat waves (see Table SPM.2). {9.4}

[12] Consideration of remaining uncertainty is based on current methodologies.

[13] In particular, the Southern and Northern Annular Modes and related changes in the North Atlantic Oscillation. {3.6, 9.5, Box TS.2}

Global and Continental Temperature Change

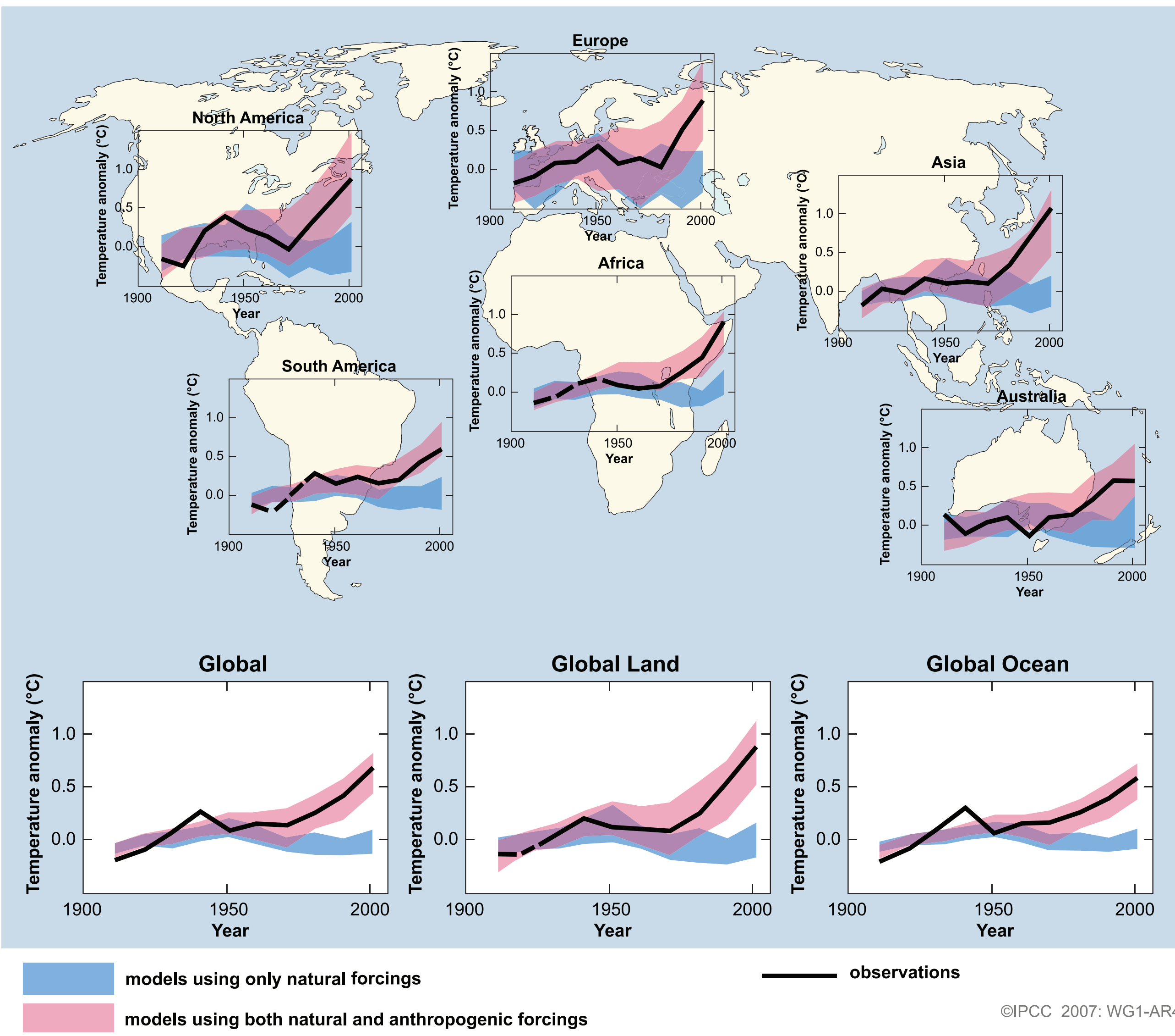

Figure SPM.4. *Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from five climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. {FAQ 9.2, Figure 1}*

Analysis of climate models together with constraints from observations enables an assessed *likely* range to be given for climate sensitivity for the first time and provides increased confidence in the understanding of the climate system response to radiative forcing. {6.6, 8.6, 9.6, Box 10.2}

- The equilibrium climate sensitivity is a measure of the climate system response to sustained radiative forcing. It is not a projection but is defined as the global average surface warming following a doubling of carbon dioxide concentrations. It is *likely* to be in the range 2°C to 4.5°C with a best estimate of about 3°C, and is *very unlikely* to be less than 1.5°C. Values substantially higher than 4.5°C cannot be excluded, but agreement of models with observations is not as good for those values. Water vapour changes represent the largest feedback affecting climate sensitivity and are now better understood than in the TAR. Cloud feedbacks remain the largest source of uncertainty. {8.6, 9.6, Box 10.2}

- It is *very unlikely* that climate changes of at least the seven centuries prior to 1950 were due to variability generated within the climate system alone. A significant fraction of the reconstructed Northern Hemisphere inter-decadal temperature variability over those centuries is *very likely* attributable to volcanic eruptions and changes in solar irradiance, and it is *likely* that anthropogenic forcing contributed to the early 20th-century warming evident in these records. {2.7, 2.8, 6.6, 9.3}

Projections of Future Changes in Climate

A major advance of this assessment of climate change projections compared with the TAR is the large number of simulations available from a broader range of models. Taken together with additional information from observations, these provide a quantitative basis for estimating likelihoods for many aspects of future climate change. Model simulations cover a range of possible futures including idealised emission or concentration assumptions. These include SRES[14] illustrative marker scenarios for the 2000 to 2100 period and model experiments with greenhouse gases and aerosol concentrations held constant after year 2000 or 2100.

For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. {10.3, 10.7}

- Since IPCC's first report in 1990, assessed projections have suggested global average temperature increases between about 0.15°C and 0.3°C per decade for 1990 to 2005. This can now be compared with observed values of about 0.2°C per decade, strengthening confidence in near-term projections. {1.2, 3.2}

- Model experiments show that even if all radiative forcing agents were held constant at year 2000 levels, a further warming trend would occur in the next two decades at a rate of about 0.1°C per decade, due mainly to the slow response of the oceans. About twice as much warming (0.2°C per decade) would be expected if emissions are within the range of the SRES scenarios. Best-estimate projections from models indicate that decadal average warming over each inhabited continent by 2030 is insensitive to the choice among SRES scenarios and is *very likely* to be at least twice as large as the corresponding model-estimated natural variability during the 20th century. {9.4, 10.3, 10.5, 11.2–11.7, Figure TS-29}

[14] SRES refers to the *IPCC Special Report on Emission Scenarios* (2000). The SRES scenario families and illustrative cases, which did not include additional climate initiatives, are summarised in a box at the end of this Summary for Policymakers. Approximate carbon dioxide equivalent concentrations corresponding to the computed radiative forcing due to anthropogenic greenhouse gases and aerosols in 2100 (see p. 823 of the TAR) for the SRES B1, A1T, B2, A1B, A2 and A1FI illustrative marker scenarios are about 600, 700, 800, 850, 1250 and 1,550 ppm respectively. Scenarios B1, A1B and A2 have been the focus of model intercomparison studies and many of those results are assessed in this report.

Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century. {10.3}

- Advances in climate change modelling now enable best estimates and *likely* assessed uncertainty ranges to be given for projected warming for different emission scenarios. Results for different emission scenarios are provided explicitly in this report to avoid loss of this policy-relevant information. Projected global average surface warmings for the end of the 21st century (2090–2099) relative to 1980–1999 are shown in Table SPM.3. These illustrate the differences between lower and higher SRES emission scenarios, and the projected warming uncertainty associated with these scenarios. {10.5}

- Best estimates and *likely* ranges for global average surface air warming for six SRES emissions marker scenarios are given in this assessment and are shown in Table SPM.3. For example, the best estimate for the low scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and the best estimate for the high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C). Although these projections are broadly consistent with the span quoted in the TAR (1.4°C to 5.8°C), they are not directly comparable (see Figure SPM.5). The Fourth Assessment Report is more advanced as it provides best estimates and an assessed likelihood range for each of the marker scenarios. The new assessment of the *likely* ranges now relies on a larger number of climate models of increasing complexity and realism, as well as new information regarding the nature of feedbacks from the carbon cycle and constraints on climate response from observations. {10.5}

- Warming tends to reduce land and ocean uptake of atmospheric carbon dioxide, increasing the fraction of anthropogenic emissions that remains in the atmosphere. For the A2 scenario, for example, the climate-carbon cycle feedback increases the corresponding global average warming at 2100 by more than 1°C. Assessed upper ranges for temperature projections are larger than in the TAR (see Table SPM.3) mainly because the broader range of models now available suggests stronger climate-carbon cycle feedbacks. {7.3, 10.5}

- Model-based projections of global average sea level rise at the end of the 21st century (2090–2099) are shown in Table SPM.3. For each scenario, the midpoint of the range in Table SPM.3 is within 10% of the

Table SPM.3. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
Case	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Table notes:
[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth System Models of Intermediate Complexity and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs).
[b] Year 2000 constant composition is derived from AOGCMs only.

Multi-Model Averages and Assessed Ranges for Surface Warming

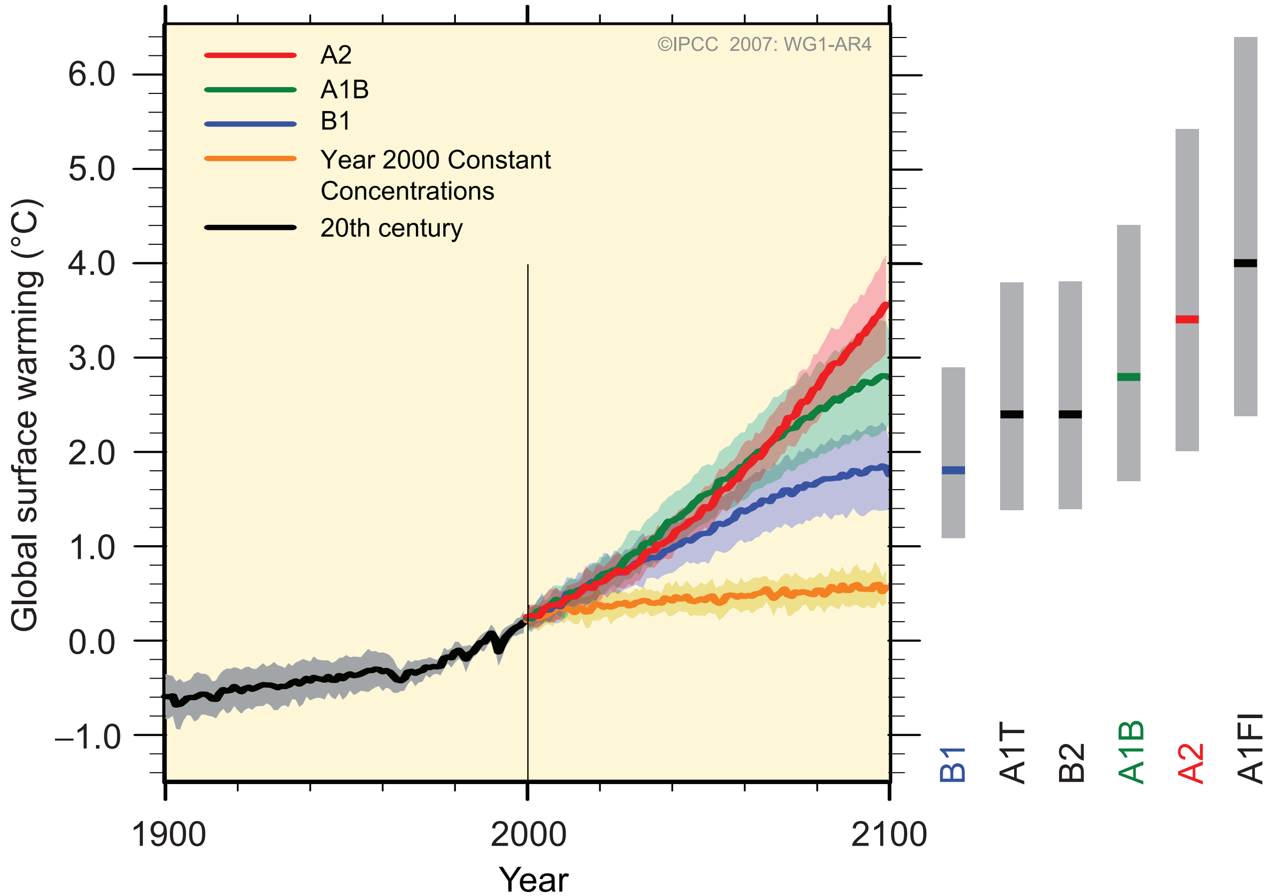

Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* ***likely*** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* ***likely*** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

TAR model average for 2090–2099. The ranges are narrower than in the TAR mainly because of improved information about some uncertainties in the projected contributions.[15] {10.6}

- Models used to date do not include uncertainties in climate-carbon cycle feedback nor do they include the full effects of changes in ice sheet flow, because a basis in published literature is lacking. The projections include a contribution due to increased ice flow from Greenland and Antarctica at the rates observed for 1993 to 2003, but these flow rates could increase or decrease in the future. For example, if this contribution were to grow linearly with global average temperature change, the upper ranges of sea level rise for SRES scenarios shown in Table SPM.3 would increase by 0.1 to 0.2 m. Larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise. {10.6}

- Increasing atmospheric carbon dioxide concentrations lead to increasing acidification of the ocean. Projections based on SRES scenarios give reductions in average global surface ocean pH[16] of between 0.14 and 0.35 units over the 21st century, adding to the present decrease of 0.1 units since pre-industrial times. {5.4, Box 7.3, 10.4}

[15] TAR projections were made for 2100, whereas projections in this report are for 2090–2099. The TAR would have had similar ranges to those in Table SPM.3 if it had treated the uncertainties in the same way.

[16] Decreases in pH correspond to increases in acidity of a solution. See Glossary for further details.

There is now higher confidence in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation and some aspects of extremes and of ice. {8.2, 8.3, 8.4, 8.5, 9.4, 9.5, 10.3, 11.1}

- Projected warming in the 21st century shows scenario-independent geographical patterns similar to those observed over the past several decades. Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean and parts of the North Atlantic Ocean (see Figure SPM.6). {10.3}

- Snow cover is projected to contract. Widespread increases in thaw depth are projected over most permafrost regions. {10.3, 10.6}

- Sea ice is projected to shrink in both the Arctic and Antarctic under all SRES scenarios. In some projections, arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century. {10.3}

- It is *very likely* that hot extremes, heat waves and heavy precipitation events will continue to become more frequent. {10.3}

- Based on a range of models, it is *likely* that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures. There is less confidence in projections of a global decrease in numbers of tropical cyclones. The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period. {9.5, 10.3, 3.8}

Projections of Surface Temperatures

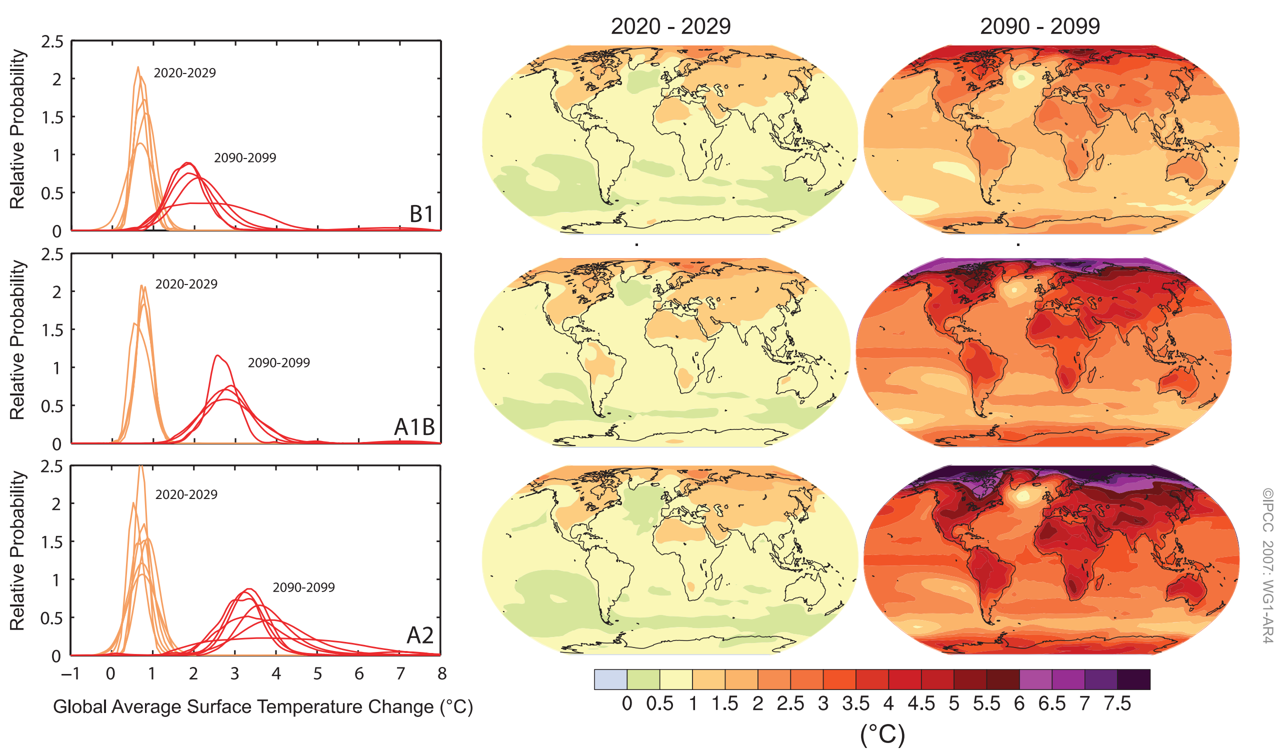

Figure SPM.6. *Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999. The central and right panels show the AOGCM multi-model average projections for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over the decades 2020–2029 (centre) and 2090–2099 (right). The left panels show corresponding uncertainties as the relative probabilities of estimated global average warming from several different AOGCM and Earth System Model of Intermediate Complexity studies for the same periods. Some studies present results only for a subset of the SRES scenarios, or for various model versions. Therefore the difference in the number of curves shown in the left-hand panels is due only to differences in the availability of results. {Figures 10.8 and 10.28}*

Projected Patterns of Precipitation Changes

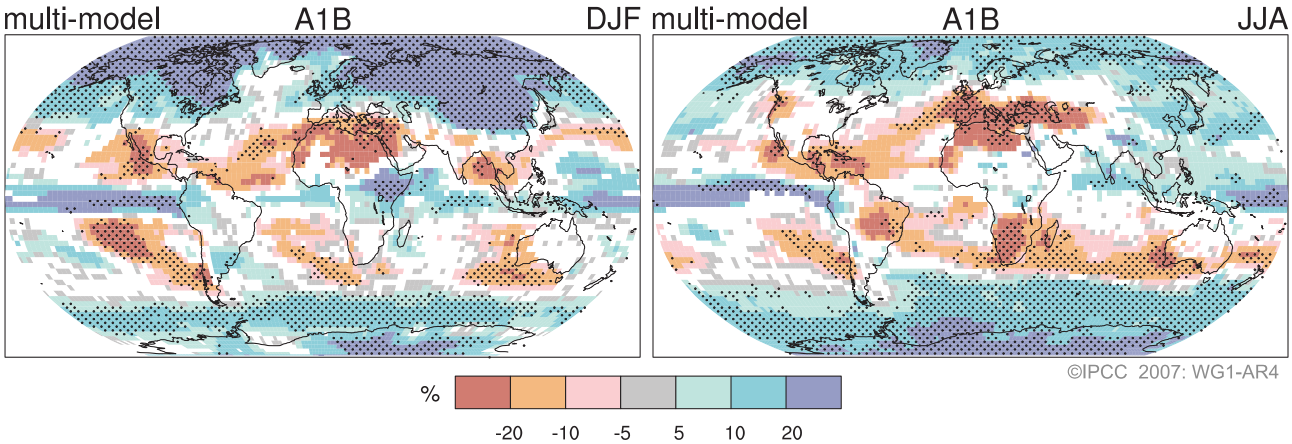

Figure SPM.7. *Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}*

- Extratropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation and temperature patterns, continuing the broad pattern of observed trends over the last half-century. {3.6, 10.3}

- Since the TAR, there is an improving understanding of projected patterns of precipitation. Increases in the amount of precipitation are *very likely* in high latitudes, while decreases are *likely* in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100, see Figure SPM.7), continuing observed patterns in recent trends. {3.3, 8.3, 9.5, 10.3, 11.2 to 11.9}

- Based on current model simulations, it is *very likely* that the meridional overturning circulation (MOC) of the Atlantic Ocean will slow down during the 21st century. The multi-model average reduction by 2100 is 25% (range from zero to about 50%) for SRES emission scenario A1B. Temperatures in the Atlantic region are projected to increase despite such changes due to the much larger warming associated with projected increases in greenhouse gases. It is *very unlikely* that the MOC will undergo a large abrupt transition during the 21st century. Longer-term changes in the MOC cannot be assessed with confidence. {10.3, 10.7}

Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilised. {10.4, 10.5, 10.7}

- Climate-carbon cycle coupling is expected to add carbon dioxide to the atmosphere as the climate system warms, but the magnitude of this feedback is uncertain. This increases the uncertainty in the trajectory of carbon dioxide emissions required to achieve a particular stabilisation level of atmospheric carbon dioxide concentration. Based on current understanding of climate-carbon cycle feedback, model studies suggest that to stabilise at 450 ppm carbon dioxide could require that cumulative emissions over the 21st century be reduced from an average of approximately 670 [630 to 710] GtC (2460 [2310 to 2600] $GtCO_2$) to approximately 490 [375 to 600] GtC (1800 [1370 to 2200] $GtCO_2$). Similarly, to stabilise at 1000 ppm, this feedback could require that cumulative emissions be reduced from a model average of approximately 1415 [1340 to 1490] GtC (5190 [4910 to 5460] $GtCO_2$) to approximately 1100 [980 to 1250] GtC (4030 [3590 to 4580] $GtCO_2$). {7.3, 10.4}

- If radiative forcing were to be stabilised in 2100 at B1 or A1B levels[14] a further increase in global average temperature of about 0.5°C would still be expected, mostly by 2200. {10.7}

- If radiative forcing were to be stabilised in 2100 at A1B levels[14], thermal expansion alone would lead to 0.3 to 0.8 m of sea level rise by 2300 (relative to 1980–1999). Thermal expansion would continue for many centuries, due to the time required to transport heat into the deep ocean. {10.7}

- Contraction of the Greenland Ice Sheet is projected to continue to contribute to sea level rise after 2100. Current models suggest that ice mass losses increase with temperature more rapidly than gains due to precipitation and that the surface mass balance becomes negative at a global average warming (relative to pre-industrial values) in excess of 1.9°C to 4.6°C. If a negative surface mass balance were sustained for millennia, that would lead to virtually complete elimination of the Greenland Ice Sheet and a resulting contribution to sea level rise of about 7 m. The corresponding future temperatures in Greenland are comparable to those inferred for the last interglacial period 125,000 years ago, when palaeoclimatic information suggests reductions of polar land ice extent and 4 to 6 m of sea level rise. {6.4, 10.7}

- Dynamical processes related to ice flow not included in current models but suggested by recent observations could increase the vulnerability of the ice sheets to warming, increasing future sea level rise. Understanding of these processes is limited and there is no consensus on their magnitude. {4.6, 10.7}

- Current global model studies project that the Antarctic Ice Sheet will remain too cold for widespread surface melting and is expected to gain in mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance. {10.7}

- Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the time scales required for removal of this gas from the atmosphere. {7.3, 10.3}

The Emission Scenarios of the IPCC Special Report on Emission Scenarios (SRES)[17]

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T) or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

[17] Emission scenarios are not assessed in this Working Group I Report of the IPCC. This box summarising the SRES scenarios is taken from the TAR and has been subject to prior line-by-line approval by the Panel.

Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change

Summary for Policymakers

This summary, approved in detail at the Eighth Session of IPCC Working Group II (Brussels, Belgium, 2-5 April 2007), represents the formally agreed statement of the IPCC concerning the sensitivity, adaptive capacity and vulnerability of natural and human systems to climate change, and the potential consequences of climate change.

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This Summary for Policymakers should be cited as:

IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

A. Introduction

This Summary sets out the key policy-relevant findings of the Fourth Assessment of Working Group II of the Intergovernmental Panel on Climate Change (IPCC).

The Assessment is of current scientific understanding of the impacts of climate change on natural, managed and human systems, the capacity of these systems to adapt and their vulnerability.[1] It builds upon past IPCC assessments and incorporates new knowledge gained since the Third Assessment.

Statements in this Summary are based on chapters in the Assessment and principal sources are given at the end of each paragraph.[2]

B. Current knowledge about observed impacts of climate change on the natural and human environment

A full consideration of observed climate change is provided in the Working Group I Fourth Assessment. This part of the Working Group II Summary concerns the relationship between observed climate change and recent observed changes in the natural and human environment.

The statements presented here are based largely on data sets that cover the period since 1970. The number of studies of observed trends in the physical and biological environment and their relationship to regional climate changes has increased greatly since the Third Assessment in 2001. The quality of the data sets has also improved. There is, however, a notable lack of geographical balance in the data and literature on observed changes, with marked scarcity in developing countries.

Recent studies have allowed a broader and more confident assessment of the relationship between observed warming and impacts than was made in the Third Assessment. That Assessment concluded that "there is high confidence[3] that recent regional changes in temperature have had discernible impacts on many physical and biological systems".

From the current Assessment we conclude the following.

Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.

With regard to changes in snow, ice and frozen ground (including permafrost),[4] there is high confidence that natural systems are affected. Examples are:
- enlargement and increased numbers of glacial lakes [1.3];
- increasing ground instability in permafrost regions, and rock avalanches in mountain regions [1.3];
- changes in some Arctic and Antarctic ecosystems, including those in sea-ice biomes, and also predators high in the food chain [1.3, 4.4, 15.4].

Based on growing evidence, there is high confidence that the following effects on hydrological systems are occurring:
- increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers [1.3];
- warming of lakes and rivers in many regions, with effects on thermal structure and water quality [1.3].

There is very high confidence, based on more evidence from a wider range of species, that recent warming is strongly affecting terrestrial biological systems, including such changes as:
- earlier timing of spring events, such as leaf-unfolding, bird migration and egg-laying [1.3];
- poleward and upward shifts in ranges in plant and animal species [1.3, 8.2, 14.2].

Based on satellite observations since the early 1980s, there is high confidence that there has been a trend in many regions towards earlier 'greening'[5] of vegetation in the spring linked to longer thermal growing seasons due to recent warming [1.3, 14.2].

There is high confidence, based on substantial new evidence, that observed changes in marine and freshwater biological systems are associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation [1.3]. These include:
- shifts in ranges and changes in algal, plankton and fish abundance in high-latitude oceans [1.3];
- increases in algal and zooplankton abundance in high-latitude and high-altitude lakes [1.3];
- range changes and earlier migrations of fish in rivers [1.3].

[1] For definitions, see Endbox 1.
[2] Sources to statements are given in square brackets. For example, [3.3] refers to Chapter 3, Section 3. In the sourcing, F = Figure, T = Table, B = Box and ES = Executive Summary.
[3] See Endbox 2.
[4] See Working Group I Fourth Assessment.
[5] Measured by the Normalised Difference Vegetation Index, which is a relative measure of the amount of green vegetation in an area based on satellite images.

The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic, with an average decrease in pH of 0.1 units [IPCC Working Group I Fourth Assessment]. However, the effects of observed ocean acidification on the marine biosphere are as yet undocumented [1.3].

A global assessment of data since 1970 has shown it is likely[6] that anthropogenic warming has had a discernible influence on many physical and biological systems.

Much more evidence has accumulated over the past five years to indicate that changes in many physical and biological systems are linked to anthropogenic warming. There are four sets of evidence which, taken together, support this conclusion:

1. The Working Group I Fourth Assessment concluded that most of the observed increase in the globally averaged temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

2. Of the more than 29,000 observational data series,[7] from 75 studies, that show significant change in many physical and biological systems, more than 89% are consistent with the direction of change expected as a response to warming (Figure SPM.1) [1.4].

3. A global synthesis of studies in this Assessment strongly demonstrates that the spatial agreement between regions of significant warming across the globe and the locations of significant observed changes in many systems consistent with warming is very unlikely to be due solely to natural variability of temperatures or natural variability of the systems (Figure SPM.1) [1.4].

4. Finally, there have been several modelling studies that have linked responses in some physical and biological systems to anthropogenic warming by comparing observed responses in these systems with modelled responses in which the natural forcings (solar activity and volcanoes) and anthropogenic forcings (greenhouse gases and aerosols) are explicitly separated. Models with combined natural and anthropogenic forcings simulate observed responses significantly better than models with natural forcing only [1.4].

Limitations and gaps prevent more complete attribution of the causes of observed system responses to anthropogenic warming. First, the available analyses are limited in the number of systems and locations considered. Second, natural temperature variability is larger at the regional than at the global scale, thus affecting identification of changes due to external forcing. Finally, at the regional scale other factors (such as land-use change, pollution, and invasive species) are influential [1.4].

Nevertheless, the consistency between observed and modelled changes in several studies and the spatial agreement between significant regional warming and consistent impacts at the global scale is sufficient to conclude with high confidence that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems [1.4].

Other effects of regional climate changes on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers.

Effects of temperature increases have been documented in the following (medium confidence):

- effects on agricultural and forestry management at Northern Hemisphere higher latitudes, such as earlier spring planting of crops, and alterations in disturbance regimes of forests due to fires and pests [1.3];
- some aspects of human health, such as heat-related mortality in Europe, infectious disease vectors in some areas, and allergenic pollen in Northern Hemisphere high and mid-latitudes [1.3, 8.2, 8.ES];
- some human activities in the Arctic (e.g., hunting and travel over snow and ice) and in lower-elevation alpine areas (such as mountain sports) [1.3].

Recent climate changes and climate variations are beginning to have effects on many other natural and human systems. However, based on the published literature, the impacts have not yet become established trends. Examples include:

- Settlements in mountain regions are at enhanced risk of glacier lake outburst floods caused by melting glaciers. Governmental institutions in some places have begun to respond by building dams and drainage works [1.3].

- In the Sahelian region of Africa, warmer and drier conditions have led to a reduced length of growing season with detrimental effects on crops. In southern Africa, longer dry seasons and more uncertain rainfall are prompting adaptation measures [1.3].

- Sea-level rise and human development are together contributing to losses of coastal wetlands and mangroves and increasing damage from coastal flooding in many areas [1.3].

[6] See Endbox 2.
[7] A subset of about 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: (1) ending in 1990 or later; (2) spanning a period of at least 20 years; and (3) showing a significant change in either direction, as assessed in individual studies.

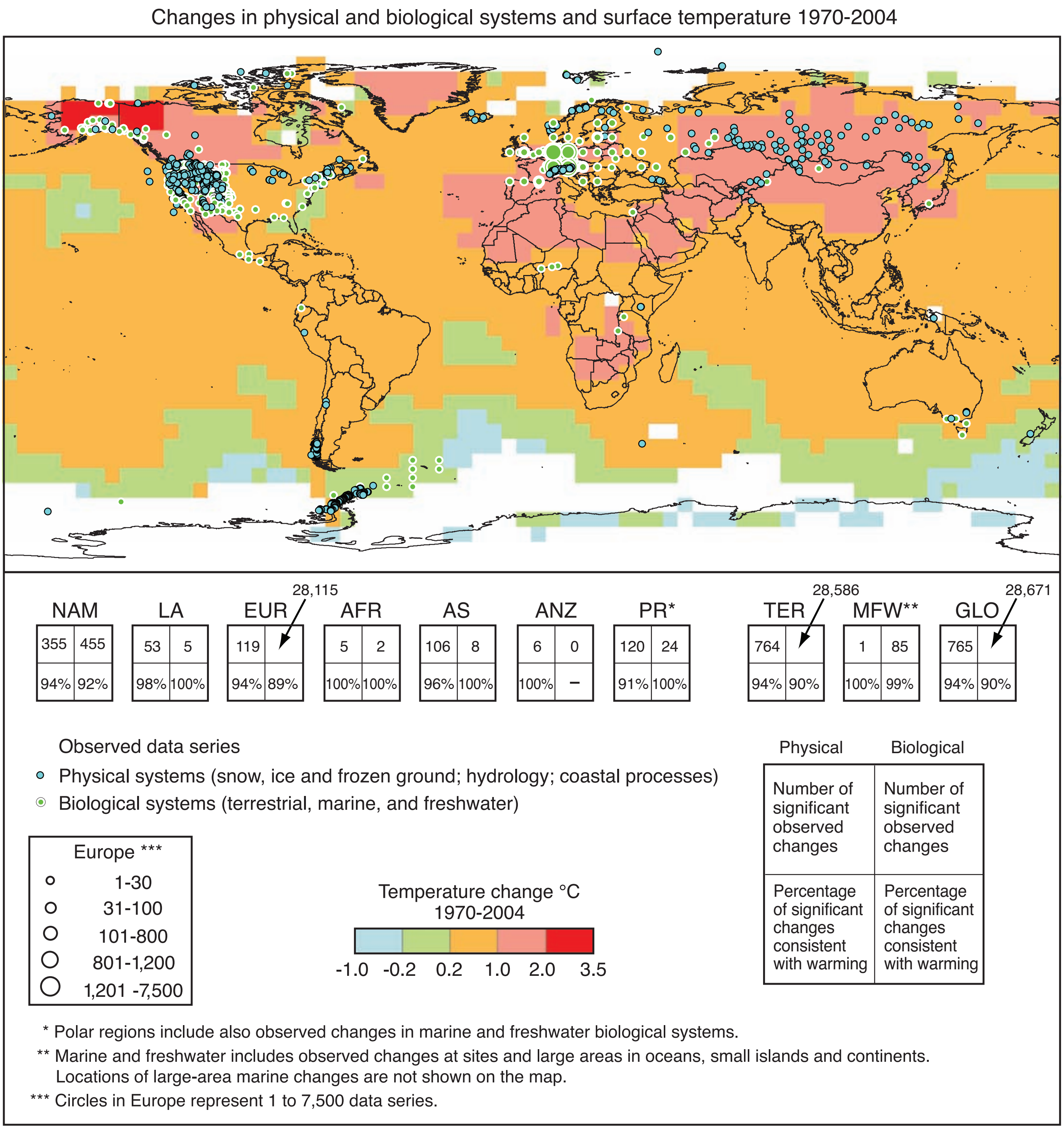


Figure SPM.1. *Locations of significant changes in data series of physical systems (snow, ice and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine, and freshwater biological systems), are shown together with surface air temperature changes over the period 1970-2004. A subset of about 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: (1) ending in 1990 or later; (2) spanning a period of at least 20 years; and (3) showing a significant change in either direction, as assessed in individual studies. These data series are from about 75 studies (of which about 70 are new since the Third Assessment) and contain about 29,000 data series, of which about 28,000 are from European studies. White areas do not contain sufficient observational climate data to estimate a temperature trend. The 2 x 2 boxes show the total number of data series with significant changes (top row) and the percentage of those consistent with warming (bottom row) for (i) continental regions: North America (NAM), Latin America (LA), Europe (EUR), Africa (AFR), Asia (AS), Australia and New Zealand (ANZ), and Polar Regions (PR) and (ii) global-scale: Terrestrial (TER), Marine and Freshwater (MFW), and Global (GLO). The numbers of studies from the seven regional boxes (NAM, …, PR) do not add up to the global (GLO) totals because numbers from regions except Polar do not include the numbers related to Marine and Freshwater (MFW) systems. Locations of large-area marine changes are not shown on the map. [Working Group II Fourth Assessment F1.8, F1.9; Working Group I Fourth Assessment F3.9b].*

C. Current knowledge about future impacts

The following is a selection of the key findings regarding projected impacts, as well as some findings on vulnerability and adaptation, in each system, sector and region for the range of (unmitigated) climate changes projected by the IPCC over this century[8] judged to be relevant for people and the environment.[9] The impacts frequently reflect projected changes in precipitation and other climate variables in addition to temperature, sea level and concentrations of atmospheric carbon dioxide. The magnitude and timing of impacts will vary with the amount and timing of climate change and, in some cases, the capacity to adapt. These issues are discussed further in later sections of the Summary.

More specific information is now available across a wide range of systems and sectors concerning the nature of future impacts, including for some fields not covered in previous assessments.

Freshwater resources and their management

By mid-century, annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water-stressed areas. In some places and in particular seasons, changes differ from these annual figures. ** D[10] [3.4]

Drought-affected areas will likely increase in extent. Heavy precipitation events, which are very likely to increase in frequency, will augment flood risk. ** N [Working Group I Fourth Assessment Table SPM-2, Working Group II Fourth Assessment 3.4]

In the course of the century, water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater from major mountain ranges, where more than one-sixth of the world population currently lives. ** N [3.4]

Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions that have recognised projected hydrological changes with related uncertainties. *** N [3.6]

Ecosystems

The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g., land-use change, pollution, over-exploitation of resources). ** N [4.1 to 4.6]

Over the course of this century, net carbon uptake by terrestrial ecosystems is likely to peak before mid-century and then weaken or even reverse,[11] thus amplifying climate change. ** N [4.ES, F4.2]

Approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C. * N [4.4, T4.1]

For increases in global average temperature exceeding 1.5-2.5°C and in concomitant atmospheric carbon dioxide concentrations, there are projected to be major changes in ecosystem structure and function, species' ecological interactions, and species' geographical ranges, with predominantly negative consequences for biodiversity, and ecosystem goods and services e.g., water and food supply. ** N [4.4]

The progressive acidification of oceans due to increasing atmospheric carbon dioxide is expected to have negative impacts on marine shell-forming organisms (e.g., corals) and their dependent species. * N [B4.4, 6.4]

Food, fibre and forest products

Crop productivity is projected to increase slightly at mid- to high latitudes for local mean temperature increases of up to 1-3°C depending on the crop, and then decrease beyond that in some regions. * D [5.4]

At lower latitudes, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C), which would increase the risk of hunger. * D [5.4]

Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1-3°C, but above this it is projected to decrease. * D [5.4, 5.6]

[8] Temperature changes are expressed as the difference from the period 1980-1999. To express the change relative to the period 1850-1899, add 0.5°C.
[9] Criteria of choice: magnitude and timing of impact, confidence in the assessment, representative coverage of the system, sector and region.
[10] In Section C, the following conventions are used:
Relationship to the Third Assessment:
D Further development of a conclusion in the Third Assessment
N New conclusion, not in the Third Assessment
Level of confidence in the whole statement:
**** Very high confidence*
*** High confidence*
** Medium confidence*
[11] Assuming continued greenhouse gas emissions at or above current rates and other global changes including land-use changes.

Increases in the frequency of droughts and floods are projected to affect local crop production negatively, especially in subsistence sectors at low latitudes. ** D [5.4, 5.ES]

Adaptations such as altered cultivars and planting times allow low- and mid- to high-latitude cereal yields to be maintained at or above baseline yields for modest warming. * N [5.5]

Globally, commercial timber productivity rises modestly with climate change in the short- to medium-term, with large regional variability around the global trend. * D [5.4]

Regional changes in the distribution and production of particular fish species are expected due to continued warming, with adverse effects projected for aquaculture and fisheries. ** D [5.4]

Coastal systems and low-lying areas

Coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea-level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas. *** D [6.3, 6.4]

Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1-3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals. *** D [B6.1, 6.4]

Coastal wetlands including salt marshes and mangroves are projected to be negatively affected by sea-level rise especially where they are constrained on their landward side, or starved of sediment. *** D [6.4]

Many millions more people are projected to be flooded every year due to sea-level rise by the 2080s. Those densely-populated and low-lying areas where adaptive capacity is relatively low, and which already face other challenges such as tropical storms or local coastal subsidence, are especially at risk. The numbers affected will be largest in the mega-deltas of Asia and Africa while small islands are especially vulnerable. *** D [6.4]

Adaptation for coasts will be more challenging in developing countries than in developed countries, due to constraints on adaptive capacity. ** D [6.4, 6.5, T6.11]

Industry, settlement and society

Costs and benefits of climate change for industry, settlement and society will vary widely by location and scale. In the aggregate, however, net effects will tend to be more negative the larger the change in climate. ** N [7.4, 7.6]

The most vulnerable industries, settlements and societies are generally those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources, and those in areas prone to extreme weather events, especially where rapid urbanisation is occurring. ** D [7.1, 7.3 to 7.5]

Poor communities can be especially vulnerable, in particular those concentrated in high-risk areas. They tend to have more limited adaptive capacities, and are more dependent on climate-sensitive resources such as local water and food supplies. ** N [7.2, 7.4, 5.4]

Where extreme weather events become more intense and/or more frequent, the economic and social costs of those events will increase, and these increases will be substantial in the areas most directly affected. Climate change impacts spread from directly impacted areas and sectors to other areas and sectors through extensive and complex linkages. ** N [7.4, 7.5]

Health

Projected climate change-related exposures are likely to affect the health status of millions of people, particularly those with low adaptive capacity, through:

- increases in malnutrition and consequent disorders, with implications for child growth and development;
- increased deaths, disease and injury due to heatwaves, floods, storms, fires and droughts;
- the increased burden of diarrhoeal disease;
- the increased frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone related to climate change; and,
- the altered spatial distribution of some infectious disease vectors. ** D [8.4, 8.ES, 8.2]

Climate change is expected to have some mixed effects, such as a decrease or increase in the range and transmission potential of malaria in Africa. ** D [8.4]

Studies in temperate areas[12] have shown that climate change is projected to bring some benefits, such as fewer deaths from cold exposure. Overall it is expected that these benefits will be outweighed by the negative health effects of rising temperatures worldwide, especially in developing countries. ** D [8.4]

The balance of positive and negative health impacts will vary from one location to another, and will alter over time as temperatures continue to rise. Critically important will be factors that directly shape the health of populations such as education, health care, public health initiatives and infrastructure and economic development. *** N [8.3]

[12] Studies mainly in industrialised countries.

More specific information is now available across the regions of the world concerning the nature of future impacts, including for some places not covered in previous assessments.

Africa

By 2020, between 75 million and 250 million people are projected to be exposed to increased water stress due to climate change. If coupled with increased demand, this will adversely affect livelihoods and exacerbate water-related problems. ** D [9.4, 3.4, 8.2, 8.4]

Agricultural production, including access to food, in many African countries and regions is projected to be severely compromised by climate variability and change. The area suitable for agriculture, the length of growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease. This would further adversely affect food security and exacerbate malnutrition in the continent. In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020. ** N [9.2, 9.4, 9.6]

Local food supplies are projected to be negatively affected by decreasing fisheries resources in large lakes due to rising water temperatures, which may be exacerbated by continued over-fishing. ** N [9.4, 5.4, 8.4]

Towards the end of the 21st century, projected sea-level rise will affect low-lying coastal areas with large populations. The cost of adaptation could amount to at least 5-10% of Gross Domestic Product (GDP). Mangroves and coral reefs are projected to be further degraded, with additional consequences for fisheries and tourism. ** D [9.4]

New studies confirm that Africa is one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capacity. Some adaptation to current climate variability is taking place; however, this may be insufficient for future changes in climate. ** N [9.5]

Asia

Glacier melt in the Himalayas is projected to increase flooding, and rock avalanches from destabilised slopes, and to affect water resources within the next two to three decades. This will be followed by decreased river flows as the glaciers recede. * N [10.2, 10.4]

Freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease due to climate change which, along with population growth and increasing demand arising from higher standards of living, could adversely affect more than a billion people by the 2050s. ** N [10.4]

Coastal areas, especially heavily-populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers. ** D [10.4]

Climate change is projected to impinge on the sustainable development of most developing countries of Asia, as it compounds the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation, and economic development. ** D [10.5]

It is projected that crop yields could increase up to 20% in East and South-East Asia while they could decrease up to 30% in Central and South Asia by the mid-21st century. Taken together, and considering the influence of rapid population growth and urbanisation, the risk of hunger is projected to remain very high in several developing countries. * N [10.4]

Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle associated with global warming. Increases in coastal water temperature would exacerbate the abundance and/or toxicity of cholera in South Asia. **N [10.4]

Australia and New Zealand

As a result of reduced precipitation and increased evaporation, water security problems are projected to intensify by 2030 in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions. ** D [11.4]

Significant loss of biodiversity is projected to occur by 2020 in some ecologically rich sites including the Great Barrier Reef and Queensland Wet Tropics. Other sites at risk include Kakadu wetlands, south-west Australia, sub-Antarctic islands and the alpine areas of both countries. *** D [11.4]

Ongoing coastal development and population growth in areas such as Cairns and South-east Queensland (Australia) and Northland to Bay of Plenty (New Zealand), are projected to exacerbate risks from sea-level rise and increases in the severity and frequency of storms and coastal flooding by 2050. *** D [11.4, 11.6]

Production from agriculture and forestry by 2030 is projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits are projected in western and southern areas and close to major rivers due to a longer growing season, less frost and increased rainfall. ** N [11.4]

The region has substantial adaptive capacity due to well-developed economies and scientific and technical capabilities, but there are considerable constraints to implementation and major challenges from changes in extreme events. Natural systems have limited adaptive capacity. ** N [11.2, 11.5]

Europe

For the first time, wide-ranging impacts of changes in current climate have been documented: retreating glaciers, longer growing seasons, shift of species ranges, and health impacts due to a heatwave of unprecedented magnitude. The observed changes described above are consistent with those projected for future climate change. *** N [12.2, 12.4, 12.6]

Nearly all European regions are anticipated to be negatively affected by some future impacts of climate change, and these will pose challenges to many economic sectors. Climate change is expected to magnify regional differences in Europe's natural resources and assets. Negative impacts will include increased risk of inland flash floods, and more frequent coastal flooding and increased erosion (due to storminess and sea-level rise). The great majority of organisms and ecosystems will have difficulty adapting to climate change. Mountainous areas will face glacier retreat, reduced snow cover and winter tourism, and extensive species losses (in some areas up to 60% under high emission scenarios by 2080). *** D [12.4]

In Southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity. It is also projected to increase health risks due to heat-waves, and the frequency of wildfires. ** D [12.2, 12.4, 12.7]

In Central and Eastern Europe, summer precipitation is projected to decrease, causing higher water stress. Health risks due to heatwaves are projected to increase. Forest productivity is expected to decline and the frequency of peatland fires to increase. ** D [12.4]

In Northern Europe, climate change is initially projected to bring mixed effects, including some benefits such as reduced demand for heating, increased crop yields and increased forest growth. However, as climate change continues, its negative impacts (including more frequent winter floods, endangered ecosystems and increasing ground instability) are likely to outweigh its benefits. ** D [12.4]

Adaptation to climate change is likely to benefit from experience gained in reaction to extreme climate events, specifically by implementing proactive climate change risk management adaptation plans. *** N [12.5]

Latin America

By mid-century, increases in temperature and associated decreases in soil water are projected to lead to gradual replacement of tropical forest by savanna in eastern Amazonia. Semi-arid vegetation will tend to be replaced by arid-land vegetation. There is a risk of significant biodiversity loss through species extinction in many areas of tropical Latin America. ** D [13.4]

In drier areas, climate change is expected to lead to salinisation and desertification of agricultural land. Productivity of some important crops is projected to decrease and livestock productivity to decline, with adverse consequences for food security. In temperate zones soybean yields are projected to increase. ** N [13.4, 13.7]

Sea-level rise is projected to cause increased risk of flooding in low-lying areas. Increases in sea surface temperature due to climate change are projected to have adverse effects on Mesoamerican coral reefs, and cause shifts in the location of south-east Pacific fish stocks. ** N [13.4, 13.7]

Changes in precipitation patterns and the disappearance of glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation. ** D [13.4]

Some countries have made efforts to adapt, particularly through conservation of key ecosystems, early warning systems, risk management in agriculture, strategies for flood drought and coastal management, and disease surveillance systems. However, the effectiveness of these efforts is outweighed by: lack of basic information, observation and monitoring systems; lack of capacity building and appropriate political, institutional and technological frameworks; low income; and settlements in vulnerable areas, among others. ** D [13.2]

North America

Warming in western mountains is projected to cause decreased snowpack, more winter flooding, and reduced summer flows, exacerbating competition for over-allocated water resources. *** D [14.4, B14.2]

Disturbances from pests, diseases and fire are projected to have increasing impacts on forests, with an extended period of high fire risk and large increases in area burned. *** N [14.4, B14.1]

Moderate climate change in the early decades of the century is projected to increase aggregate yields of rain-fed agriculture by 5-

20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilised water resources. ** D [14.4]

Cities that currently experience heatwaves are expected to be further challenged by an increased number, intensity and duration of heatwaves during the course of the century, with potential for adverse health impacts. Elderly populations are most at risk. *** D [14.4].

Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution. Population growth and the rising value of infrastructure in coastal areas increase vulnerability to climate variability and future climate change, with losses projected to increase if the intensity of tropical storms increases. Current adaptation is uneven and readiness for increased exposure is low. *** N [14.2, 14.4]

Polar Regions

In the Polar Regions, the main projected biophysical effects are reductions in thickness and extent of glaciers and ice sheets, and changes in natural ecosystems with detrimental effects on many organisms including migratory birds, mammals and higher predators. In the Arctic, additional impacts include reductions in the extent of sea ice and permafrost, increased coastal erosion, and an increase in the depth of permafrost seasonal thawing. ** D [15.3, 15.4, 15.2]

For human communities in the Arctic, impacts, particularly those resulting from changing snow and ice conditions, are projected to be mixed. Detrimental impacts would include those on infrastructure and traditional indigenous ways of life. ** D [15.4]

Beneficial impacts would include reduced heating costs and more navigable northern sea routes. * D [15.4]

In both polar regions, specific ecosystems and habitats are projected to be vulnerable, as climatic barriers to species invasions are lowered. ** D [15.6, 15.4]

Arctic human communities are already adapting to climate change, but both external and internal stressors challenge their adaptive capacities. Despite the resilience shown historically by Arctic indigenous communities, some traditional ways of life are being threatened and substantial investments are needed to adapt or re-locate physical structures and communities. ** D [15.ES, 15.4, 15.5, 15.7]

Small islands

Small islands, whether located in the tropics or higher latitudes, have characteristics which make them especially vulnerable to the effects of climate change, sea-level rise and extreme events. *** D [16.1, 16.5]

Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected to affect local resources, e.g., fisheries, and reduce the value of these destinations for tourism. ** D [16.4]

Sea-level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities. *** D [16.4]

Climate change is projected by mid-century to reduce water resources in many small islands, e.g., in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low-rainfall periods. *** D [16.4]

With higher temperatures, increased invasion by non-native species is expected to occur, particularly on mid- and high-latitude islands. ** N [16.4]

Magnitudes of impact can now be estimated more systematically for a range of possible increases in global average temperature.

Since the IPCC Third Assessment, many additional studies, particularly in regions that previously had been little researched, have enabled a more systematic understanding of how the timing and magnitude of impacts may be affected by changes in climate and sea level associated with differing amounts and rates of change in global average temperature.

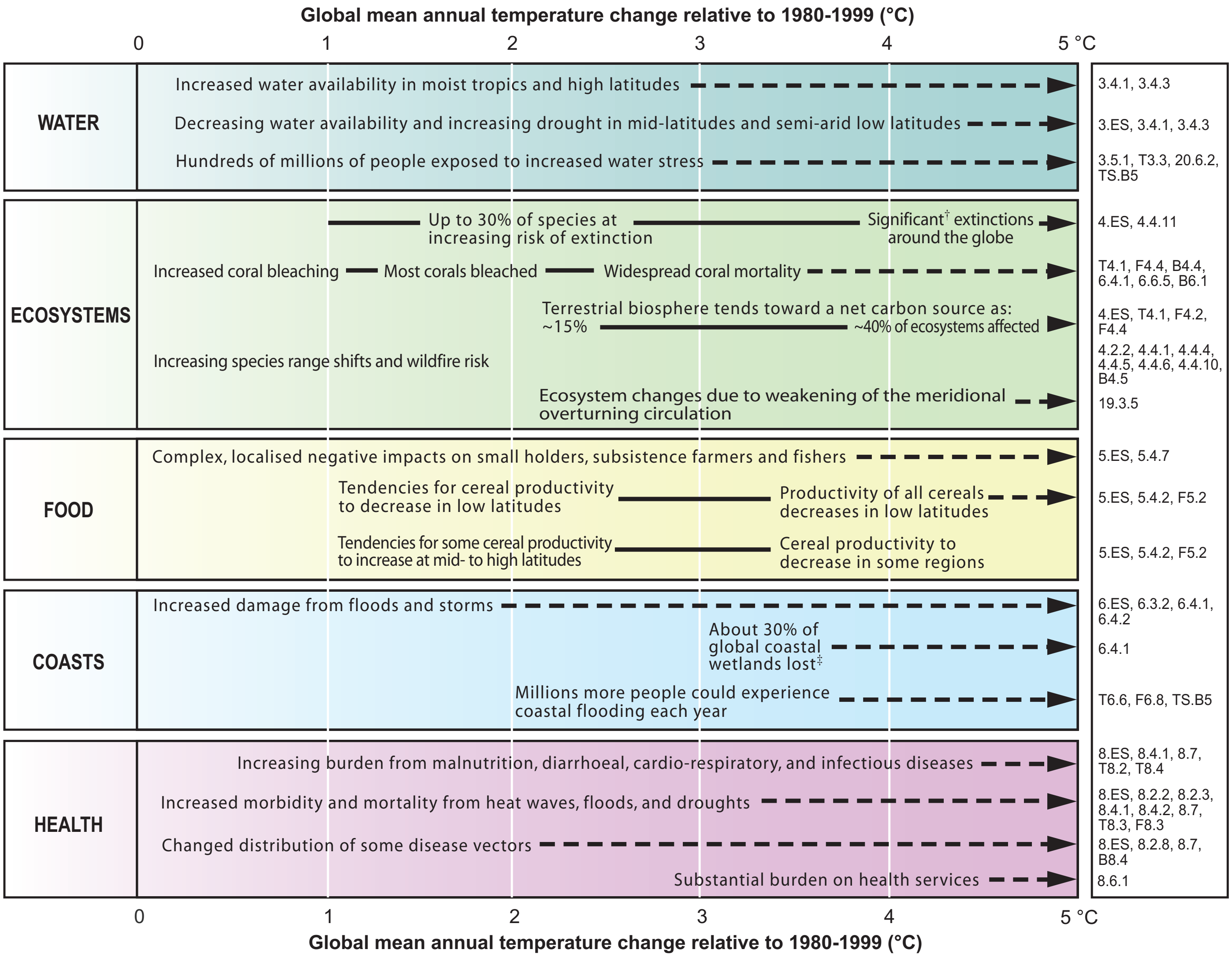
Examples of this new information are presented in Figure SPM.2. Entries have been selected which are judged to be relevant for people and the environment and for which there is high confidence in the assessment. All examples of impact are drawn from chapters of the Assessment, where more detailed information is available.

Depending on circumstances, some of these impacts could be associated with 'key vulnerabilities', based on a number of criteria in the literature (magnitude, timing, persistence/reversibility, the potential for adaptation, distributional aspects, likelihood and 'importance' of the impacts). Assessment of potential key vulnerabilities is intended to provide information on rates and levels of climate change to help decision-makers make appropriate responses to the risks of climate change [19.ES, 19.1].

The 'reasons for concern' identified in the Third Assessment remain a viable framework for considering key vulnerabilities. Recent research has updated some of the findings from the Third Assessment [19.3].

Key impacts as a function of increasing global average temperature change

(Impacts will vary by extent of adaptation, rate of temperature change, and socio-economic pathway)



† Significant is defined here as more than 40%.
‡ Based on average rate of sea level rise of 4.2 mm/year from 2000 to 2080.

Figure SPM.2. *Illustrative examples of global impacts projected for climate changes (and sea level and atmospheric carbon dioxide where relevant) associated with different amounts of increase in global average surface temperature in the 21st century [T20.8]. The black lines link impacts, dotted arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left-hand side of the text indicates the approximate onset of a given impact. Quantitative entries for water stress and flooding represent the additional impacts of climate change relative to the conditions projected across the range of Special Report on Emissions Scenarios (SRES) scenarios A1FI, A2, B1 and B2 (see Endbox 3). Adaptation to climate change is not included in these estimations. All entries are from published studies recorded in the chapters of the Assessment. Sources are given in the right-hand column of the Table. Confidence levels for all statements are high.*

Impacts due to altered frequencies and intensities of extreme weather, climate and sea-level events are very likely to change.

Since the IPCC Third Assessment, confidence has increased that some weather events and extremes will become more frequent, more widespread and/or more intense during the 21st century; and more is known about the potential effects of such changes. A selection of these is presented in Table SPM.1.

The direction of trend and likelihood of phenomena are for IPCC SRES projections of climate change.

Some large-scale climate events have the potential to cause very large impacts, especially after the 21st century.

Very large sea-level rises that would result from widespread deglaciation of Greenland and West Antarctic ice sheets imply major changes in coastlines and ecosystems, and inundation of low-lying areas, with greatest effects in river deltas. Relocating populations, economic activity, and infrastructure would be costly and challenging. There is medium confidence that at least partial deglaciation of the Greenland ice sheet, and possibly the West Antarctic ice sheet, would occur over a period of time ranging from centuries to millennia for a global average temperature increase of 1-4°C (relative to 1990-2000), causing a contribution to sea-level rise of 4-6 m or more. The complete melting of the Greenland ice sheet and the West Antarctic ice sheet would lead to a contribution to sea-level rise of up to 7 m and about 5 m, respectively [Working Group I Fourth Assessment 6.4, 10.7; Working Group II Fourth Assessment 19.3].

Based on climate model results, it is very unlikely that the Meridional Overturning Circulation (MOC) in the North Atlantic will undergo a large abrupt transition during the 21st century. Slowing of the MOC during this century is very likely, but temperatures over the Atlantic and Europe are projected to increase nevertheless, due to global warming. Impacts of large-scale and persistent changes in the MOC are likely to include changes to marine ecosystem productivity, fisheries, ocean carbon dioxide uptake, oceanic oxygen concentrations and terrestrial vegetation [Working Group I Fourth Assessment 10.3, 10.7; Working Group II Fourth Assessment 12.6, 19.3].

Impacts of climate change will vary regionally but, aggregated and discounted to the present, they are very likely to impose net annual costs which will increase over time as global temperatures increase.

This Assessment makes it clear that the impacts of future climate change will be mixed across regions. For increases in global mean temperature of less than 1-3°C above 1990 levels, some impacts are projected to produce benefits in some places and some sectors, and produce costs in other places and other sectors. It is, however, projected that some low-latitude and polar regions will experience net costs even for small increases in temperature. It is very likely that all regions will experience either declines in net benefits or increases in net costs for increases in temperature greater than about 2-3°C [9.ES, 9.5, 10.6, T10.9, 15.3, 15.ES]. These observations confirm evidence reported in the Third Assessment that, while developing countries are expected to experience larger percentage losses, global mean losses could be 1-5% GDP for 4°C of warming [F20.3].

Many estimates of aggregate net economic costs of damages from climate change across the globe (i.e., the social cost of carbon (SCC), expressed in terms of future net benefits and costs that are discounted to the present) are now available. Peer-reviewed estimates of the SCC for 2005 have an average value of US$43 per tonne of carbon (i.e., US$12 per tonne of carbon dioxide), but the range around this mean is large. For example, in a survey of 100 estimates, the values ran from US$-10 per tonne of carbon (US$-3 per tonne of carbon dioxide) up to US$350 per tonne of carbon (US$95 per tonne of carbon dioxide) [20.6].

The large ranges of SCC are due in the large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses, and discount rates. It is very likely that globally aggregated figures underestimate the damage costs because they cannot include many non-quantifiable impacts. Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time [T20.3, 20.6, F20.4].

It is virtually certain that aggregate estimates of costs mask significant differences in impacts across sectors, regions, countries and populations. In some locations and among some groups of people with high exposure, high sensitivity and/or low adaptive capacity, net costs will be significantly larger than the global aggregate [20.6, 20.ES, 7.4].

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems [4.4, 5.4]	Water resources [3.4]	Human health [8.2, 8.4]	Industry, settlement and society [7.4]
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	Virtually certain[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snow melt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	Very likely	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g., algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially-isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	Very likely	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	Likely	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortages for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	Likely	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, potential for population migrations, loss of property
Increased incidence of extreme high sea level (excludes tsunamis)[c]	Likely[d]	Salinisation of irrigation water, estuaries and freshwater systems	Decreased freshwater availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

[a] See Working Group I Fourth Assessment Table 3.7 for further details regarding definitions.
[b] Warming of the most extreme days and nights each year.
[c] Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
[d] In all scenarios, the projected global average sea level at 2100 is higher than in the reference period [Working Group I Fourth Assessment 10.6]. The effect of changes in regional weather systems on sea level extremes has not been assessed.

Table SPM.1. *Examples of possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid- to late 21st century. These do not take into account any changes or developments in adaptive capacity. Examples of all entries are to be found in chapters in the full Assessment (see source at top of columns). The first two columns of the table (shaded yellow) are taken directly from the Working Group I Fourth Assessment (Table SPM-2). The likelihood estimates in Column 2 relate to the phenomena listed in Column 1.*

D. Current knowledge about responding to climate change

Some adaptation is occurring now, to observed and projected future climate change, but on a limited basis.

There is growing evidence since the IPCC Third Assessment of human activity to adapt to observed and anticipated climate change. For example, climate change is considered in the design of infrastructure projects such as coastal defence in the Maldives and The Netherlands, and the Confederation Bridge in Canada. Other examples include prevention of glacial lake outburst flooding in Nepal, and policies and strategies such as water management in Australia and government responses to heat-waves in, for example, some European countries [7.6, 8.2, 8.6, 17.ES, 17.2, 16.5, 11.5].

Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions.

Past emissions are estimated to involve some unavoidable warming (about a further 0.6°C by the end of the century relative to 1980-1999) even if atmospheric greenhouse gas concentrations remain at 2000 levels (see Working Group I Fourth Assessment). There are some impacts for which adaptation is the only available and appropriate response. An indication of these impacts can be seen in Figure SPM.2.

A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to future climate change. There are barriers, limits and costs, but these are not fully understood.

Impacts are expected to increase with increases in global average temperature, as indicated in Figure SPM.2. Although many early impacts of climate change can be effectively addressed through adaptation, the options for successful adaptation diminish and the associated costs increase with increasing climate change. At present we do not have a clear picture of the limits to adaptation, or the cost, partly because effective adaptation measures are highly dependent on specific, geographical and climate risk factors as well as institutional, political and financial constraints [7.6, 17.2, 17.4].

The array of potential adaptive responses available to human societies is very large, ranging from purely technological (e.g., sea defences), through behavioural (e.g., altered food and recreational choices), to managerial (e.g., altered farm practices) and to policy (e.g., planning regulations). While most technologies and strategies are known and developed in some countries, the assessed literature does not indicate how effective various options[13] are at fully reducing risks, particularly at higher levels of warming and related impacts, and for vulnerable groups. In addition, there are formidable environmental, economic, informational, social, attitudinal and behavioural barriers to the implementation of adaptation. For developing countries, availability of resources and building adaptive capacity are particularly important [see Sections 5 and 6 in Chapters 3-16; also 17.2, 17.4].

Adaptation alone is not expected to cope with all the projected effects of climate change, and especially not over the long term as most impacts increase in magnitude [Figure SPM.2].

Vulnerability to climate change can be exacerbated by the presence of other stresses.

Non-climate stresses can increase vulnerability to climate change by reducing resilience and can also reduce adaptive capacity because of resource deployment to competing needs. For example, current stresses on some coral reefs include marine pollution and chemical runoff from agriculture as well as increases in water temperature and ocean acidification. Vulnerable regions face multiple stresses that affect their exposure and sensitivity as well as their capacity to adapt. These stresses arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict, and incidence of diseases such as HIV/AIDS [7.4, 8.3, 17.3, 20.3]. Adaptation measures are seldom undertaken in response to climate change alone but can be integrated within, for example, water resource management, coastal defence and risk-reduction strategies [17.2, 17.5].

Future vulnerability depends not only on climate change but also on development pathway.

An important advance since the IPCC Third Assessment has been the completion of impacts studies for a range of different development pathways taking into account not only projected climate change but also projected social and economic changes. Most have been based on characterisations of population and income level drawn from the IPCC Special Report on Emission Scenarios (SRES) (see Endbox 3) [2.4].

[13] A table of options is given in the Technical Summary

These studies show that the projected impacts of climate change can vary greatly due to the development pathway assumed. For example, there may be large differences in regional population, income and technological development under alternative scenarios, which are often a strong determinant of the level of vulnerability to climate change [2.4].

To illustrate, in a number of recent studies of global impacts of climate change on food supply, risk of coastal flooding and water scarcity, the projected number of people affected is considerably greater under the A2-type scenario of development (characterised by relatively low per capita income and large population growth) than under other SRES futures [T20.6]. This difference is largely explained, not by differences in changes of climate, but by differences in vulnerability [T6.6].

Sustainable development[14] can reduce vulnerability to climate change, and climate change could impede nations' abilities to achieve sustainable development pathways.

Sustainable development can reduce vulnerability to climate change by enhancing adaptive capacity and increasing resilience. At present, however, few plans for promoting sustainability have explicitly included either adapting to climate change impacts, or promoting adaptive capacity [20.3].

On the other hand, it is very likely that climate change can slow the pace of progress towards sustainable development, either directly through increased exposure to adverse impact or indirectly through erosion of the capacity to adapt. This point is clearly demonstrated in the sections of the sectoral and regional chapters of this report that discuss the implications for sustainable development [See Section 7 in Chapters 3-8, 20.3, 20.7].

The Millennium Development Goals (MDGs) are one measure of progress towards sustainable development. Over the next half-century, climate change could impede achievement of the MDGs [20.7].

Many impacts can be avoided, reduced or delayed by mitigation.

A small number of impact assessments have now been completed for scenarios in which future atmospheric concentrations of greenhouse gases are stabilised. Although these studies do not take full account of uncertainties in projected climate under stabilisation, they nevertheless provide indications of damages avoided or vulnerabilities and risks reduced for different amounts of emissions reduction [2.4, T20.6].

A portfolio of adaptation and mitigation measures can diminish the risks associated with climate change.

Even the most stringent mitigation efforts cannot avoid further impacts of climate change in the next few decades, which makes adaptation essential, particularly in addressing near-term impacts. Unmitigated climate change would, in the long term, be likely to exceed the capacity of natural, managed and human systems to adapt [20.7].

This suggests the value of a portfolio or mix of strategies that includes mitigation, adaptation, technological development (to enhance both adaptation and mitigation) and research (on climate science, impacts, adaptation and mitigation). Such portfolios could combine policies with incentive-based approaches, and actions at all levels from the individual citizen through to national governments and international organisations [18.1, 18.5].

One way of increasing adaptive capacity is by introducing the consideration of climate change impacts in development planning [18.7], for example, by:
- including adaptation measures in land-use planning and infrastructure design [17.2];
- including measures to reduce vulnerability in existing disaster risk reduction strategies [17.2, 20.8].

E. Systematic observing and research

Although the science to provide policymakers with information about climate change impacts and adaptation potential has improved since the Third Assessment, it still leaves many important questions to be answered. The chapters of the Working Group II Fourth Assessment include a number of judgements about priorities for further observation and research, and this advice should be considered seriously (a list of these recommendations is given in the Technical Summary Section TS-6).

[14] The Brundtland Commission definition of sustainable development is used in this Assessment: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The same definition was used by the IPCC Working Group II Third Assessment and Third Assessment Synthesis Report.

Endbox 1. Definitions of key terms

Climate change in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the Framework Convention on Climate Change, where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Endbox 2. Communication of Uncertainty in the Working Group II Fourth Assessment

A set of terms to describe uncertainties in current knowledge is common to all parts of the IPCC Fourth Assessment.

Description of confidence
Authors have assigned a confidence level to the major statements in the Summary for Policymakers on the basis of their assessment of current knowledge, as follows:

Terminology	*Degree of confidence in being correct*
Very high confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than a 1 out of 10 chance

Description of likelihood
Likelihood refers to a probabilistic assessment of some well-defined outcome having occurred or occurring in the future, and may be based on quantitative analysis or an elicitation of expert views. In the Summary for Policymakers, when authors evaluate the likelihood of certain outcomes, the associated meanings are:

Terminology	*Likelihood of the occurrence/ outcome*
Virtually certain	>99% probability of occurrence
Very likely	90 to 99% probability
Likely	66 to 90% probability
About as likely as not	33 to 66% probability
Unlikely	10 to 33% probability
Very unlikely	1 to 10% probability
Exceptionally unlikely	<1% probability

Endbox 3. The Emissions Scenarios of the IPCC Special Report on Emissions Scenarios (SRES)

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change

Summary for Policymakers

This Summary for Policymakers was formally approved at the 9th Session of Working Group III of the IPCC, Bangkok, Thailand. 30 April - 4 May 2007

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This Summary for Policymakers should be cited as:

IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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A. Introduction

1. The Working Group III contribution to the IPCC Fourth Assessment Report (AR4) focuses on new literature on the scientific, technological, environmental, economic and social aspects of mitigation of climate change, published since the IPCC Third Assessment Report (TAR) and the Special Reports on CO_2 Capture and Storage (SRCCS) and on Safeguarding the Ozone Layer and the Global Climate System (SROC).

   The following summary is organised into six sections after this introduction:
   - Greenhouse gas (GHG) emission trends
   - Mitigation in the short and medium term, across different economic sectors (until 2030)
   - Mitigation in the long-term (beyond 2030)
   - Policies, measures and instruments to mitigate climate change
   - Sustainable development and climate change mitigation
   - Gaps in knowledge.

   References to the corresponding chapter sections are indicated at each paragraph in square brackets. An explanation of terms, acronyms and chemical symbols used in this SPM can be found in the glossary to the main report.

B. Greenhouse gas emission trends

2. **Global greenhouse gas (GHG) emissions have grown since pre-industrial times, with an increase of 70% between 1970 and 2004** *(high agreement, much evidence)*[1].
   - Since pre-industrial times, increasing emissions of GHGs due to human activities have led to a marked increase in atmospheric GHG concentrations [1.3; Working Group I SPM].
   - Between 1970 and 2004, global emissions of CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, weighted by their global warming potential (GWP), have increased by 70% (24% between 1990 and 2004), from 28.7 to 49 Gigatonnes of carbon dioxide equivalents ($GtCO_2$-eq)[2] (see Figure SPM.1). The emissions of these gases have increased at different rates. CO_2 emissions have grown between 1970 and 2004 by about 80% (28% between 1990 and 2004) and represented 77% of total anthropogenic GHG emissions in 2004.
   - The largest growth in global GHG emissions between 1970 and 2004 has come from the energy supply sector (an increase of 145%). The growth in direct emissions[3] from transport in this period was 120%, industry 65% and land use, land use change, and forestry (LULUCF)[4] 40%[5]. Between 1970 and 1990 direct emissions from agriculture grew by 27% and from buildings by 26%, and the latter remained at approximately at 1990 levels thereafter. However, the buildings sector has a high level of electricity use and hence the total of direct and indirect emissions in this sector is much higher (75%) than direct emissions [1.3, 6.1, 11.3, Figures 1.1 and 1.3].
   - The effect on global emissions of the decrease in global energy intensity (-33%) during 1970 to 2004 has been smaller than the combined effect of global per capita income growth (77 %) and global population growth (69%); both drivers of increasing energy-related CO_2 emissions (Figure SPM.2). The long-term trend of a declining carbon intensity of energy supply reversed after 2000. Differences in terms of per capita income, per capita emissions, and energy intensity among countries remain significant. (Figure SPM.3). In 2004 UNFCCC Annex I countries held a 20% share in world population, produced 57% of world Gross Domestic Product based on Purchasing Power Parity (GDP_{ppp})[6], and accounted for 46% of global GHG emissions (Figure SPM.3) [1.3].
   - The emissions of ozone depleting substances (ODS) controlled under the Montreal Protocol[7], which are also GHGs, have declined significantly since the 1990s. By 2004 the emissions of these gases were about 20% of their 1990 level [1.3].
   - A range of policies, including those on climate change, energy security[8], and sustainable development, have been effective in reducing GHG emissions in different sectors and many countries. The scale of such measures, however, has not yet been large enough to counteract the global growth in emissions [1.3, 12.2].

1 Each headline statement has an "agreement/evidence" assessment attached that is supported by the bullets underneath. This does not necessarily mean that this level of "agreement/evidence"applies to each bullet. Endbox 1 provides an explanation of this representation of uncertainty.
2 The definition of carbon dioxide equivalent (CO_2-eq) is the amount of CO2 emission that would cause the same radiative forcing as an emitted amount of a well mixed greenhouse gas or a mixture of well mixed greenhouse gases, all multiplied with their respective GWPs to take into account the differing times they remain in the atmosphere [WGI AR4 Glossary].
3 Direct emissions in each sector do not include emissions from the electricity sector for the electricity consumed in the building, industry and agricultural sectors or of the emissions from refinery operations supplying fuel to the transport sector.
4 The term "land use, land use change and forestry" is used here to describe the aggregated emissions of CO_2, CH_4, N_2O from deforestation, biomass and burning, decay of biomass from logging and deforestation, decay of peat and peat fires [1.3.1]. This is broader than emissions from deforestation, which is included as a subset. The emissions reported here do not include carbon uptake (removals).
5 This trend is for the total LULUCF emissions, of which emissions from deforestation are a subset and, owing to large data uncertainties, is significantly less certain than for other sectors. The rate of deforestation globally was slightly lower in the 2000-2005 period than in the 1990-2000 period [9.2.1].
6 The GDPppp metric is used for illustrative purposes only for this report. For an explanation of PPP and Market Exchange Rate (MER) GDP calculations, see footnote 12.
7 Halons, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), methyl chloroform (CH_3CCl_3), carbon tetrachloride (CCl_4) and methyl bromide (CH_3Br).
8 Energy security refers to security of energy supply.

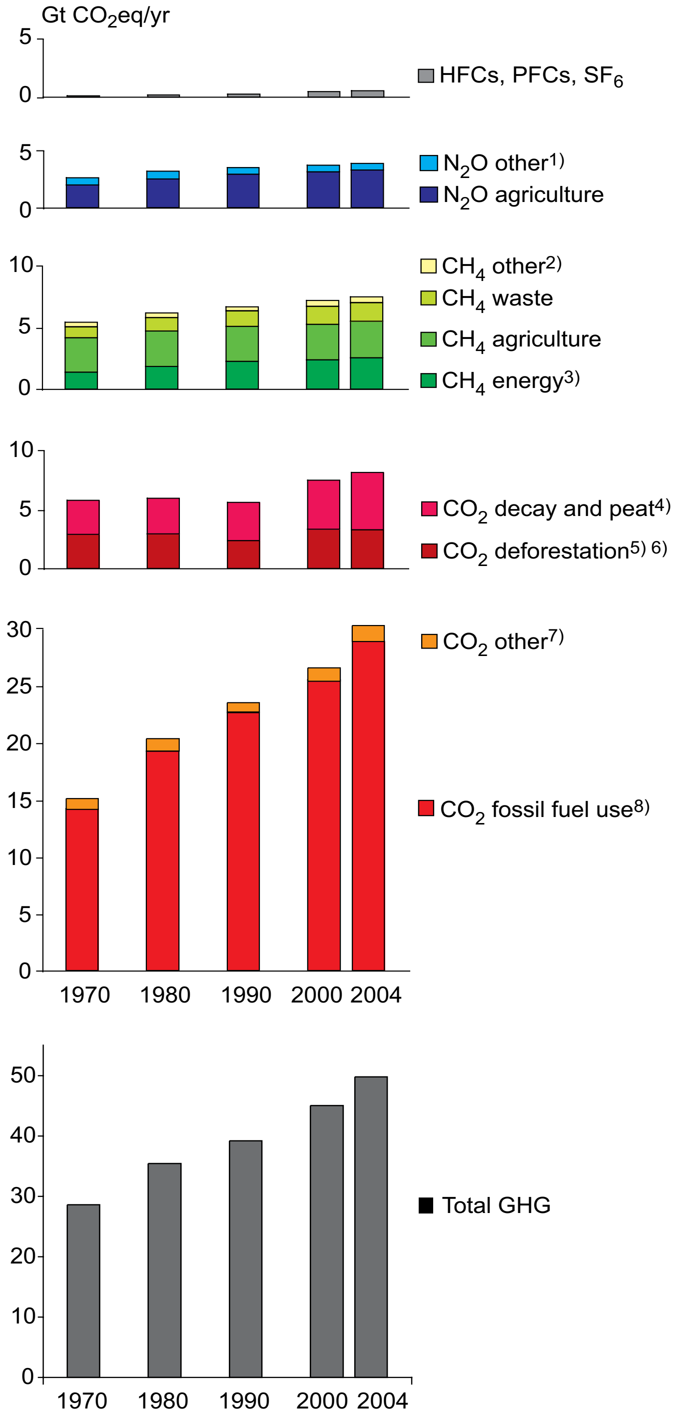


Figure SPM.1: *Global Warming Potential (GWP) weighted global greenhouse gas emissions 1970-2004. 100 year GWPs from IPCC 1996 (SAR) were used to convert emissions to CO_2-eq. (cf. UNFCCC reporting guidelines). CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 from all sources are included.*
The two CO_2 emission categories reflect CO_2 emissions from energy production and use (second from bottom) and from land use changes (third from the bottom) [Figure 1.1a].

Notes:
1. Other N_2O includes industrial processes, deforestation/savannah burning, waste water and waste incineration.
2. Other is CH_4 from industrial processes and savannah burning.
3. Including emissions from bioenergy production and use
4. CO_2 emissions from decay (decomposition) of above ground biomass that remains after logging and deforestation and CO_2 from peat fires and decay of drained peat soils.
5. As well as traditional biomass use at 10% of total, assuming 90% is from sustainable biomass production. Corrected for 10% carbon of biomass that is assumed to remain as charcoal after combustion.
6. For large-scale forest and scrubland biomass burning averaged data for 1997-2002 based on Global Fire Emissions Data base satellite data.
7. Cement production and natural gas flaring.
8. Fossil fuel use includes emissions from feedstocks.

3. **With current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades** *(high agreement, much evidence).*
   - The SRES (non-mitigation) scenarios project an increase of baseline global GHG emissions by a range of 9.7 $GtCO_2$-eq to 36.7 $GtCO_2$-eq (25-90%) between 2000 and 2030[9] (Box SPM.1 and Figure SPM.4). In these scenarios, fossil fuels are projected to maintain their dominant position in the global energy mix to 2030 and beyond. Hence CO_2 emissions between 2000 and 2030 from energy use are projected to grow 40 to 110% over that period. Two thirds to three quarters of this increase in energy CO_2 emissions is projected to come from non-Annex I regions, with their average per capita energy CO_2 emissions being projected to remain substantially lower (2.8-5.1 tCO_2/cap) than those in Annex I regions (9.6-15.1 tCO_2/cap) by 2030. According to SRES scenarios, their economies are projected to have a lower energy use per unit of GDP (6.2 – 9.9 MJ/US$ GDP) than that of non-Annex I countries (11.0 – 21.6 MJ/US$ GDP). [1.3, 3.2]

9 The SRES 2000 GHG emissions assumed here are 39.8 GtCO2-eq, i.e. lower than the emissions reported in the EDGAR database for 2000 (45 GtCO2-eq). This is mostly due to differences in LULUCF emissions.

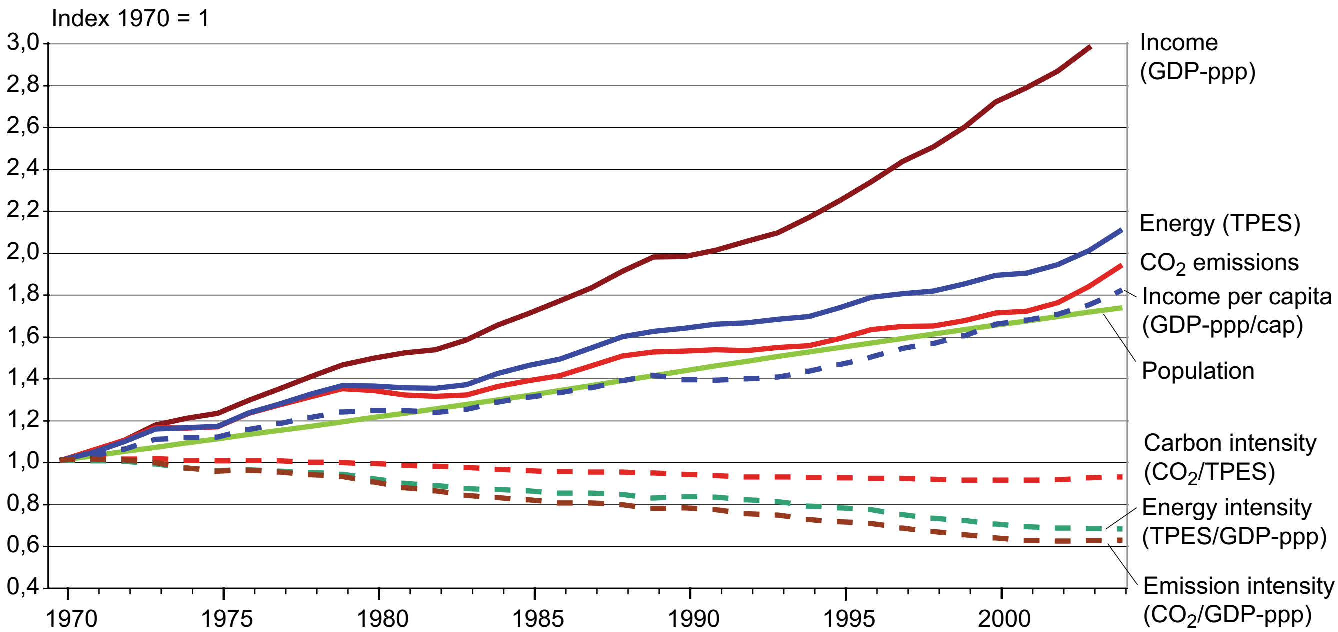


Figure SPM.2: *Relative global development of Gross Domestic Product measured in PPP (GDP_{ppp}), Total Primary Energy Supply (TPES), CO_2 emissions (from fossil fuel burning, gas flaring and cement manufacturing) and Population (Pop). In addition, in dotted lines, the figure shows Income per capita (GDP_{ppp}/Pop), Energy Intensity (TPES/GDP_{ppp}), Carbon Intensity of energy supply (CO_2/TPES), and Emission Intensity of the economic production process (CO_2/GDP_{ppp}) for the period 1970-2004. [Figure 1.5]*

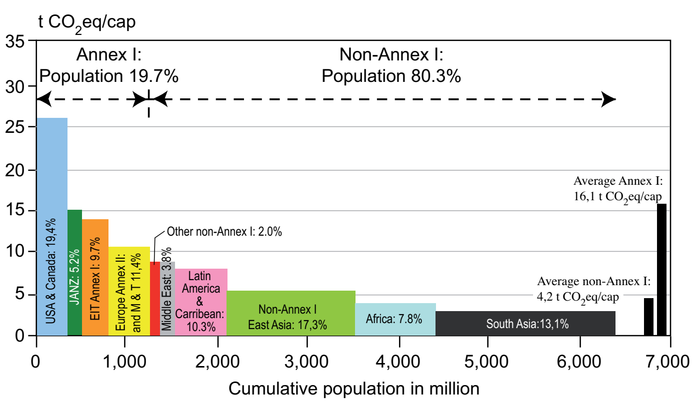


Figure SPM.3a: *Year 2004 distribution of regional per capita GHG emissions (all Kyoto gases, including those from land-use) over the population of different country groupings. The percentages in the bars indicate a regions share in global GHG emissions [Figure 1.4a].*

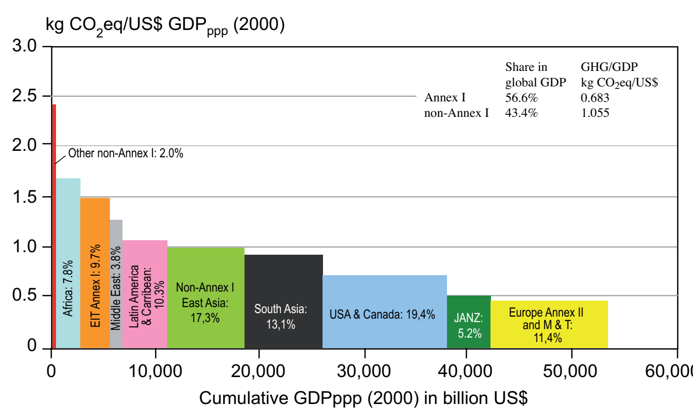


Figure SPM.3b: *Year 2004 distribution of regional GHG emissions (all Kyoto gases, including those from land-use) per US$ of GDP_{ppp} over the GDP_{ppp} of different country groupings. The percentages in the bars indicate a regions share in global GHG emissions [Figure 1.4b].*

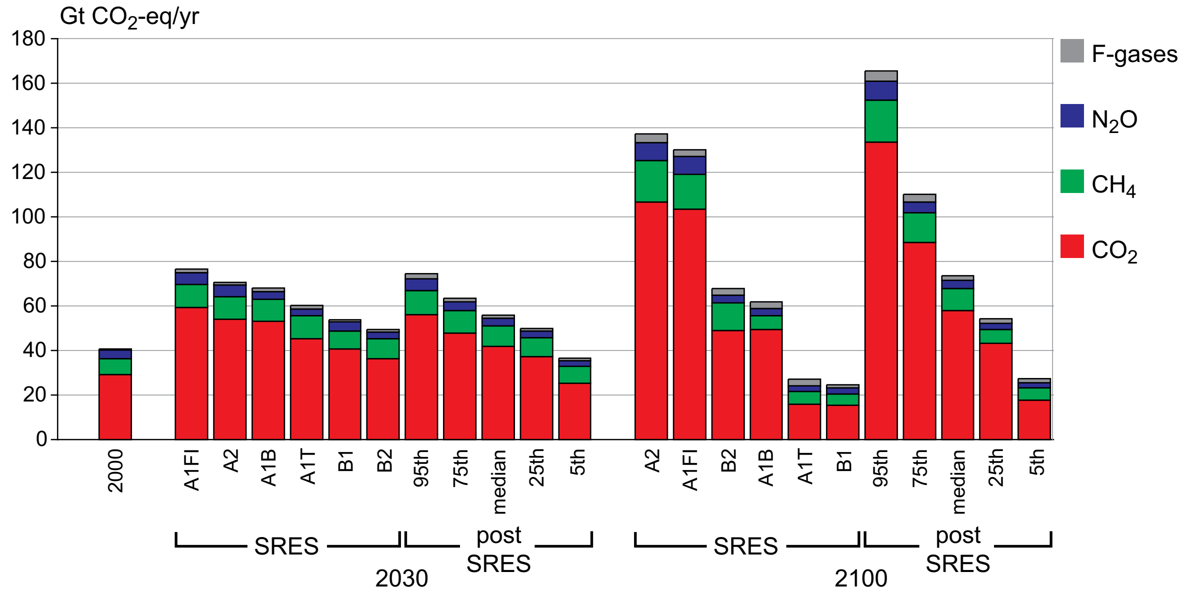


Figure SPM.4: *Global GHG emissions for 2000 and projected baseline emissions[10] for 2030 and 2100 from IPCC SRES and the post-SRES literature. The figure provides the emissions from the six illustrative SRES scenarios. It also provides the frequency distribution of the emissions in the post-SRES scenarios (5th, 25th, median, 75th, 95th percentile), as covered in Chapter 3. F-gases cover HFCs, PFCs and SF_6 [1.3, 3.2, Figure 1.7].*

4. **Baseline emissions scenarios published since SRES[10], are comparable in range to those presented in the IPCC Special Report on Emission Scenarios (SRES) (25- 135 $GtCO_2$-eq/yr in 2100, see Figure SPM.4)** *(high agreement, much evidence)*.
   - Studies since SRES used lower values for some drivers for emissions, notably population projections. However, for those studies incorporating these new population projections, changes in other drivers, such as economic growth, resulted in little change in overall emission levels. Economic growth projections for Africa, Latin America and the Middle East to 2030 in post-SRES baseline scenarios are lower than in SRES, but this has only minor effects on global economic growth and overall emissions [3.2].
   - Representation of aerosol and aerosol precursor emissions, including sulphur dioxide, black carbon, and organic carbon, which have a net cooling effect[11] has improved. Generally, they are projected to be lower than reported in SRES [3.2].
   - Available studies indicate that the choice of exchange rate for GDP (MER or PPP) does not appreciably affect the projected emissions, when used consistently[12]. The differences, if any, are small compared to the uncertainties caused by assumptions on other parameters in the scenarios, e.g. technological change [3.2].

10 Baseline scenarios do not include additional climate policy above current ones; more recent studies differ with respect to UNFCCC and Kyoto Protocol inclusion.
11 See AR4 WG I report, Chapter 10.2.
12 Since TAR, there has been a debate on the use of different exchange rates in emission scenarios. Two metrics are used to compare GDP between countries. Use of MER is preferable for analyses involving internationally traded products. Use of PPP, is preferable for analyses involving comparisons of income between countries at very different stages of development. Most of the monetary units in this report are expressed in MER. This reflects the large majority of emissions mitigation literature that is calibrated in MER. When monetary units are expressed in PPP, this is denoted by GDP_{ppp}.

Box SPM.1: The emission scenarios of the IPCC Special Report on Emission Scenarios (SRES)

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

This box summarizing the SRES scenarios is taken from the Third Assessment Report and has been subject to prior line by line approval by the Panel.

Box SPM.2: Mitigation potential and analytical approaches

The concept of “mitigation potential” has been developed to assess the scale of GHG reductions that could be made, relative to emission baselines, for a given level of carbon price (expressed in cost per unit of carbon dioxide equivalent emissions avoided or reduced). Mitigation potential is further differentiated in terms of “market potential” and “economic potential”.

Market potential is the mitigation potential based on private costs and private discount rates[13], which might be expected to occur under forecast market conditions, including policies and measures currently in place, noting that barriers limit actual uptake [2.4].

13 Private costs and discount rates reflect the perspective of private consumers and companies; see Glossary for a fuller description.

(Box SPM.2 Continued)

Economic potential is the mitigation potential, which takes into account social costs and benefits and social discount rates[14], assuming that market efficiency is improved by policies and measures and barriers are removed [2.4].

Studies of market potential can be used to inform policy makers about mitigation potential with existing policies and barriers, while studies of economic potentials show what might be achieved if appropriate new and additional policies were put into place to remove barriers and include social costs and benefits. The economic potential is therefore generally greater than the market potential.

Mitigation potential is estimated using different types of approaches. There are two broad classes – "bottom-up" and "top-down" approaches, which primarily have been used to assess the economic potential.

Bottom-up studies are based on assessment of mitigation options, emphasizing specific technologies and regulations. They are typically sectoral studies taking the macro-economy as unchanged. Sector estimates have been aggregated, as in the TAR, to provide an estimate of global mitigation potential for this assessment.

Top-down studies assess the economy-wide potential of mitigation options. They use globally consistent frameworks and aggregated information about mitigation options and capture macro-economic and market feedbacks.

Bottom-up and top-down models have become more similar since the TAR as top-down models have incorporated more technological mitigation options and bottom-up models have incorporated more macroeconomic and market feedbacks as well as adopting barrier analysis into their model structures. Bottom-up studies in particular are useful for the assessment of specific policy options at sectoral level, e.g. options for improving energy efficiency, while top-down studies are useful for assessing cross-sectoral and economy-wide climate change policies, such as carbon taxes and stabilization policies. However, current bottom-up and top-down studies of economic potential have limitations in considering life-style choices, and in including all externalities such as local air pollution. They have limited representation of some regions, countries, sectors, gases, and barriers. The projected mitigation costs do not take into account potential benefits of avoided climate change.

Box SPM.3: Assumptions in studies on mitigation portfolios and macro-economic costs

Studies on mitigation portfolios and macro-economic costs assessed in this report are based on top-down modelling. Most models use a global least cost approach to mitigation portfolios and with universal emissions trading, assuming transparent markets, no transaction cost, and thus perfect implementation of mitigation measures throughout the 21st century. Costs are given for a specific point in time.

Global modelled costs will increase if some regions, sectors (e.g. land-use), options or gases are excluded. Global modelled costs will decrease with lower baselines, use of revenues from carbon taxes and auctioned permits, and if induced technological learning is included. These models do not consider climate benefits and generally also co-benefits of mitigation measures, or equity issues.

Box SPM.4: Modelling induced technological change

Relevant literature implies that policies and measures may induce technological change. Remarkable progress has been achieved in applying approaches based on induced technological change to stabilisation studies; however, conceptual issues remain. In the models that adopt these approaches, projected costs for a given stabilization level are reduced; the reductions are greater at lower stabilisation levels.

14 Social costs and discount rates reflect the perspective of society. Social discount rates are lower than those used by private investors; see Glossary for a fuller description.

C. Mitigation in the short and medium term (until 2030)

5. **Both bottom-up and top-down studies indicate that there is substantial economic potential for the mitigation of global GHG emissions over the coming decades, that could offset the projected growth of global emissions or reduce emissions below current levels** *(high agreement, much evidence).*

Uncertainties in the estimates are shown as ranges in the tables below to reflect the ranges of baselines, rates of technological change and other factors that are specific to the different approaches. Furthermore, uncertainties also arise from the limited information for global coverage of countries, sectors and gases.

Bottom-up studies:

- In 2030, the economic potential estimated for this assessment from bottom-up approaches (see Box SPM.2) is presented in Table SPM.1 below and Figure SPM.5A. For reference: emissions in 2000 were equal to 43 $GtCO_2$-eq. [11.3]:
- Studies suggest that mitigation opportunities with net negative costs[15] have the potential to reduce emissions by around 6 $GtCO_2$-eq/yr in 2030. Realizing these requires dealing with implementation barriers [11.3].
- No one sector or technology can address the entire mitigation challenge. All assessed sectors contribute to the total (see Figure SPM.6). The key mitigation technologies and practices for the respective sectors are shown in Table SPM 3 [4.3, 4.4, 5.4, 6.5, 7.5, 8.4, 9.4, 10.4].

Top-down studies:

- Top-down studies calculate an emission reduction for 2030 as presented in Table SPM.2 below and Figure SPM.5B. The global economic potentials found in the top-down studies are in line with bottom-up studies (see Box SPM.2), though there are considerable differences at the sectoral level [3.6].
- The estimates in Table SPM.2 were derived from stabilization scenarios, i.e., runs towards long-run stabilization of atmospheric GHG concentration [3.6].

Table SPM.1: *Global economic mitigation potential in 2030 estimated from bottom-up studies.*

Carbon price (US$/$tCO_2$-eq)	**Economic potential** ($GtCO_2$-eq/yr)	**Reduction relative to SRES A1 B** (68 $GtCO_2$-eq/yr) (%)	**Reduction relative to SRES B2** (49 $GtCO_2$-eq/yr) (%)
0	5-7	7-10	10-14
20	9-17	14-25	19-35
50	13-26	20-38	27-52
100	16-31	23-46	32-63

Table SPM.2: *Global economic mitigation potential in 2030 estimated from top-down studies.*

Carbon price (US$/$tCO_2$-eq)	**Economic potential** ($GtCO_2$-eq/yr)	**Reduction relative to SRES A1 B** (68 $GtCO_2$-eq/yr) (%)	**Reduction relative to SRES B2** (49 $GtCO_2$-eq/yr) (%)
20	9-18	13-27	18-37
50	14-23	21-34	29-47
100	17-26	25-38	35-53

15 In this report, as in the SAR and the TAR, options with net negative costs (no regrets opportunities) are defined as those options whose benefits such as reduced energy costs and reduced emissions of local/regional pollutants equal or exceed their costs to society, excluding the benefits of avoided climate change (see Box SPM.1).

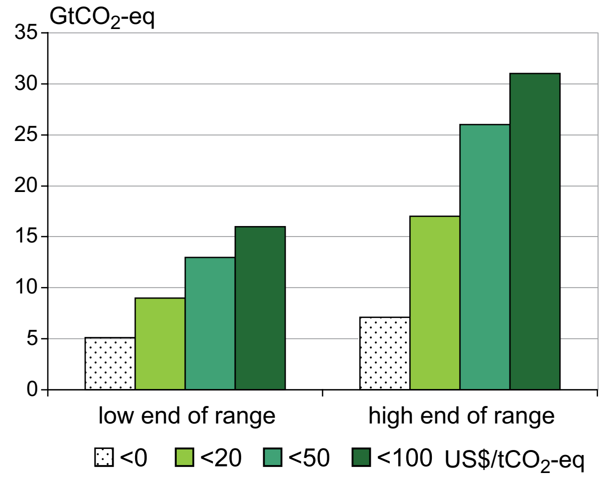


Figure SPM.5A: *Global economic mitigation potential in 2030 estimated from bottom-up studies (data from Table SPM.1)*

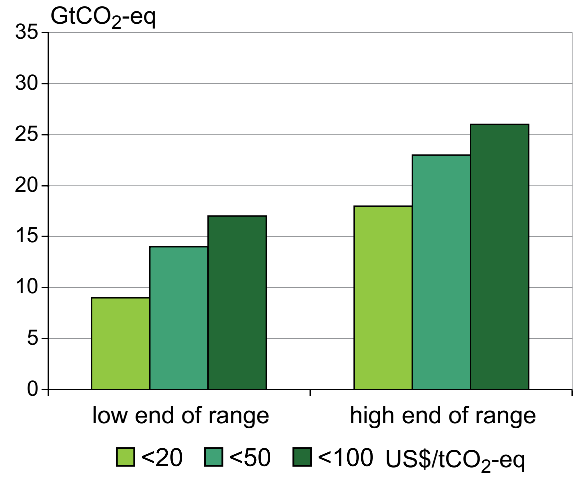
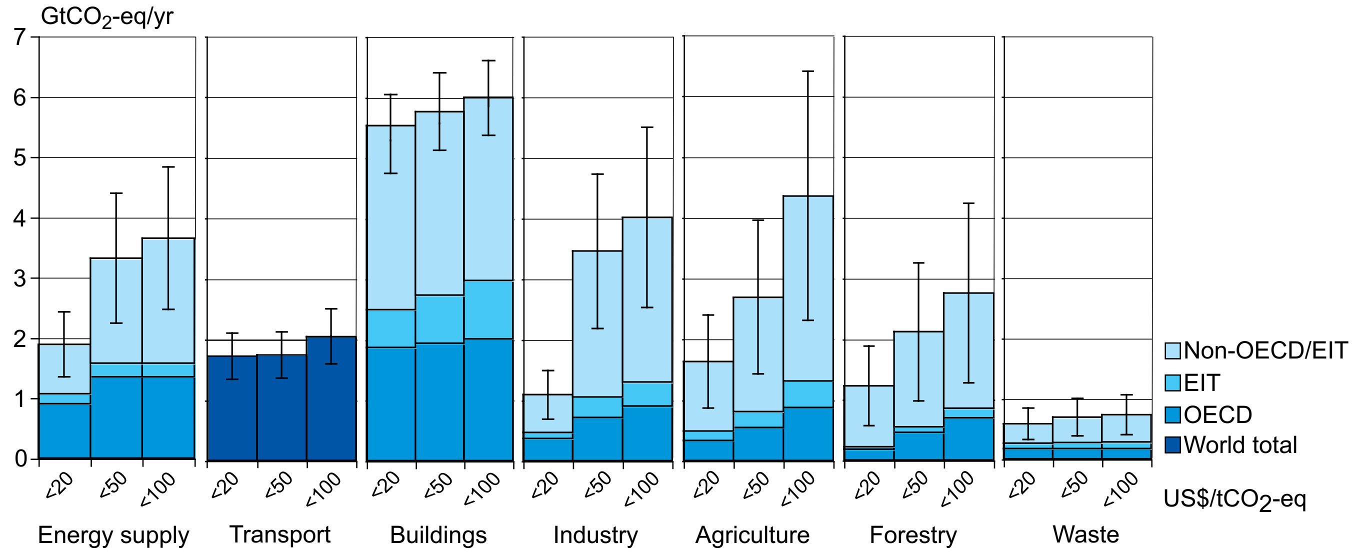


Figure SPM.5B: *Global economic mitigation potential in 2030 estimated from top-down studies (data from Table SPM.2)*

Table SPM.3: *Key mitigation technologies and practices by sector. Sectors and technologies are listed in no particular order. Non-technological practices, such as lifestyle changes, which are cross-cutting, are not included in this table (but are addressed in paragraph 7 in this SPM).*

Sector	**Key mitigation technologies and practices currently commercially available**	**Key mitigation technologies and practices projected to be commercialized before 2030**
Energy supply [4.3, 4.4]	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of Carbon Capture and Storage (CCS, e.g. storage of removed CO_2 from natural gas).	CCS for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and waves energy, concentrating solar, and solar PV.
Transport [5.4]	More fuel efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning.	Second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries.
Buildings [6.5]	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation ; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycle of fluorinated gases.	Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar PV integrated in buildings.
Industry [7.5]	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions; and a wide array of process-specific technologies.	Advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture.
Agriculture [8.4]	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertilizer application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency.	Improvements of crops yields.
Forestry/forests [9.4]	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use.	Tree species improvement to increase biomass productivity and carbon sequestration. Improved remote sensing technologies for analysis of vegetation/ soil carbon sequestration potential and mapping land use change.
Waste management [10.4]	Landfill methane recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; recycling and waste minimization.	Biocovers and biofilters to optimize CH_4 oxidation.



Energy supply	Transport	Buildings	Industry	Agriculture	Forestry	Waste
(potential at <US$100/ tCO_2-eq: 2.4 - 4.7 Gt CO_2-eq/yr)	*(potential at <US$100/ tCO_2-eq: 1.6 - 2.5 Gt CO_2-eq/yr)*	*(potential at <US$100/ tCO_2-eq: 5.3 -6.7 Gt CO_2-eq/yr)*	*(potential at <US$100/ tCO_2-eq: 2.5 - 5.5 Gt CO_2-eq/yr)*	*(potential at <US$100/ tCO_2-eq: 2.3 -6.4 Gt CO_2-eq/yr)*	*(potential at <US$100/ tCO_2-eq: 1.3 - 4.2 Gt CO_2-eq/yr)*	*(potential at <US$100/ tCO_2-eq: 0.4 - 1 Gt CO_2-eq/yr)*

Figure SPM.6: *Estimated sectoral economic potential for global mitigation for different regions as a function of carbon price in 2030 from bottom-up studies, compared to the respective baselines assumed in the sector assessments. A full explanation of the derivation of this figure is found in Section 11.3.*

Notes:
1. The ranges for global economic potentials as assessed in each sector are shown by vertical lines. The ranges are based on end-use allocations of emissions, meaning that emissions of electricity use are counted towards the end-use sectors and not to the energy supply sector.
2. The estimated potentials have been constrained by the availability of studies particularly at high carbon price levels.
3. Sectors used different baselines. For industry the SRES B2 baseline was taken, for energy supply and transport the WEO 2004 baseline was used; the building sector is based on a baseline in between SRES B2 and A1B; for waste, SRES A1B driving forces were used to construct a waste specific baseline, agriculture and forestry used baselines that mostly used B2 driving forces.
4. Only global totals for transport are shown because international aviation is included [5.4].
5. Categories excluded are: non-CO_2 emissions in buildings and transport, part of material efficiency options, heat production and cogeneration in energy supply, heavy duty vehicles, shipping and high-occupancy passenger transport, most high-cost options for buildings, wastewater treatment, emission reduction from coal mines and gas pipelines, fluorinated gases from energy supply and transport. The underestimation of the total economic potential from these emissions is of the order of 10-15%.

6. **In 2030 macro-economic costs for multi-gas mitigation, consistent with emissions trajectories towards stabilization between 445 and 710 ppm CO_2-eq, are estimated at between a 3% decrease of global GDP and a small increase, compared to the baseline (see Table SPM.4). However, regional costs may differ significantly from global averages** (*high agreement, medium evidence)* **(see Box SPM.3 for the methodologies and assumptions of these results).**
   - The majority of studies conclude that reduction of GDP relative to the GDP baseline increases with the stringency of the stabilization target.
   - Depending on the existing tax system and spending of the revenues, modelling studies indicate that costs may be substantially lower under the assumption that revenues from carbon taxes or auctioned permits under an emission trading system are used to promote low-carbon technologies or reform of existing taxes [11.4].
   - Studies that assume the possibility that climate change policy induces enhanced technological change also give lower costs. However, this may require higher upfront investment in order to achieve costs reductions thereafter (see Box SPM.4) [3.3, 3.4, 11.4, 11.5, 11.6].
   - Although most models show GDP losses, some show GDP gains because they assume that baselines are non-optimal and mitigation policies improve market efficiencies, or they assume that more technological change may be induced by mitigation policies. Examples of market inefficiencies include unemployed resources, distortionary taxes and/or subsidies [3.3, 11.4].
   - A multi-gas approach and inclusion of carbon sinks generally reduces costs substantially compared to CO_2 emission abatement only [3.3].
   - Regional costs are largely dependent on the assumed stabilization level and baseline scenario. The allocation regime is also important, but for most countries to a lesser extent than the stabilization level [11.4, 13.3].

Table SPM.4: *Estimated global macro-economic costs in 2030[a)] for least-cost trajectories towards different long-term stabilization levels.[b), c)]*

Stabilization levels (ppm CO_2-eq)	**Median GDP reduction[d)]** (%)	**Range of GDP reduction[d), e)]** (%)	**Reduction of average annual GDP growth rates[d), f)]** (percentage points)
590-710	0.2	-0.6-1.2	<0.06
535-590	0.6	0.2-2.5	<0.1
445-535[g)]	not available	<3	<0.12

Notes:
a) For a given stabilization level, GDP reduction would increase over time in most models after 2030. Long-term costs also become more uncertain. [Figure 3.25]
b) Results based on studies using various baselines.
c) Studies vary in terms of the point in time stabilization is achieved; generally this is in 2100 or later.
d) This is global GDP based market exchange rates.
e) The median and the 10^{th} and 90^{th} percentile range of the analyzed data are given.
f) The calculation of the reduction of the annual growth rate is based on the average reduction during the period till 2030 that would result in the indicated GDP decrease in 2030.
g) The number of studies that report GDP results is relatively small and they generally use low baselines.

7. **Changes in lifestyle and behaviour patterns can contribute to climate change mitigation across all sectors. Management practices can also have a positive role** *(high agreement, medium evidence).*
   - Lifestyle changes can reduce GHG emissions. Changes in lifestyles and consumption patterns that emphasize resource conservation can contribute to developing a low-carbon economy that is both equitable and sustainable [4.1, 6.7].
   - Education and training programmes can help overcome barriers to the market acceptance of energy efficiency, particularly in combination with other measures [Table 6.6].
   - Changes in occupant behaviour, cultural patterns and consumer choice and use of technologies can result in considerable reduction in CO_2 emissions related to energy use in buildings [6.7].
   - Transport Demand Management, which includes urban planning (that can reduce the demand for travel) and provision of information and educational techniques (that can reduce car usage and lead to an efficient driving style) can support GHG mitigation [5.1].
   - In industry, management tools that include staff training, reward systems, regular feedback, documentation of existing practices can help overcome industrial organization barriers, reduce energy use, and GHG emissions [7.3].

8. **While studies use different methodologies, in all analyzed world regions near-term health co-benefits from reduced air pollution as a result of actions to reduce GHG emissions can be substantial and may offset a substantial fraction of mitigation costs** *(high agreement, much evidence).*
   - Including co-benefits other than health, such as increased energy security, and increased agricultural production and reduced pressure on natural ecosystems, due to decreased tropospheric ozone concentrations, would further enhance cost savings [11.8].
   - Integrating air pollution abatement and climate change mitigation policies offers potentially large cost reductions compared to treating those policies in isolation [11.8].

9. **Literature since TAR confirms that there may be effects from Annex I countries' action on the global economy and global emissions, although the scale of carbon leakage remains uncertain** *(high agreement, medium evidence).*
   - Fossil fuel exporting nations (in both Annex I and non-Annex I countries) may expect, as indicated in TAR[16], lower demand and prices and lower GDP growth due to mitigation policies. The extent of this spill over[17] depends strongly on assumptions related to policy decisions and oil market conditions [11.7].
   - Critical uncertainties remain in the assessment of carbon leakage[18]. Most equilibrium modelling support the conclusion in the TAR of economy-wide leakage from Kyoto action in the order of 5-20%, which would be less if competitive low-emissions technologies were effectively diffused [11.7] .

10. **New energy infrastructure investments in developing countries, upgrades of energy infrastructure in industrialized countries, and policies that promote energy security, can, in many cases, create opportunities to achieve GHG emission reductions[19] compared to baseline scenarios. Additional co-benefits are country-**

16 See TAR WG III (2001) SPM paragraph 16.
17 Spill over effects of mitigation in a cross-sectoral perspective are the effects of mitigation policies and measures in one country or group of countries on sectors in other countries.
18 Carbon leakage is defined as the increase in CO_2 emissions outside the countries taking domestic mitigation action divided by the reduction in the emissions of these countries.
19 See table SPM.1 and Figure SPM.6

specific but often include air pollution abatement, balance of trade improvement, provision of modern energy services to rural areas and employment *(high agreement, much evidence).*

- Future energy infrastructure investment decisions, expected to total over 20 trillion US$[20] between now and 2030, will have long term impacts on GHG emissions, because of the long life-times of energy plants and other infrastructure capital stock. The widespread diffusion of low-carbon technologies may take many decades, even if early investments in these technologies are made attractive. Initial estimates show that returning global energy-related CO_2 emissions to 2005 levels by 2030 would require a large shift in the pattern of investment, although the net additional investment required ranges from negligible to 5-10% [4.1, 4.4, 11.6].
- It is often more cost-effective to invest in end-use energy efficiency improvement than in increasing energy supply to satisfy demand for energy services. Efficiency improvement has a positive effect on energy security, local and regional air pollution abatement, and employment [4.2, 4.3, 6.5, 7.7, 11.3, 11.8].
- Renewable energy generally has a positive effect on energy security, employment and on air quality. Given costs relative to other supply options, renewable electricity, which accounted for 18% of the electricity supply in 2005, can have a 30-35% share of the total electricity supply in 2030 at carbon prices up to 50 US$/t$CO_2$-eq [4.3, 4.4, 11.3, 11.6, 11.8].
- The higher the market prices of fossil fuels, the more low-carbon alternatives will be competitive, although price volatility will be a disincentive for investors. Higher priced conventional oil resources, on the other hand, may be replaced by high carbon alternatives such as from oil sands, oil shales, heavy oils, and synthetic fuels from coal and gas, leading to increasing GHG emissions, unless production plants are equipped with CCS [4.2, 4.3, 4.4, 4.5].
- Given costs relative to other supply options, nuclear power, which accounted for 16% of the electricity supply in 2005, can have an 18% share of the total electricity supply in 2030 at carbon prices up to 50 US$/t$CO_2$-eq, but safety, weapons proliferation and waste remain as constraints [4.2, 4.3, 4.4][21].
- CCS in underground geological formations is a new technology with the potential to make an important contribution to mitigation by 2030. Technical, economic and regulatory developments will affect the actual contribution [4.3, 4.4, 7.3].

11. There are multiple mitigation options in the transport sector[19], but their effect may be counteracted by growth in the sector. Mitigation options are faced with many barriers, such as consumer preferences and lack of policy frameworks *(medium agreement, medium evidence).*

- Improved vehicle efficiency measures, leading to fuel savings, in many cases have net benefits (at least for light-duty vehicles), but the market potential is much lower than the economic potential due to the influence of other consumer considerations, such as performance and size. There is not enough information to assess the mitigation potential for heavy-duty vehicles. Market forces alone, including rising fuel costs, are therefore not expected to lead to significant emission reductions [5.3, 5.4].
- Biofuels might play an important role in addressing GHG emissions in the transport sector, depending on their production pathway. Biofuels used as gasoline and diesel fuel additives/substitutes are projected to grow to 3% of total transport energy demand in the baseline in 2030. This could increase to about 5-10%, depending on future oil and carbon prices, improvements in vehicle efficiency and the success of technologies to utilise cellulose biomass [5.3, 5.4].
- Modal shifts from road to rail and to inland and coastal shipping and from low-occupancy to high-occupancy passenger transportation[22], as well as land-use, urban planning and non-motorized transport offer opportunities for GHG mitigation, depending on local conditions and policies [5.3, 5.5].
- Medium term mitigation potential for CO_2 emissions from the aviation sector can come from improved fuel efficiency, which can be achieved through a variety of means, including technology, operations and air traffic management. However, such improvements are expected to only partially offset the growth of aviation emissions. Total mitigation potential in the sector would also need to account for non-CO_2 climate impacts of aviation emissions [5.3, 5.4].
- Realizing emissions reductions in the transport sector is often a co-benefit of addressing traffic congestion, air quality and energy security [5.5].

12. Energy efficiency options[19] for new and existing buildings could considerably reduce CO_2 emissions with net economic benefit. Many barriers exist against tapping this potential, but there are also large co-benefits *(high agreement, much evidence).*

- By 2030, about 30% of the projected GHG emissions in the building sector can be avoided with net economic benefit [6.4, 6.5].

20 20 trillion = 20000 billion= $20*10^{12}$.
21 Austria could not agree with this statement.
22 Including rail, road and marine mass transit and carpooling.

- Energy efficient buildings, while limiting the growth of CO_2 emissions, can also improve indoor and outdoor air quality, improve social welfare and enhance energy security [6.6, 6.7].
- Opportunities for realising GHG reductions in the building sector exist worldwide. However, multiple barriers make it difficult to realise this potential. These barriers include availability of technology, financing, poverty, higher costs of reliable information, limitations inherent in building designs and an appropriate portfolio of policies and programs [6.7, 6.8].
- The magnitude of the above barriers is higher in the developing countries and this makes it more difficult for them to achieve the GHG reduction potential of the building sector [6.7].

13. **The economic potential in the industrial sector[19] is predominantly located in energy intensive industries. Full use of available mitigation options is not being made in either industrialized or developing nations** (*high agreement, much evidence*).
    - Many industrial facilities in developing countries are new and include the latest technology with the lowest specific emissions. However, many older, inefficient facilities remain in both industrialized and developing countries. Upgrading these facilities can deliver significant emission reductions [7.1, 7.3, 7.4].
    - The slow rate of capital stock turnover, lack of financial and technical resources, and limitations in the ability of firms, particularly small and medium-sized enterprises, to access and absorb technological information are key barriers to full use of available mitigation options [7.6].

14. **Agricultural practices collectively can make a significant contribution at low cost[19] to increasing soil carbon sinks, to GHG emission reductions, and by contributing biomass feedstocks for energy use** *(medium agreement, medium evidence)***.**
    - A large proportion of the mitigation potential of agriculture (excluding bioenergy) arises from soil carbon sequestration, which has strong synergies with sustainable agriculture and generally reduces vulnerability to climate change [8.4, 8.5, 8.8].
    - Stored soil carbon may be vulnerable to loss through both land management change and climate change [8.10].
    - Considerable mitigation potential is also available from reductions in methane and nitrous oxide emissions in some agricultural systems [8.4, 8.5].
    - There is no universally applicable list of mitigation practices; practices need to be evaluated for individual agricultural systems and settings [8.4].
    - Biomass from agricultural residues and dedicated energy crops can be an important bioenergy feedstock, but its contribution to mitigation depends on demand for bioenergy from transport and energy supply, on water availability, and on requirements of land for food and fibre production. Widespread use of agricultural land for biomass production for energy may compete with other land uses and can have positive and negative environmental impacts and implications for food security [8.4, 8.8].

15. **Forest-related mitigation activities can considerably reduce emissions from sources and increase CO_2 removals by sinks at low costs[19], and can be designed to create synergies with adaptation and sustainable development** *(high agreement, much evidence)*[23].
    - About 65% of the total mitigation potential (up to 100 US$/t$CO_2$-eq) is located in the tropics and about 50% of the total could be achieved by reducing emissions from deforestation [9.4].
    - Climate change can affect the mitigation potential of the forest sector (i.e., native and planted forests) and is expected to be different for different regions and sub-regions, both in magnitude and direction [9.5].
    - Forest-related mitigation options can be designed and implemented to be compatible with adaptation, and can have substantial co-benefits in terms of employment, income generation, biodiversity and watershed conservation, renewable energy supply and poverty alleviation [9.5, 9.6, 9.7].

16. **Post-consumer waste[24] is a small contributor to global GHG emissions[25] (<5%), but the waste sector can positively contribute to GHG mitigation at low cost[19] and promote sustainable development** *(high agreement, much evidence)*.
    - Existing waste management practices can provide effective mitigation of GHG emissions from this sector: a wide range of mature, environmentally effective technologies are commercially available to mitigate emissions and provide co-benefits for improved public health and safety, soil protection and pollution prevention, and local energy supply [10.3, 10.4, 10.5].
    - Waste minimization and recycling provide important indirect mitigation benefits through the conservation of energy and materials [10.4].

23 Tuvalu noted difficulties with the reference to “low costs” as Chapter 9, page 15 of the WG III report states that: “the cost of forest mitigation projects rise significantly when opportunity costs of land are taken into account”.
24 Industrial waste is covered in the industry sector.
25 GHGs from waste include landfill and wastewater methane, wastewater N_2O, and CO_2 from incineration of fossil carbon.

- Lack of local capital is a key constraint for waste and wastewater management in developing countries and countries with economies in transition. Lack of expertise on sustainable technology is also an important barrier [10.6].

17. **Geo-engineering options, such as ocean fertilization to remove CO_2 directly from the atmosphere, or blocking sunlight by bringing material into the upper atmosphere, remain largely speculative and unproven, and with the risk of unknown side-effects. Reliable cost estimates for these options have not been published** *(medium agreement, limited evidence)* [11.2].

D. Mitigation in the long term (after 2030)

18. **In order to stabilize the concentration of GHGs in the atmosphere, emissions would need to peak and decline thereafter. The lower the stabilization level, the more quickly this peak and decline would need to occur. Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilization levels (see Table SPM.5, and Figure SPM. 8)[26]** (*high agreement, much evidence*).

- Recent studies using multi-gas reduction have explored lower stabilization levels than reported in TAR [3.3].
- Assessed studies contain a range of emissions profiles for achieving stabilization of GHG concentrations[27]. Most of these studies used a least cost approach and include both early and delayed emission reductions (Figure SPM.7) [Box SPM.2]. Table SPM.5 summarizes the required emissions levels for different groups of stabilization concentrations and the associated equilibrium global mean temperature increase[28], using the 'best estimate' of climate sensitivity (see also Figure SPM.8 for the likely range of uncertainty)[29]. Stabilization at lower concentration and related equilibrium temperature levels advances the date when emissions need to peak, and requires greater emissions reductions by 2050 [3.3].

Table SPM.5: *Characteristics of post-TAR stabilization scenarios [Table TS 2, 3.10][a)]*

Category	Radiative forcing (W/m^2)	CO_2 concentration[c)] (ppm)	CO_2-eq concentration[c)] (ppm)	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity[b), c)] (ºC)	Peaking year for CO_2 emissions[d)]	Change in global CO_2 emissions in 2050 (% of 2000 emissions)[d)]	No. of assessed scenarios
I	2.5-3.0	350-400	445-490	2.0-2.4	2000-2015	-85 to -50	6
II	3.0-3.5	400-440	490-535	2.4-2.8	2000-2020	-60 to -30	18
III	3.5-4.0	440-485	535-590	2.8-3.2	2010-2030	-30 to +5	21
IV	4.0-5.0	485-570	590-710	3.2-4.0	2020-2060	+10 to +60	118
V	5.0-6.0	570-660	710-855	4.0-4.9	2050-2080	+25 to +85	9
VI	6.0-7.5	660-790	855-1130	4.9-6.1	2060-2090	+90 to +140	5
						Total	177

a) The understanding of the climate system response to radiative forcing as well as feedbacks is assessed in detail in the AR4 WGI Report. Feedbacks between the carbon cycle and climate change affect the required mitigation for a particular stabilization level of atmospheric carbon dioxide concentration. These feedbacks are expected to increase the fraction of anthropogenic emissions that remains in the atmosphere as the climate system warms. Therefore, the emission reductions to meet a particular stabilization level reported in the mitigation studies assessed here might be underestimated.
b) The best estimate of climate sensitivity is 3ºC [WG 1 SPM].
c) Note that global mean temperature at equilibrium is different from expected global mean temperature at the time of stabilization of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150.
d) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios.

26 Paragraph 2 addresses historical GHG emissions since pre-industrial times.
27 Studies vary in terms of the point in time stabilization is achieved; generally this is around 2100 or later.
28 The information on global mean temperature is taken from the AR4 WGI report, chapter 10.8. These temperatures are reached well after concentrations are stabilized.
29 The equilibrium climate sensitivity is a measure of the climate system response to sustained radiative forcing. It is not a projection but is defined as the global average surface warming following a doubling of carbon dioxide concentrations [AR4 WGI SPM].

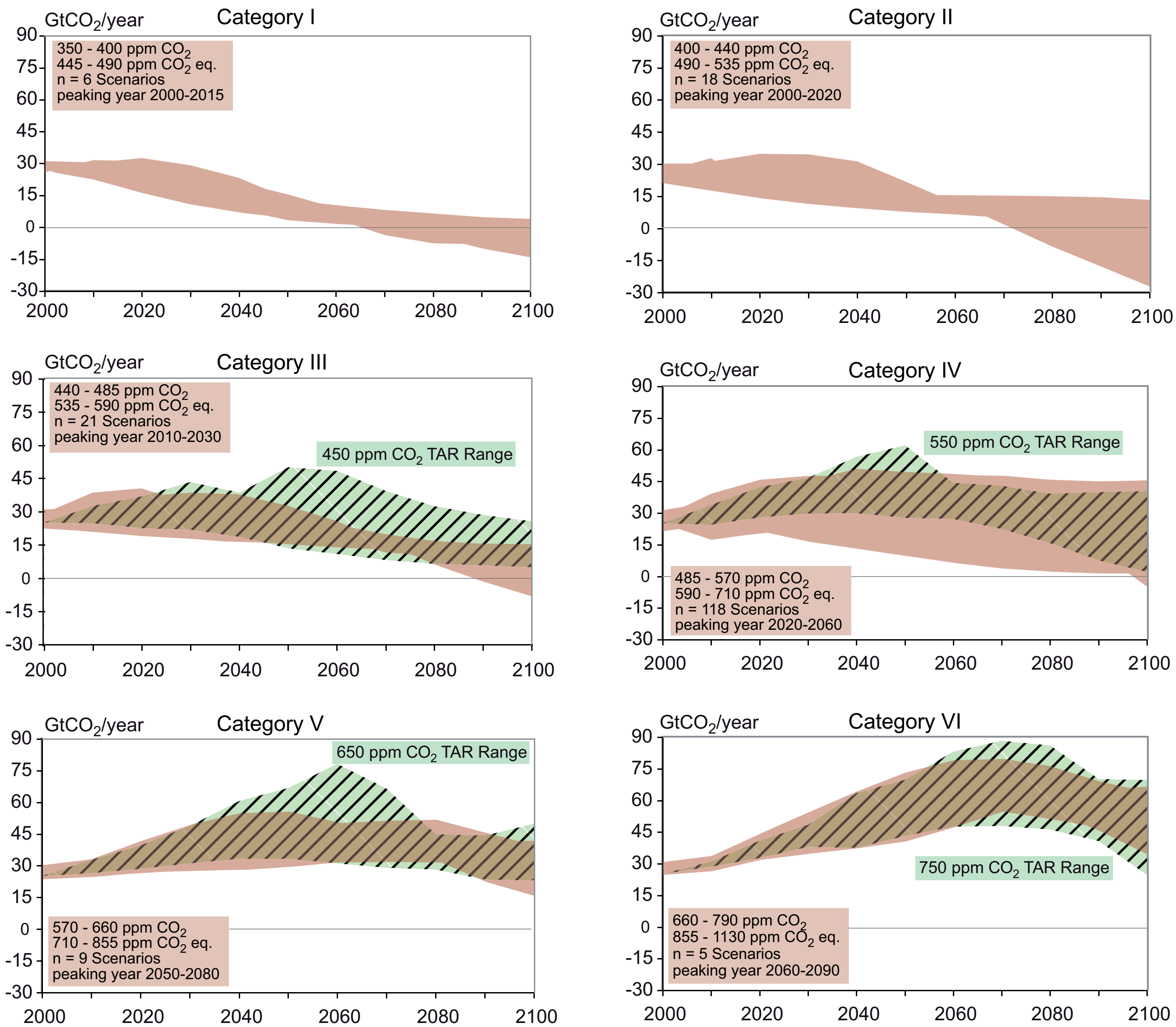


Figure SPM.7: *Emissions pathways of mitigation scenarios for alternative categories of stabilization levels (Category I to VI as defined in the box in each panel). The pathways are for CO_2 emissions only. Light brown shaded areas give the CO_2 emissions for the post-TAR emissions scenarios. Green shaded and hatched areas depict the range of more than 80 TAR stabilization scenarios. Base year emissions may differ between models due to differences in sector and industry coverage. To reach the lower stabilization levels some scenarios deploy removal of CO_2 from the atmosphere (negative emissions) using technologies such as biomass energy production utilizing carbon capture and storage. [Figure 3.17]*

19. **The range of stabilization levels assessed can be achieved by deployment of a portfolio of technologies that are currently available and those that are expected to be commercialised in coming decades. This assumes that appropriate and effective incentives are in place for development, acquisition, deployment and diffusion of technologies and for addressing related barriers** *(high agreement, much evidence)*.
   - The contribution of different technologies to emission reductions required for stabilization will vary over time, region and stabilization level.
     - o Energy efficiency plays a key role across many scenarios for most regions and timescales.
     - o For lower stabilization levels, scenarios put more emphasis on the use of low-carbon energy sources, such as renewable energy and nuclear power, and the use of CO_2 capture and storage (CCS). In these scenarios improvements of carbon intensity of energy supply and the whole economy need to be much faster than in the past.
     - o Including non-CO_2 and CO_2 land-use and forestry mitigation options provides greater flexibility and cost-effectiveness for achieving stabilization. Modern bioenergy could contribute substantially to the share of renewable energy in the mitigation portfolio.

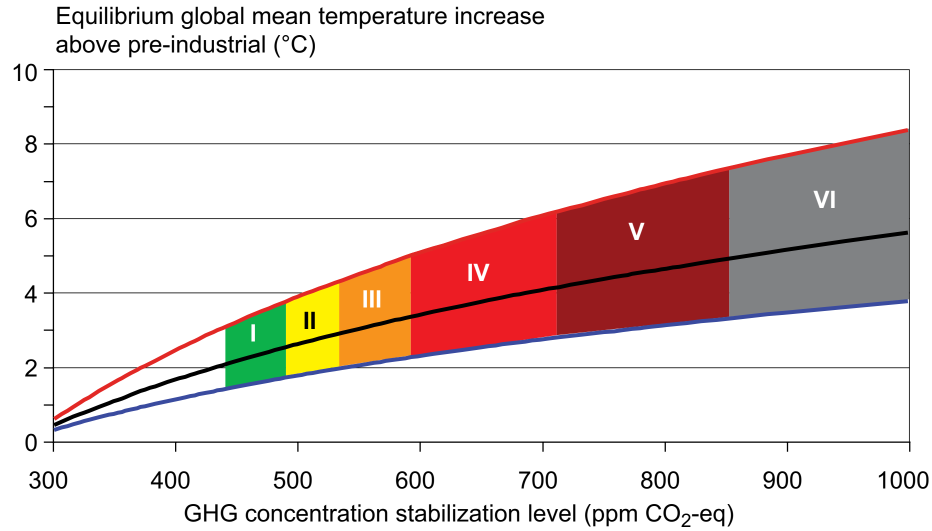


Figure SPM.8: *Stabilization scenario categories as reported in Figure SPM.7 (coloured bands) and their relationship to equilibrium global mean temperature change above pre-industrial, using (i) "best estimate" climate sensitivity of 3°C (black line in middle of shaded area), (ii) upper bound of likely range of climate sensitivity of 4.5°C (red line at top of shaded area) (iii) lower bound of likely range of climate sensitivity of 2°C (blue line at bottom of shaded area). Coloured shading shows the concentration bands for stabilization of greenhouse gases in the atmosphere corresponding to the stabilization scenario categories I to VI as indicated in Figure SPM.7. The data are drawn from AR4 WGI, Chapter 10.8.*

- o For illustrative examples of portfolios of mitigation options, see figure SPM.9 [3.3, 3.4].
- Investments in and world-wide deployment of low-GHG emission technologies as well as technology improvements through public and private Research, Development & Demonstration (RD&D) would be required for achieving stabilization targets as well as cost reduction. The lower the stabilization levels, especially those of 550 ppm CO_2-eq or lower, the greater the need for more efficient RD&D efforts and investment in new

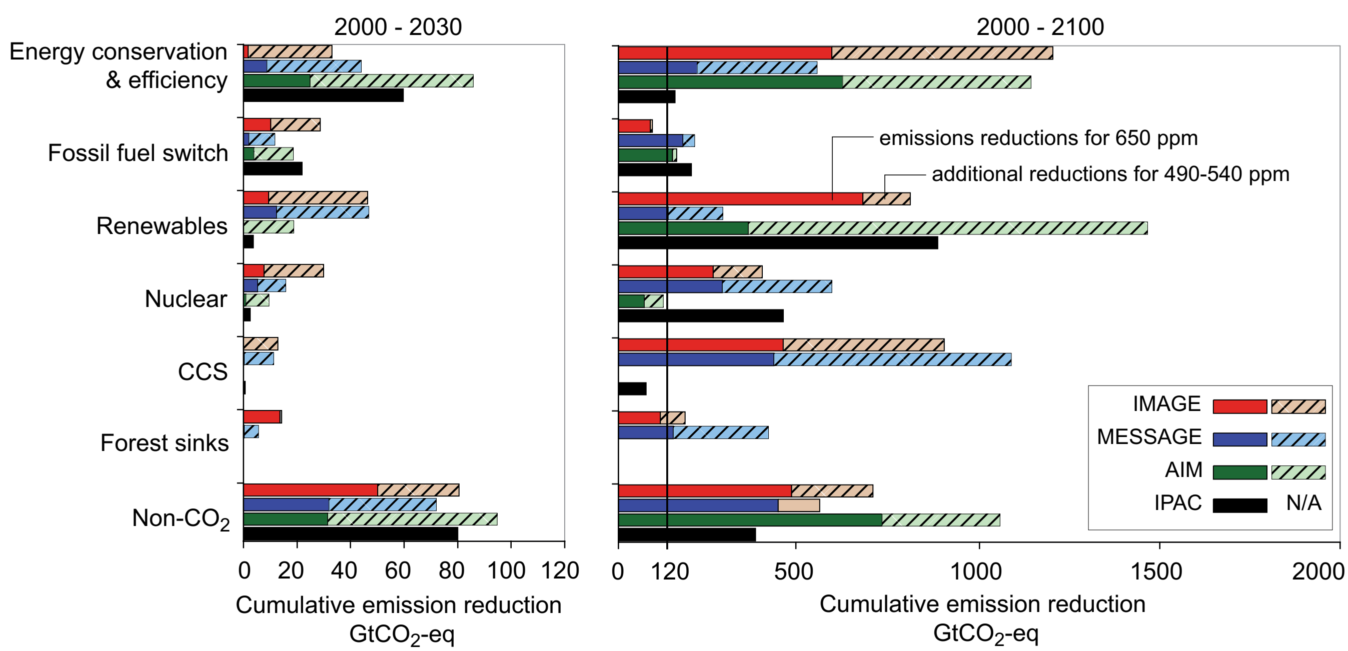


Figure SPM.9: *Cumulative emissions reductions for alternative mitigation measures for 2000 to 2030 (left-hand panel) and for 2000-2100 (right-hand panel). The figure shows illustrative scenarios from four models (AIM, IMAGE, IPAC and MESSAGE) aiming at the stabilization at 490-540 ppm CO_2-eq and levels of 650 ppm CO_2-eq, respectively. Dark bars denote reductions for a target of 650 ppm CO_2-eq and light bars the additional reductions to achieve 490-540 ppm CO_2-eq. Note that some models do not consider mitigation through forest sink enhancement (AIM and IPAC) or CCS (AIM) and that the share of low-carbon energy options in total energy supply is also determined by inclusion of these options in the baseline. CCS includes carbon capture and storage from biomass. Forest sinks include reducing emissions from deforestation. [Figure 3.23]* technologies during the next few decades. This requires that barriers to development, acquisition, deployment and diffusion of technologies are effectively addressed.

- Appropriate incentives could address these barriers and help realize the goals across a wide portfolio of technologies. [2.7, 3.3, 3.4, 3.6, 4.3, 4.4, 4.6].

20. In 2050[30] global average macro-economic costs for multi-gas mitigation towards stabilization between 710 and 445 ppm CO_2-eq, are between a 1% gain to a 5.5% decrease of global GDP (see Table SPM.6). For specific countries and sectors, costs vary considerably from the global average. (See Box SPM.3 and SPM.4 for the methodologies and assumptions and paragraph 5 for explanation of negative costs) *(high agreement, medium evidence)*.

21. Decision-making about the appropriate level of global mitigation over time involves an iterative risk management process that includes mitigation and adaptation, taking into account actual and avoided climate change damages, co-benefits, sustainability, equity, and attitudes to risk. Choices about the scale and timing of GHG mitigation involve balancing the economic costs of more rapid emission reductions now against the corresponding medium-term and long-term climate risks of delay *[high agreement, much evidence]*.

- Limited and early analytical results from integrated analyses of the costs and benefits of mitigation indicate that these are broadly comparable in magnitude, but do not as yet permit an unambiguous determination of an emissions pathway or stabilization level where benefits exceed costs [3.5].
- Integrated assessment of the economic costs and benefits of different mitigation pathways shows that the economically optimal timing and level of mitigation depends upon the uncertain shape and character of the assumed climate change damage cost curve. To illustrate this dependency:

  o if the climate change damage cost curve grows slowly and regularly, and there is good foresight (which increases the potential for timely adaptation), later and less stringent mitigation is economically justified;

  o alternatively if the damage cost curve increases steeply, or contains non-linearities (e.g. vulnerability thresholds or even small probabilities of catastrophic events), earlier and more stringent mitigation is economically justified [3.6].
- Climate sensitivity is a key uncertainty for mitigation scenarios that aim to meet a specific temperature level. Studies show that if climate sensitivity is high then the timing and level of mitigation is earlier and more stringent than when it is low [3.5, 3.6].
- Delayed emission reductions lead to investments that lock in more emission-intensive infrastructure and development pathways. This significantly constrains the opportunities to achieve lower stabilization levels (as shown in Table SPM.5) and increases the risk of more severe climate change impacts [3.4, 3.1, 3.5, 3.6]

Table SPM.6: *Estimated global macro-economic costs in 2050 relative to the baseline for least-cost trajectories towards different long-term stabilization targets[a)] [3.3, 13.3]*

Stabilization levels (ppm CO_2-eq)	**Median GDP reduction[b)]** (%)	**Range of GDP reduction[b), c)]** (%)	**Reduction of average annual GDP growth rates[b), d)]** (percentage points)
590-710	0.5	-1 - 2	<0.05
535-590	1.3	slightly negative - 4	<0.1
445-535[e)]	not available	<5.5	<0.12

Notes:
a) This corresponds to the full literature across all baselines and mitigation scenarios that provide GDP numbers.
b) This is global GDP based market exchange rates.
c) The median and the 10th and 90th percentile range of the analyzed data are given.
d) The calculation of the reduction of the annual growth rate is based on the average reduction during the period until 2050 that would result in the indicated GDP decrease in 2050.
e) The number of studies is relatively small and they generally use low baselines. High emissions baselines generally lead to higher costs.

30 Cost estimates for 2030 are presented in paragraph 5.

E. Policies, measures and instruments to mitigate climate change

22. A wide variety of national policies and instruments are available to governments to create the incentives for mitigation action. Their applicability depends on national circumstances and an understanding of their interactions, but experience from implementation in various countries and sectors shows there are advantages and disadvantages for any given instrument *(high agreement, much evidence).*

- Four main criteria are used to evaluate policies and instruments: environmental effectiveness, cost effectiveness, distributional effects, including equity, and institutional feasibility [13.2].
- All instruments can be designed well or poorly, and be stringent or lax. In addition, monitoring to improve implementation is an important issue for all instruments. General findings about the performance of policies are: [7.9, 12.2,13.2]
    - o *Integrating climate policies in broader development policies* makes implementation and overcoming barriers easier.
    - o *Regulations and standards* generally provide some certainty about emission levels. They may be preferable to other instruments when information or other barriers prevent producers and consumers from responding to price signals. However, they may not induce innovations and more advanced technologies.
    - o *Taxes and charges* can set a price for carbon, but cannot guarantee a particular level of emissions. Literature identifies taxes as an efficient way of internalizing costs of GHG emissions.
    - o *Tradable permits* will establish a carbon price. The volume of allowed emissions determines their environmental effectiveness, while the allocation of permits has distributional consequences. Fluctuation in the price of carbon makes it difficult to estimate the total cost of complying with emission permits.
    - o *Financial incentives* (subsidies and tax credits) are frequently used by governments to stimulate the development and diffusion of new technologies. While economic costs are generally higher than for the instruments listed above, they are often critical to overcome barriers.
    - o *Voluntary agreements* between industry and governments are politically attractive, raise awareness among stakeholders, and have played a role in the evolution of many national policies. The majority of agreements has not achieved significant emissions reductions beyond business as usual. However, some recent agreements, in a few countries, have accelerated the application of best available technology and led to measurable emission reductions.
    - o *Information instruments* (e.g. awareness campaigns) may positively affect environmental quality by promoting informed choices and possibly contributing to behavioural change, however, their impact on emissions has not been measured yet.
    - o *RD&D* can stimulate technological advances, reduce costs, and enable progress toward stabilization.
- Some corporations, local and regional authorities, NGOs and civil groups are adopting a wide variety of voluntary actions. These voluntary actions may limit GHG emissions, stimulate innovative policies, and encourage the deployment of new technologies. On their own, they generally have limited impact on the national or regional level emissions [13.4].
- Lessons learned from specific sector application of national policies and instruments are shown in Table SPM.7.

23. Policies that provide a real or implicit price of carbon could create incentives for producers and consumers to significantly invest in low-GHG products, technologies and processes. Such policies could include economic instruments, government funding and regulation (*high agreement, much evidence*).

- An effective carbon-price signal could realize significant mitigation potential in all sectors [11.3, 13.2].
- Modelling studies, consistent with stabilization at around 550 ppm CO_2-eq by 2100 (see Box SPM.3), show carbon prices rising to 20 to 80 US\$/tCO_2-eq by 2030 and 30 to 155 US\$/tCO_2-eq by 2050. For the same stabilization level, studies since TAR that take into account induced technological change lower these price ranges to 5 to 65 US\$/tCO_2-eq in 2030 and 15 to 130 US\$/tCO_2-eq in 2050 [3.3, 11.4, 11.5].
- Most top-down, as well as some 2050 bottom-up assessments, suggest that real or implicit carbon prices of 20 to 50 US\$/tCO_2-eq, sustained or increased over decades, could lead to a power generation sector with low-GHG emissions by 2050 and make many mitigation options in the end-use sectors economically attractive. [4.4,11.6]
- Barriers to the implementation of mitigation options are manifold and vary by country and sector. They can be related to financial, technological, institutional, informational and behavioural aspects [4.5, 5.5, 6.7, 7.6, 8.6, 9.6, 10.5].

Table SPM.7: *Selected sectoral policies, measures and instruments that have shown to be environmentally effective in the respective sector in at least a number of national cases.*

Sector	Policies[a)], measures and instruments shown to be environmentally effective	Key constraints or opportunities
Energy supply [4.5]	Reduction of fossil fuel subsidies Taxes or carbon charges on fossil fuels	Resistance by vested interests may make them difficult to implement
	Feed-in tariffs for renewable energy technologies Renewable energy obligations Producer subsidies	May be appropriate to create markets for low emissions technologies
Transport [5.5]	Mandatory fuel economy, biofuel blending and CO_2 standards for road transport	Partial coverage of vehicle fleet may limit effectiveness
	Taxes on vehicle purchase, registration, use and motor fuels, road and parking pricing	Effectiveness may drop with higher incomes
	Influence mobility needs through land use regulations, and infrastructure planning Investment in attractive public transport facilities and non-motorised forms of transport	Particularly appropriate for countries that are building up their transportation systems
Buildings [6.8]	Appliance standards and labelling	Periodic revision of standards needed
	Building codes and certification	Attractive for new buildings. Enforcement can be difficult
	Demand-side management programmes	Need for regulations so that utilities may profit
	Public sector leadership programmes, including procurement	Government purchasing can expand demand for energy-efficient products
	Incentives for energy service companies (ESCOs)	Success factor: Access to third party financing
Industry [7.9]	Provision of benchmark information Performance standards Subsidies, tax credits	May be appropriate to stimulate technology uptake. Stability of national policy important in view of international competitiveness
	Tradable permits	Predictable allocation mechanisms and stable price signals important for investments
	Voluntary agreements	Success factors include: clear targets, a baseline scenario, third party involvement in design and review and formal provisions of monitoring, close cooperation between government and industry
Agriculture [8.6, 8.7, 8.8]	Financial incentives and regulations for improved land management, maintaining soil carbon content, efficient use of fertilizers and irrigation	May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation
Forestry/ forests [9.6]	Financial incentives (national and international) to increase forest area, to reduce deforestation, and to maintain and manage forests	Constraints include lack of investment capital and land tenure issues. Can help poverty alleviation
	Land use regulation and enforcement	
Waste management [10.5]	Financial incentives for improved waste and wastewater management	May stimulate technology diffusion
	Renewable energy incentives or obligations	Local availability of low-cost fuel
	Waste management regulations	Most effectively applied at national level with enforcement strategies

Note:
a) Public RD & D investment in low emissions technologies have proven to be effective in all sectors

24. **Government support through financial contributions, tax credits, standard setting and market creation is important for effective technology development, innovation and deployment. Transfer of technology to developing countries depends on enabling conditions and financing** *(high agreement, much evidence).*

- Public benefits of RD&D investments are bigger than the benefits captured by the private sector, justifying government support of RD&D.
- Government funding in real absolute terms for most energy research programmes has been flat or declining for nearly two decades (even after the UNFCCC came into force) and is now about half of the 1980 level [2.7, 3.4, 4.5, 11.5, 13.2].

- Governments have a crucial supportive role in providing appropriate enabling environment, such as, institutional, policy, legal and regulatory frameworks[31], to sustain investment flows and for effective technology transfer – without which it may be difficult to achieve emission reductions at a significant scale. Mobilizing financing of incremental costs of low-carbon technologies is important. International technology agreements could strengthen the knowledge infrastructure [13.3].
- The potential beneficial effect of technology transfer to developing countries brought about by Annex I countries action may be substantial, but no reliable estimates are available [11.7].
- Financial flows to developing countries through Clean Development Mechanism (CDM) projects have the potential to reach levels of the order of several billions US$ per year[32], which is higher than the flows through the Global Environment Facility (GEF), comparable to the energy oriented development assistance flows, but at least an order of magnitude lower than total foreign direct investment flows. The financial flows through CDM, GEF and development assistance for technology transfer have so far been limited and geographically unequally distributed [12.3, 13.3].

25. **Notable achievements of the UNFCCC and its Kyoto Protocol are the establishment of a global response to the climate problem, stimulation of an array of national policies, the creation of an international carbon market and the establishment of new institutional mechanisms that may provide the foundation for future mitigation efforts** *(high agreement, much evidence).*
    - The impact of the Protocol's first commitment period relative to global emissions is projected to be limited. Its economic impacts on participating Annex-B countries are projected to be smaller than presented in TAR, that showed 0.2-2% lower GDP in 2012 without emissions trading, and 0.1-1.1% lower GDP with emissions trading among Annex-B countries [1.4, 11.4, 13.3].
26. **The literature identifies many options for achieving reductions of global GHG emissions at the international level through cooperation. It also suggests that successful agreements are environmentally effective, cost-effective, incorporate distributional considerations and equity, and are institutionally feasible** *(high agreement, much evidence).*
    - Greater cooperative efforts to reduce emissions will help to reduce global costs for achieving a given level of mitigation, or will improve environmental effectiveness [13.3].
    - Improving, and expanding the scope of, market mechanisms (such as emission trading, Joint Implementation and CDM) could reduce overall mitigation costs [13.3].
    - Efforts to address climate change can include diverse elements such as emissions targets; sectoral, local, sub-national and regional actions; RD&D programmes; adopting common policies; implementing development oriented actions; or expanding financing instruments. These elements can be implemented in an integrated fashion, but comparing the efforts made by different countries quantitatively would be complex and resource intensive [13.3].
    - Actions that could be taken by participating countries can be differentiated both in terms of when such action is undertaken, who participates and what the action will be. Actions can be binding or non-binding, include fixed or dynamic targets, and participation can be static or vary over time [13.3].

F. Sustainable development and climate change mitigation

27. **Making development more sustainable by changing development paths can make a major contribution to climate change mitigation, but implementation may require resources to overcome multiple barriers. There is a growing understanding of the possibilities to choose and implement mitigation options in several sectors to realize synergies and avoid conflicts with other dimensions of sustainable development** *(high agreement, much evidence).*
    - Irrespective of the scale of mitigation measures, adaptation measures are necessary [1.2].
    - Addressing climate change can be considered an integral element of sustainable development policies. National circumstances and the strengths of institutions determine how development policies impact GHG emissions. Changes in development paths emerge from the interactions of public and private decision processes involving government, business and civil society, many of which are not traditionally considered as climate policy. This process is most effective when actors participate equitably and decentralized decision making processes are coordinated [2.2, 3.3, 12.2].
    - Climate change and other sustainable development policies are often but not always synergistic. There is growing evidence that decisions about macroeconomic policy, agricultural policy, multilateral development bank lending, insurance practices, electricity market reform, energy security and forest conservation, for example, which are often treated as being apart from

31 See the IPCC Special Report on Methodological and Technological Issues in Technology Transfer.

32 Depends strongly on the market price that has fluctuated between 4 and 26 US$/tCO2-eq and based on approximately 1000 CDM proposed plus registered projects likely to generate more than 1.3 billion emission reduction credits before 2012.

climate policy, can significantly reduce emissions. On the other hand, decisions about improving rural access to modern energy sources for example may not have much influence on global GHG emissions [12.2].

- Climate change policies related to energy efficiency and renewable energy are often economically beneficial, improve energy security and reduce local pollutant emissions. Other energy supply mitigation options can be designed to also achieve sustainable development benefits such as avoided displacement of local populations, job creation, and health benefits [4.5,12.3].
- Reducing both loss of natural habitat and deforestation can have significant biodiversity, soil and water conservation benefits, and can be implemented in a socially and economically sustainable manner. Forestation and bioenergy plantations can lead to restoration of degraded land, manage water runoff, retain soil carbon and benefit rural economies, but could compete with land for food production and may be negative for biodiversity, if not properly designed [9.7, 12.3].
- There are also good possibilities for reinforcing sustainable development through mitigation actions in the waste management, transportation and buildings sectors [5.4, 6.6, 10.5, 12.3].
- Making development more sustainable can enhance both mitigative and adaptive capacity, and reduce emissions and vulnerability to climate change. Synergies between mitigation and adaptation can exist, for example properly designed biomass production, formation of protected areas, land management, energy use in buildings and forestry. In other situations, there may be trade-offs, such as increased GHG emissions due to increased consumption of energy related to adaptive responses [2.5, 3.5, 4.5, 6.9, 7.8, 8.5, 9.5, 11.9, 12.1].

G. Gaps in knowledge

28. There are still relevant gaps in currently available knowledge regarding some aspects of mitigation of climate change, especially in developing countries. Additional research addressing those gaps would further reduce uncertainties and thus facilitate decision-making related to mitigation of climate change [TS.14].

Endbox 1: Uncertainty representation

Uncertainty is an inherent feature of any assessment. The fourth assessment report clarifies the uncertainties associated with essential statements.

Fundamental differences between the underlying disciplinary sciences of the three Working Group reports make a common approach impractical. The "likelihood" approach applied in "Climate change 2007, the physical science basis" and the "confidence" and "likelihood" approaches used in "Climate change 2007, impacts, adaptation, and vulnerability" were judged to be inadequate to deal with the specific uncertainties involved in this mitigation report, as here human choices are considered.

In this report a two-dimensional scale is used for the treatment of uncertainty. The scale is based on the expert judgment of the authors of WGIII on the level of concurrence in the literature on a particular finding (level of agreement), and the number and quality of independent sources qualifying under the IPCC rules upon which the finding is based (amount of evidence[1]) (see Table SPM.E.1). This is not a quantitative approach, from which probabilities relating to uncertainty can be derived.

Table SPM.E.1: *Qualitative definition of uncertainty*

Level of agreement (on a particular finding) ↑			
	High agreement, limited evidence	**High agreement, medium evidence**	**High agreement, much evidence**
	Medium agreement, limited evidence	**Medium agreement, medium evidence**	**Medium agreement, much evidence**
	Low agreement, limited evidence	**Low agreement, medium evidence**	**Low agreement, much evidence**

Amount of evidence[33] (number and quality of independent sources) →

Because the future is inherently uncertain, scenarios i.e. internally consistent images of different futures - not predictions of the future - have been used extensively in this report.

33 "Evidence" in this report is defined as: Information or signs indicating whether a belief or proposition is true or valid. See Glossary.

20

Perspectives on climate change and sustainability

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This chapter should be cited as:

Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos and R.T. Perez, 2007: Perspectives on climate change and sustainability. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 811-841.

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Executive summary

Vulnerability to specific impacts of climate change will be most severe when and where they are felt together with stresses from other sources [20.3, 20.4, 20.7, Chapter 17 Section 17.3.3] (very high confidence).

Non-climatic stresses can include poverty, unequal access to resources, food security, environmental degradation and risks from natural hazards [20.3, 20.4, 20.7, Chapter 17 Section 17.3.3]. Climate change itself can, in some places, produce its own set of multiple stresses; total vulnerability to climate change, *per se*, is greater than the sum of vulnerabilities to specific impacts in these cases [20.7.2].

Efforts to cope with the impacts of climate change and attempts to promote sustainable development share common goals and determinants including access to resources (including information and technology), equity in the distribution of resources, stocks of human and social capital, access to risk-sharing mechanisms and abilities of decision-support mechanisms to cope with uncertainty [20.3.2, Chapter 17 Section 17.3.3, Chapter 18 Sections 18.6 and 18.7] (very high confidence). Nonetheless, some development activities exacerbate climate-related vulnerabilities [20.8.2, 20.8.3] (very high confidence).

It is very likely that significant synergies can be exploited in bringing climate change to the development community and critical development issues to the climate-change community [20.3.3, 20.8.2, 20.8.3]. Effective communication in assessment, appraisal and action are likely to be important tools, both in participatory assessment and governance as well as in identifying productive areas for shared learning initiatives. Despite these synergies, few discussions about promoting sustainability have thus far explicitly included adapting to climate impacts, reducing hazard risks and/or promoting adaptive capacity [20.4, 20.5, 20.8.3].

Climate change will result in net costs into the future, aggregated across the globe and discounted to today; these costs will grow over time [20.6.1, 20.6.2] (very high confidence).

More than 100 estimates of the social cost of carbon are available. They run from US$-10 to US$+350 per tonne of carbon. Peer-reviewed estimates have a mean value of US$43 per tonne of carbon with a standard deviation of US$83 per tonne. Uncertainties in climate sensitivity, response lags, discount rates, the treatment of equity, the valuation of economic and non-economic impacts and the treatment of possible catastrophic losses explain much of this variation including, for example, the US$310 per tonne of carbon estimate published by Stern (2007). Other estimates of the social cost of carbon span at least three orders of magnitude, from less than US$1 per tonne of carbon to over US$1,500 per tonne [20.6.1]. It is likely that the globally-aggregated figures from integrated assessment models underestimate climate costs because they do not include significant impacts that have not yet been monetised [20.6.1, 20.6.2, 20.7.2, 20.8, Chapter 17 Section 17.2.3, Chapter 19]. It is virtually certain that aggregate estimates mask significant differences in impacts across sectors and across regions, countries and locally [20.6, 20.7, 20.8, Chapter 17 Section 17.3.3]. It is virtually certain that the real social cost of carbon and other greenhouse gases will rise over time; it is very likely that the rate of increase will be 2% to 4% per year [20.6, 20.7]. By 2080, it is likely that 1.1 to 3.2 billion people will be experiencing water scarcity (depending on scenario); 200 to 600 million, hunger; 2 to 7 million more per year, coastal flooding [20.6.2].

Reducing vulnerability to the hazards associated with current and future climate variability and extremes through specific policies and programmes, individual initiatives, participatory planning processes and other community approaches can reduce vulnerability to climate change [20.8.1, 20.8.2, Chapter 17 Sections 17.2.1, 17.2.2 and 17.2.3] (high confidence). Efforts to reduce vulnerability will be not be sufficient to eliminate all damages associated with climate change [20.5, 20.7.2, 20.7.3] (very high confidence).

Climate change will impede nations' abilities to achieve sustainable development pathways as measured, for example, by long-term progress towards the Millennium Development Goals [20.7.1] (very high confidence).

Over the next half-century, it is very likely that climate change will make it more difficult for nations to achieve the Millennium Development Goals for the middle of the century. It is very likely that climate change attributed with high confidence to anthropogenic sources, *per se*, will not be a significant extra impediment to nations reaching their 2015 Millennium Development Targets since many other obstacles with more immediate impacts stand in the way [20.7.1].

Synergies between adaptation and mitigation measures will be effective until the middle of this century (high confidence), but even a combination of aggressive mitigation and significant investment in adaptive capacity could be overwhelmed by the end of the century along a likely development scenario [20.7.3, Chapter 18 Sections 18.4, 18.7, Chapter 19] (high confidence).

Until around 2050, it is likely that global mitigation efforts designed to cap effective greenhouse gas concentrations at 550 ppm would benefit developing countries significantly, regardless of whether climate sensitivity turns out to be high or low and especially when combined with enhanced adaptation. Developed countries would also likely see significant benefits from an adaptation-mitigation intervention portfolio, especially for high climate sensitivities and in sectors and regions that are already showing signs of being vulnerable. However, by 2100, climate change will likely produce significant impacts across the globe, even if aggressive mitigation were implemented in combination with significantly enhanced adaptive capacity [20.7.3].

20.1 Introduction – setting the context

Consistent with the Bruntland Commission (WCED, 1987), the Third Assessment Report (TAR) (IPCC, 2001b) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". There are many alternative definitions, of course, and none is universally accepted. Nonetheless, they all emphasise one or more of the following critical elements: identifying what to develop, identifying what to sustain, characterising links between entities to be sustained and entities to be developed and envisioning future contexts for these links (NRC, 1999). Goals, indicators, values and practices can also frame examinations of sustainable development (Kates et al., 2005). The essence of sustainable development throughout is meeting fundamental human needs in ways that preserve the life support systems of the planet (Kates et al., 2000). Its strength lies in reconciling real and perceived conflicts between the economy and the environment and between the present and the future (NRC, 1999). Authors have emphasised the economic, ecological and human/social dimensions that are the pillars of sustainable development (Robinson and Herbert, 2001; Munasinghe et al., 2003; Kates et al., 2005). The economic dimension aims at improving human welfare (such as real income). The ecological dimension seeks to protect the integrity and resilience of ecological systems, and the social dimension focuses on enriching human relationships and attaining individual and group aspirations (Munasinghe and Swart, 2000), as well as addressing concerns related to social justice and promotion of greater societal awareness of environmental issues (O'Riordan, 2004).

The concept of sustainable development has permeated mainstream thinking over the past two decades, especially after the 1992 Earth Summit where 178 governments adopted Agenda 21 (UNDSD, 2006). Ten years later, the 2002 World Summit on Sustainable Development (WSSD, 2002) made it clear that sustainable development had become a widely-held social and political goal. Even though, as illustrated in Asia by the Institute for Global Environmental Strategies (IGES, 2005), implementation remains problematic, there is broad international agreement that development programmes should foster transitions to paths that meet human needs while preserving the Earth's life-support systems and alleviating hunger and poverty (ICSU, 2002) by integrating these three dimensions (economic, ecological and human/social) of sustainable development. Researchers and practitioners in merging fields, such as 'sustainability science' (Kates et al., 2000), multi-scale decision analysis (Adger et al., 2003) and 'sustainomics' (Munasinghe et al., 2003), seek to increase our understanding of how societies can do just that.

Climate change adds to the list of stressors that challenge our ability to achieve the ecologic, economic and social objectives that define sustainable development. Chapter 20 builds on the assessments in earlier chapters to note the potential for climate change to affect development paths themselves. Figure 20.1 locates its key topics schematically in the context of the three pillars of sustainable development. Topics shown in the centre of the triangle (the 'three-legged stool' of sustainable development) are linked with all three pillars. Other topics, placed outside the triangle, are located closer to one leg or another. The arrows leading from the centre indicate that adaptation to climate change can influence the processes that join the pillars rather than the individual pillars themselves. For example, the technical and economic aspects of renewable resource management could illustrate efforts to support sustainable development by working with the economy-ecology connection – all nested within a decision space of other global development pressures, including poverty.

Section 20.2 begins with a brief review of the current understanding of impacts and adaptive capacity as described earlier (see Chapter 17). Section 20.3 assesses impacts and adaptation in the context of multiple stresses. Section 20.4 focuses on links to environmental quality and explores the notion of adding climate-change impacts and adaptation to the list of components of environmental impact assessments. Section 20.5 addresses implications for risk, hazards and disaster management, including the challenge of reducing vulnerability to current climate variability and adapting to long-term climate change. Section 20.6 reviews global and regionally-aggregated estimates of economic impacts. Section 20.7 assesses the implications for achieving sustainable development across various time-scales. Section 20.8 considers opportunities, co-benefits and challenges for climate-change adaptation, and for linking (or mainstreaming) adaptation into national and regional development planning processes. Section 20.9 finally identifies research priorities.

This entire chapter should be read with the recognition that the first 19 chapters of this volume assess the regional and global impacts of climate change and the opportunities and challenges for adaptation. Chapters 17 and 19 in this volume offer synthetic overviews of this work that focus specifically on adaptation and key vulnerabilities. Chapter 20 in this volume expands the discussion to explore linkages with sustainable development, as do Chapters 2 and 12 in IPCC (2007a). Sustainable development was addressed in IPCC (2001b), but not in IPCC (2001a).

20.2 A synthesis of new knowledge relating to impacts and adaptation

Recent work at the intersection of impacts and adaptation has confirmed that adaptation to climate change is, to a limited extent, already happening (Chapter 17, Section 17.2). Perhaps more importantly for this chapter, recent work has also reconfirmed the utility of the prescription initially presented in Smit et al. (2001) that (1) any system's vulnerability to climate change and climate variability could be described productively in terms of *its exposure to the impacts of climate and its baseline sensitivity to those impacts* and that (2) both exposure and sensitivity can be influenced by that system's *adaptive capacity* (Chapter 17, Section 17.3.3). The list of critical determinants of adaptive capacity was described in Smit et al. (2001) and has been explored subsequently by, for example, Yohe and Tol (2002), Adger and Vincent (2004), Brenkert and Malone (2005)

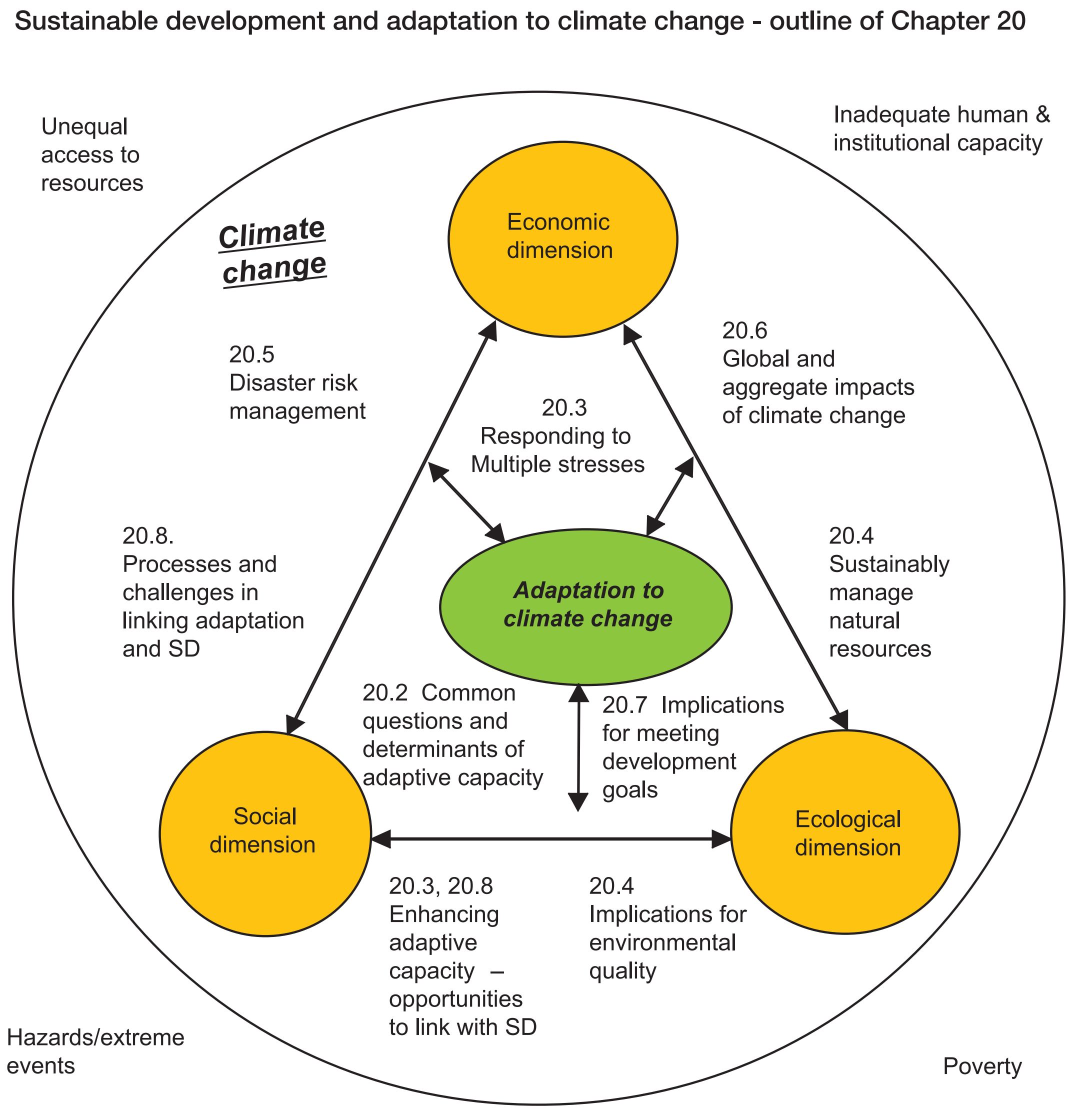

Figure 20.1. *Sustainable development and adaptation to climate change. An outline of Chapter 20 is mapped against the pillars of sustainable development. The figure is adapted from Munasinghe and Swart (2005).*

and Brooks and Adger (2005) – a list that includes access to economic and natural resources, entitlements (property rights), social networks, institutions and governance, human resources and technology (Chapter 17, Section 17.3.3).

It is, however, important to note that recent work has also emphasised the fundamental distinction between adaptive capacity and adaptation implementation. There are significant barriers to implementing adaptation (Chapter 17, Section 17.3.3) and they can arise almost anywhere. The description offered by Kates et al. (2006) of the damages and costs caused by Hurricane Katrina in New Orleans, denominated in economic and human terms, provides a seminal example of this point. Notwithstanding the widely accepted assertion that the United States has high adaptive capacity, the impacts of Hurricane Katrina were fundamentally the result of a failure of adaptive infrastructure (improperly constructed levées that led to a false sense of security) and planning (deficiencies in evacuation plans, particularly in many of the poorer sections of the cities). The capacity provided by public and private investment over the past few decades was designed to handle a hurricane like Katrina; it was the anticipatory efforts to provide protection prior to landfall and response efforts after landfall that failed.

Nothing in the recent literature has undermined a fundamental conclusion in Smit et al. (2001) that "current knowledge of adaptation and adaptive capacity is insufficient for reliable prediction of adaptations; it is also insufficient for rigorous evaluation of planned adaptation options, measures and policies of governments." (page 880). This conclusion is often supported by noting the uneven distribution of adaptive capacity across and within societies (Chapter 17, Section 17.3.2), but strong support can also be derived from the paucity of estimates of the costs of adaptation (Chapter 17, Section 17.2.3). While many adaptations can be implemented at low costs, comprehensive estimates of costs and benefits of adaptation currently do not exist except, perhaps, for costs related to adapting to sea-level rise and changes in the temporal and spatial demand for energy (heating versus cooling). Global diversity is one problem in this regard, but there are others. Anticipating the discussion of multiple stresses that appears in the next section of this chapter, it is now understood that climate change poses novel risks that often lie outside the range of past experience (Chapter 17, Section 17.2.1) and that adaptation measures are seldom undertaken in response to climate change alone (Chapter 17, Sections 17.2.2 and 17.3.3).

20.3 Impacts and adaptation in the context of multiple stresses

20.3.1 A catalogue of multiple stresses

The current literature shows a growing appreciation of the multiple stresses that ecological and socio-economic systems face, how those stresses are likely to change over the next several decades, and what some of the net environmental consequences are likely to be. The Pilot Analysis of Global Ecosystems prepared by the World Resources Institute (WRI, 2000) conducted literature reviews to document the state and condition of forests, agro-ecosystems, freshwater ecosystems and marine systems. The Millennium Ecosystem Assessment (MA) comprehensively documented the condition and recent trends of ecosystems, the services they provide and the socio-economic context within which they occur. It also provided several scenarios of possible future conditions (MA, 2005). For reference, the MA offered some startling statistics. Cultivated systems covered 25% of Earth's terrestrial surface in 2000. On the way to achieving this coverage, global agricultural enterprises converted more area to cropland between 1950 and 1980 than in the 150 years between 1700 and 1850. As of the year 2000, 35% of the world's mangrove areas and 20% of the world's coral reefs had been lost (with another 20% having been degraded significantly). Since 1960, withdrawals from rivers and lakes have doubled, flows of biologically available nitrogen in terrestrial ecosystems have doubled, and flows of phosphorus have tripled. At least 25% of major marine fish stocks have been overfished and global fish yields have actually begun to decline. MA (2005) identified major changes in land cover, the consequences of which were explored by Foley et al. (2005).

The MA (2005) recognised two different categories of drivers of change. Direct drivers of ecosystem change affect ecosystem characteristics in specific, quantifiable ways; examples include land-cover and land-use change, climate change and species introductions. Indirect drivers affect ecosystems in a more diffuse way, generally by affecting one or more direct drivers; here examples are demographic changes, socio-political changes and economic changes. Both types of drivers have changed substantially in the past few decades and will continue to do so. Among direct drivers, for example, over the past four decades, food production has increased by 150%, water use has doubled, wood harvests for pulp and paper have tripled, timber production has doubled and installed hydropower capacity has doubled. On the indirect side, global population has doubled since the 1960s to reach 6 billion people while the global economy has increased more than six fold.

Table 20.1 documents expectations for how several of the direct drivers of ecosystem change are likely to change in magnitude and importance over time. With the exception of polar regions, coastal ecosystems, some dryland systems and montane regions, climate change is not, today, a major source of stress; but climate change is the only direct driver whose magnitude and importance to a series of regions, ecosystems and resources is likely to continue to grow over the next several decades. Table 20.1 illustrates the degree to which these ecosystems are currently experiencing stresses from several direct drivers of change simultaneously. It shows that potential interactions with climate change are likely to grow over the next few decades with the magnitude of climate change itself.

20.3.2 Factors that support sustainable development

A brief excursion into some of the recent literature on economic development is sufficient to support the fundamental observation that the factors that determine a country's ability to promote (sustainable) development coincide with the factors that influence adaptive capacity relative to climate change, climate variability and climatic extremes. The underlying prerequisites for sustainability in specific contexts are highlighted in italics in the discussion which follows. The point about coincidence in underlying factors is made by matching the terms in italics with the list of determinants of adaptive capacity identified above (Chapter 17, Section 17.3.3): *access to resources, entitlements* (property rights), *institutions and governance, human resources* (human capital in the economics literature) and *technology*. They are all reflected in one or more citations from the development literature cited here, and they conform well to the "5 capital" model articulated by Porritt (2005) in terms of human, manufactured, social, natural and financial capital.

Lucas (1988) concluded early on that differences in *human capital* are large enough to explain differences between the long-run growth rates of poor and rich countries. Moretti (2004), for example, showed that businesses located in cities where the fraction of college graduates (highly *educated* work force) grew faster and experienced larger increases in productivity. Guiso et al. (2004) explored the role of *social capital* in peoples' abilities to successfully take advantage of financial structures; they found that *social capital* matters most when education levels are low and law enforcement is weak. Rozelle and Swinnen (2004) looked at transition countries in central Europe and the former Soviet Union; they observed that countries growing steadily a decade or more after economic reform had accomplished a common set of intermediate goals: achieving macroeconomic stability, *reforming property rights*, and *creating institutions to facilitate exchange*. Order and timing did not matter, but meeting all of these underlying objectives was critical. Winters et al. (2004) reviewed a wide literature on the links between trade liberalisation and poverty reduction. They concluded that a favourable relationship depends on the existence and *stability of markets*, the ability of economic actors to handle changes in risk, *access to technology, resources, competent and honest government, policies that promote conflict resolution* and *human capital accumulation*. Shortfalls in any of these underpinnings make it extremely difficult for the most disadvantaged citizens to see any advantage from trade. Finally, Sala-i-Martin et al. (2004) explained economic growth by variation in national

		Habitat change	Climate change	Invasive species	Over-exploitation	Pollution (nitrogen, phosphorus)
Forest	Boreal	Low ↗	Low ↑	Low ↗	Low →	Moderate ↑
	Temperate	High ↘	Low ↑	Low ↑	Moderate →	Moderate ↑
	Tropical	Very high ↑	Low ↑	Low ↑	High ↗	Low ↑
Dryland	Temperate grassland	Very high ↗	Low ↑	Moderate →	Low →	Very high ↑
	Mediterranean	High ↗	Low ↑	High ↑	Moderate →	Low ↑
	Tropical grassland and savanna	High ↗	Moderate ↑	Low ↑	Very high →	Moderate ↑
	Desert	Low →	Moderate ↑	Moderate →	Low →	Low ↑
Inland water		Very high ↑	Low ↑	High ↑	Moderate →	Very high ↑
Coastal		Very high ↗	Moderate ↑	High ↗	High ↗	Very high ↑
Marine		Moderate ↑	Low ↑	Low →	Very high ↗	Low ↑
Island		High →	Low ↑	Very high →	High →	Low ↑
Mountain		High →	Moderate ↑	Low →	Low →	Low ↑
Polar		Low ↗	High ↑	Low →	Moderate ↗	Moderate ↑

RESULT OF PAST EVOLUTION — Driver's impact on biodiversity over the last century: Low; Moderate; High; Very high

WHAT HAPPENS TODAY — Driver's actual trends: Decreasing impact ↘; Continuing impact →; Increasing impact ↗; Very rapid increase of the impact ↑

Source: Millennium Ecosystem Assessment

Table 20.1. *Drivers of change in ecosystem services. Source: Millennium Ecosystem Assessment (MA, 2005).*

participation in primary school education (*human capital*), other measures of human capital (e.g., health measures), *access to affordable investment goods* and the *initial level of per capita income* (access to resources).

20.3.3 Two-way causality between sustainable development and adaptive capacity

It has become increasingly evident, especially since the TAR (IPCC, 2001b), that the pace and character of development influences adaptive capacity and that adaptive capacity influences the pace and character of development. It follows that development paths, and the choices that define them, will affect the severity of climate impacts, not only through changes in exposure and sensitivity, but also through changes in the capacities of systems to adapt. This includes local-scale disaster risk reduction and resource management (e.g., Shaw, 2006; Jung et al., 2005), and broader social dimensions including governance, societal engagement and rights, and levels of education (Haddad, 2005; Tompkins and Adger, 2005; Brooks et al., 2005; Chapter 17, Section 17.3).

Munasinghe and Swart (2005) and Swart et al. (2003) argued that sustainable development measures and climate-change policies, including adaptation, can reinforce each other; Figure 20.2 portrays some of the texture of the interaction that they envisioned. Although scholarly papers on adaptation began to appear in the 1980s, it was not until the 2001 Marrakech Accords that a policy focus on adaptation within the United Nations

Framework Convention on Climate Change (UNFCCC) developed (Schipper, 2006). Klein et al. (2005) suggest that adaptation has not been seen as a viable option, in part because many observers see market forces creating the necessary conditions for adaptation even in the absence of explicit policies and, in part, because understanding of how future adaptation could differ from historical experience is limited.

Efforts to promote alternative development pathways that are more sustainable could include measures to reduce non-renewable energy consumption, for example, or shifting construction of residential or industrial infrastructure to avoid high-risk areas (AfDB et al., 2004). The MA (2005) attempted to describe a global portrait of such a pathway in its "Techno Garden" scenario. In this future, an inter-connected world promotes expanded use of innovative technology, but its authors warned that technology may not solve all problems and could lead to the loss of indigenous cultures. Climate-change measures could also encounter such limitations. Gupta and Tol (2003) describe various climate-policy dilemmas including competition between human rights and property rights.

Adaptation measures embedded within climate-change policies could, by design, try to reduce vulnerabilities and risks by enhancing the adaptive capacity of communities and economies. This would be consistent with sustainability goals. Researchers and practitioners should not equate vulnerability to poverty, though, and they should not consider adaptation and adaptive capacity in isolation. Brooks et al. (2005) conclude that efforts to promote adaptive capacity should incorporate aspects of education, health and governance and thereby extend the context beyond a particular stress (such as climate change) to include factors that are critical in a broader development context. Haddad (2005) noted the critical role played here by general rankings of economic development performance and general reflections of national and local goals and aspirations, and explained how different people might choose different development from the same set of alternatives even if they had the same information.

Past adaptation and development experience displays mixed results. Kates (2000) described several historic climate adaptations (e.g., drought in the Sahel) and development measures (e.g., the Green Revolution) and argued that development measures that were generally consistent with climate adaptation often benefited some groups (e.g., people with access to resources) while harming others (e.g., poor populations, indigenous peoples). Ford et al. (2006) showed that unequal acquisition of new technologies can, under some circumstances, increase vulnerability to external stresses by weakening social networks and thereby altering adaptive capacity within communities and between generations. Belliveau et al. (2006) makes the link to climate explicit by observing that adaptation to non-climatic forces, without explicitly considering climate, can lead to increased vulnerability to climate because adapting previous adaptations can be expensive.

Future links between sustainable development and climate change will evolve from current development frameworks; but recognising the exposure of places and peoples to multiple stresses (Chapter 17; Chapter 19; Section 20.3.1) and accepting the challenge of mainstreaming adaptation into development planning will be critical in understanding what policies will work where and when. For example, in the Sudan, there is a risk that development efforts focusing on short-term relief can undermine community coping capacity (Elasha, 2005). In the mitigation realm, incentives for carbon sequestration could promote hybrid forest plantations and therefore pose a threat to biodiversity and ecosystem adaptability (Caparrós and Jacquemont, 2003; Chapter 18). Development decisions can also produce cumulative threats. In the Columbia River Basin, for

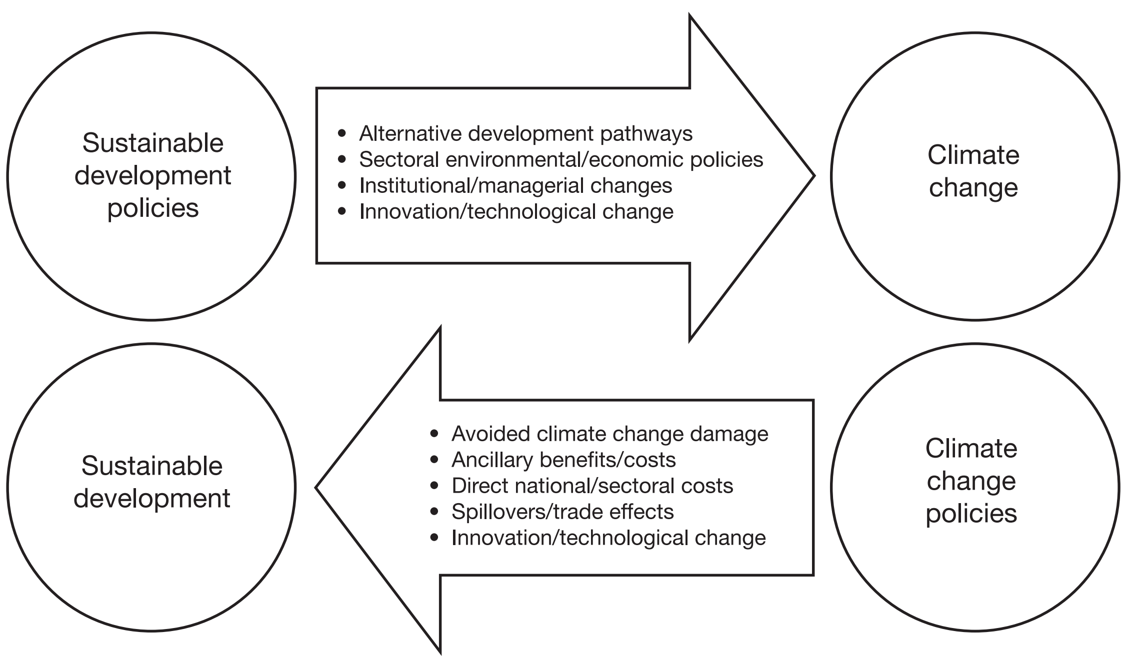

Figure 20.2. *Two-way linkages between climate and sustainable development. Source: Swart et al. (2003).*

instance, extensive water resource development can influence basin management with multiple objectives within scenarios of climate change because climate impacts on stream-flow cause policy dilemmas when decision-makers must balance hydroelectricity production and fisheries protection (Hamlet, 2003; Payne et al., 2004). Restoring in-stream flow to present-day acceptable (but sub-optimum) levels could, in particular, cause hydroelectricity production to decline and production from fossil fuel sources to rise. Interactions of this sort raise important questions on the analysis of the causes of recent climate-related disasters. For example, are observed trends in injuries/fatalities and property losses (Mileti, 1999; Mirza, 2003; MA, 2005; Munich Re, 2005) due to unsustainable development policies, climate change or a mixture of different factors? Could policy interventions reduce these losses in ways that would still meet broader objectives of sustainable development? Some proposed responses for Africa are described in Low (2005) and AfDB et al. (2004).

Globalisation also adds complexity to the management of common-pool resources because increased interdependence makes it more difficult to find equitable solutions to development problems (Ostrom et al., 1999). Increases in the costs associated with various hazards and the prospects of cumulative environmental/economic threats have been described as syndromes. Schellnhuber et al. (1997) identified three significant categories: over-utilisation (e.g., over-cultivation of marginal land in the Sahel), inconsistent development (e.g., urban sprawl and associated destruction of landscapes) and hazardous sinks (e.g., large-scale diffusion of long-lived substances). Schellnhuber et al. (2002) and Lüdeke et al. (2004) describe possible future distributions of some of these syndromes. They suggest how mechanisms of mutual reinforcement, including climate change and development drivers, can help to identify regions where syndromes may expand and others where they might contract.

20.4 Implications for environmental quality

The inseparability of environment and development has been widely recognised ever since the Brundtland Commission (WCED, 1987). In the United Nations' Millennium Development Goals (MDGs), for example, environmental considerations are reflected in the 7th goal and the operative target, among others, is to reverse loss of environmental resources by 2015. Overall, how to meet the target of integrating the principles of sustainable development in national policy and reversing the loss of environmental resources remains a partially answered question for most countries (Kates et al., 2005).

Interest in environmental indicators and performance indices to monitor change has increased recently. A compilation of different sustainable development indicators by Kates et al. (2005) showed that most implicitly or explicitly build from reflections of the health of environmental and ecological resources and/or the quality of environmental and ecological services. This is relevant in both developed and developing countries, but the drivers encouraging sustainable management are arguably strongest in the developed world. Huq and Reid (2004) and Agrawala (2004) have noted, though, that climate change is being increasingly recognised as a key factor that could affect the (sustainable) development of developed and developing countries alike. The Philippine Country Report (1999) identified 153 sustainable development indicators; some pertain to climate-change variables such as level of greenhouse gas emissions, but none refer explicitly to adaptation. There is, for example, no mention within the MDGs of potential changes in climate-related disasters or of the need to include climate-change adaptation within development programmes (Reid and Alam, 2005). This is not unusual, because links between sustainable development and climate change have historically been defined primarily in terms of mitigation.

Promoting environmental quality is about more than encouraging sustainable development or adaptive capacity. It is also about transforming use practices for environmental resources into sustainable management practices. In many countries and sectors, stakeholders who manage natural resources (such as individual farmers, small businesses or major international corporations) are susceptible, over time, to variations in resource availability and hazards; they are currently seeking to revise management practices to make their actions more sustainable. Hilson (2001), for example, describes efforts in the mineral extraction industry where the relevant players include public agencies operating at many scales (from local to national to international). Definitions of sustainability vary across sectors, but their common theme is to change the way resources are exploited or hazards are managed so that adverse impacts downstream or for subsequent generations are reduced. Climate change is, however, seldom listed among the stressors that might influence sustainability. Arnell and Delaney (2006) note, though, that water management in the United Kingdom is an exception.

Published literature on the links between sustainable management of natural resources and the impacts of and adaptation to climate change is extremely sparse. Most focuses on engineering and management techniques which achieve management objectives, such as a degree of protection against flood hazard or a volume of crop production, while having smaller impacts on the environment. Turner (2004) and Harman et al. (2002) speak to this point, but very few engineering analyses consider explicitly how the performance of these measures is affected by climate change or how suitable they would be in the face of a changing climate. Kundzewicz (2002) demonstrated how non-structural flood management measures can be sustainable adaptations to climate change because they are relatively robust to uncertainty. On the other hand, as shown in Clark (2002) and Kashyap (2004), much of the literature on integrated water management in the broadest sense emphasises adaptation to climatic variability and change through the adoption of sustainable and integrated approaches.

Several studies have highlighted the benefits of adopting more sustainable practices, in terms of reduced costs, increased efficiency or financial performance more broadly interpreted. Johnson and Walck (2004) offer an example from forestry while Epstein and Roy (2003) are illustrative of a more expansive context. None of these studies explicitly consider the effects of climate change on the benefits of adopting more sustainable practices; and none of the literature on mechanisms for incorporating sustainable behaviour into organisational practice and monitoring its implementation (e.g., Jasch, 2003; Figge and Hahn, 2004) consider how to incorporate the effects of climate change into mechanisms or monitoring procedures.

Clark (2002) and Bansal (2005) identified several drivers behind moves to become more sustainable. First, altered legal or regulatory requirements may have an effect. Many governments have adopted legislation aimed at encouraging the sustainable use of the natural environment, and some explicitly include reference to climate change. For example, Canada and some EU member states have begun to incorporate climate change in their environmental policies, particularly in the structures of required environmental impact assessments. The hope is that the impact of present and future climates on development projects might thereby be reduced (EEA, 2006; Barrow and Lee, 2000). Ramus (2002) and Thomas et al. (2004) have observed that internally-generated efforts to improve procedures (e.g., following an ethical position held by an influential champion, responding to the desire to reduce costs or risks, or attempting to attract potential clients) can push systems toward sustainability.

Of course, stakeholder expectations may change over time. While these dynamic drivers may encourage sustainable management, they may not in themselves be directly related to concerns over the impacts of and adaptation to climate change. Kates et al. (2005) noted that the principles, goals and practices of sustainability are not fixed and immutable; they are 'works in progress' because the tension between economic development and environmental protection has been opened to reinterpretation from different social and ecological perspectives.

20.5 Implications for risk, hazard and disaster management

The International Decade for Natural Disaster Reduction (1990 to 1999) led to a fundamental shift in the way disasters are viewed: away from the notion that disasters were temporary disruptions to be managed by humanitarian responses and technical interventions and towards a recognition that disasters are a function of both natural and human drivers (ISDR, 2004; UNDP, 2004). The concept of *disaster risk management* has evolved; it is defined as the systematic management of administrative decisions, organisations, operational skills and abilities to implement policies, strategies and coping capacities of society or individuals to lessen the impacts of natural and related environmental and technological hazards (ISDR, 2004). This includes measures to provide not only emergency relief and recovery, but also *disaster risk reduction* (ISDR, 2004); i.e., the development and application of policies, strategies and practices designed to minimise vulnerabilities and the impacts of disasters through a combination of technical measures to reduce physical hazards and to enhance social and economic capacity to adapt. Disaster risk reduction is conceived as taking place within the broad context of sustainable development (ISDR, 2004).

In practice, however, there has been a disconnect between disaster risk reduction and sustainable development, due to a combination of institutional structures, lack of awareness of the linkages between the two, and perceptions of 'competition' between hazard-based risk reduction, development needs and emergency relief (Yamin, 2004; Thomalla et al., 2006). The disconnect persists despite an increasing recognition that natural disasters seriously challenge the ability of countries to meet targets associated with the Millennium Development Goals (Schipper and Pelling, 2006).

A disconnect also exists between disaster risk reduction and adaptation to climate change, again reflecting different institutional structures and lack of awareness of linkages (Schipper and Pelling, 2006; O'Brien et al., 2006). Disaster risk reduction, for example, is often the responsibility of civil defence agencies, while climate-change adaptation is often covered by environmental or energy departments (Thomalla et al., 2006). Disaster risk reduction tends to focus on sudden and short-lived disasters, such as floods, storms, earthquakes and volcanic eruptions, and has tended to place less emphasis on 'creeping onset' disasters such as droughts. Many disasters covered by disaster risk reduction are not affected by climate change. However, there is an increasing recognition of the linkages between disaster risk reduction and adaptation to climate change, since climate change alters not only the physical hazard but also vulnerability. Sperling and Szekely (2005) note that many of the impacts associated with climate change exacerbate or alter existing threats, and adaptation measures can benefit from practical experience in disaster risk reduction. However, some effects of climate change are new within human history (such as the effects of sea-level rise), and there is little experience to tackle such impacts. Sperling and Szekely (2005) therefore state that co-ordinated action to address both existing and new challenges becomes urgent. There is great opportunity for collaboration in the assessment of current and future vulnerabilities, in the use of assessment tools (Thomalla et al., 2006) and through capacity-building measures. Incorporating climate change and its uncertainty into measures to reduce vulnerability to hazard is essential in order for them to be truly sustainable (O'Hare, 2002), and climate change increases the urgency to integrate disaster risk management into development interventions (DFID, 2004).

There are, effectively, two broad approaches to disaster risk reduction, and adaptation to climate change can be incorporated differently into each. The top-down approach is based on institutional responses, allocation of funding and agreed procedures and practices (O'Brien et al., 2006). It is the approach followed in most developed countries, and adaptation to climate change can be implemented by changing guidelines and procedures. In the United Kingdom, for example, design flood magnitudes can be increased by 20% to reflect possible effects of climate change (Richardson, 2002). However, institutional inertia and strongly embedded practices can make it very difficult to change. Olsen (2006), for example, shows how major methodological and institutional changes are needed before flood management in the USA can take climate change (and its uncertainty) into account. The bottom-up approach to disaster risk reduction is based on enhancing the capacity of local communities to adapt to and prepare for disaster (see, for example, Allen, 2006; Blanco, 2006). Actions here include dissemination of technical knowledge and training, awareness raising, accessing local knowledge and resources, and mobilising local communities (Allen, 2006). Climate change can be incorporated in this approach through awareness raising and the transmission of technical knowledge to local communities, but bridging the gap between scientific knowledge and local application is a key challenge (Blanco, 2006).

Reducing vulnerability to current climatic variability can effectively reduce vulnerability to increased hazard risk associated with climate change (e.g., Kashyap, 2004; Goklany, 2007; Burton et al., 2002; Davidson et al., 2003; Robledo et al., 2004). To a large extent, adaptation measures for climate variability and extremes already exist. Measures to reduce current vulnerability by capacity building rather than distribution of disaster relief, for example, will increase resilience to changes in hazard caused by climate change (Mirza, 2003). Similarly, the implementation of improved warning and forecasting methods and the adoption of some land-use planning measures would reduce both current and future vulnerability. However, many responses to current climatic variability would not in and of themselves be a sufficient response to climate change. For example, a changing climate could alter the design standard of a physical defence, such as a realigned channel or a defence wall. It could alter the effectiveness of building codes based on designing against specified return period events (such as the 10-year return period gust). It could alter the area exposed to a potential hazard, meaning that development previously assumed to be 'safe' was now located in a risk area. Finally, it could introduce hazards previously not experienced in an area. Burton and van Aalst (2004), in their assessment of the World Bank Country Strategic Programmes and project cycle, identify the need to assess the success of current adaptation to present-day climate risks and climate variability, especially as they may change with climate change.

20.6 Global and aggregate impacts

Three types of aggregate impacts are commonly reported. In the first, impacts are computed as a percent of gross domestic product (GDP) for a specified rise in global mean temperature. In the second, impacts are aggregated over time and discounted back to the present day along specified emissions scenarios such as those documented in Nakićenović and Swart (2000) under specified assumptions about economic development, changes in technology and adaptive capacity. Some of these estimates are made at the global level, but others aggregate a series of local or regional impacts to obtain a global total. A third type of estimate has recently attracted the most attention. Called the social cost of carbon (SCC), it is an estimate of the economic value of the extra (or marginal) impact caused by the emission of one more tonne of carbon (in the form of carbon dioxide) at any point in time; it can, as well, be interpreted as the marginal benefit of reducing carbon emissions by one tonne. Researchers calculate SCC by summing the extra impacts for as long as the extra tonne remains in the atmosphere – a process which requires a model of atmospheric residence time and a means of discounting economic values back to the year of emission.

This section provides a brief discussion of the historical and current status of efforts to produce aggregate estimates of the impacts of climate change. The first sub-section focuses attention on economic estimates and the second begins to expand the discussion by reporting estimates calibrated in alternative metrics. It is in this expansion that the implications of spatial and temporal diversity in systems' exposures and sensitivities to climate change begin to emerge.

20.6.1 History and present state of aggregate impact estimates

Most of the aggregate impacts reported in IPCC (1996) were of the first type; they monetised the likely damage that would be caused by a doubling of CO_2 concentrations. For developed countries, estimated damages were of the order of 1% of GDP. Developing countries were expected to suffer larger percentage damages, so mean global losses of 1.5 to 3.5% of world GDP were therefore reported. IPCC (2001a) reported essentially the same range because more modest estimates of market damages were balanced by other factors such as higher non-market impacts and improved coverage of a wide range of uncertainties. Most recently, Stern (2007) took account of a full range of both impacts and possible outcomes (i.e., it employed the basic economics of risk premiums) to suggest that the economic effects of unmitigated climate change could reduce welfare by an amount equivalent to a persistent average reduction in global per capita consumption of at least 5%. Including direct impacts on the environment and human health (i.e., 'non-market' impacts) increased their estimate of the total (average) cost of climate change to 11% GDP; including evidence which indicates that the climate system may be more responsive to greenhouse-gas emissions than previously thought increased their estimates to 14% GDP. Using equity weights to reflect the expectation that a disproportionate share of the climate-change burden will fall on poor regions of the world increased their estimated reduction in equivalent consumption per head to 20%.

Figure 20.3 compares the Stern (2007) relationship between global impacts and increases in global mean temperature with estimates drawn from earlier studies that were assessed in IPCC (2001b). The Stern (2007) trajectories all show negative impacts for all temperatures; they reflect the simple assumptions of the underlying PAGE2002 model and a focus on risks associated with higher temperatures. The Mendelsohn et al. (1998) estimates aggregate regional monetary damages (both positive and negative) without equity weighting. The two Nordhaus and Boyer (2000) trajectories track aggregated regional monetary estimates of damages with and without population-based equity weighting; they do include a 'willingness to pay (to avoid)' reflection of the costs of abrupt change. The two Tol (2002) trajectories track aggregated regional monetary estimates of damages with and without utility-based equity weighting. The various relationships depicted in Figure 20.3 therefore differ in their treatment of equity weighting, in their efforts to capture the potential of beneficial climate change (in, for example,

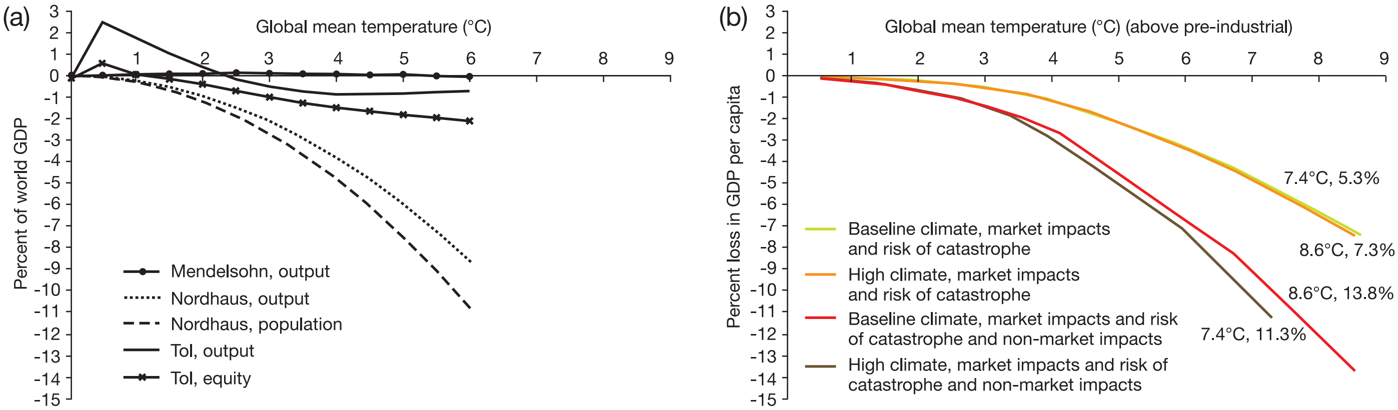

Figure 20.3. *(a) Damage estimates, as a percent of global GDP, as correlated with increases in global mean temperature. Source: IPCC (2001b). (b) Damage estimates, as a percent of global GDP, are correlated with increases in global mean temperature. Source: Stern (2007).*

agriculture for small increases in temperature; see Chapter 5, Section 5.4.7) and in their treatment of the risks of catastrophe for large increases in temperature.

Early calculations of the SCC (IPCC (1996) estimates ranged from US$5 to $125 per tonne of carbon in 1990 dollars) stimulated recurring interest, as part of wider post-Kyoto considerations, in the economic benefits of climate-change policy (Watkiss et al., 2005). After surveying the literature, Clarkson and Deyes (2002) proposed a central value of US$105 per tonne of carbon (in year 2000 prices) for the SCC, with upper and lower values of US$50 and $210 per tonne. Pearce (2003) argued that 3% is a reasonable representation of a social discount rate so the probable range of the SCC in 2003 should have been in the region of US$4 to 9 per tonne of carbon. Tol (2005) gathered over 100 estimates of the SCC from 28 published studies and combined them to form a probability density function; it displayed a median of US$14 per tonne of carbon, a mean of US$93 per tonne and a 95th percentile estimate equal to US$350 per tonne. Peer-reviewed studies generally reported lower estimates and smaller uncertainties than those which were not; their mean was US$43 per tonne of carbon with a standard deviation of US$83. The survey showed that 10% of the estimates were negative; to support these estimates, the climate sensitivity was assumed to be low and small increases in global mean temperature brought benefits (as suggested by the Tol (2002) trajectories in Figure 20.3).

Notwithstanding the differences in damage sensitivity to temperature reflected in Figure 20.3, the effect of the discount rate (see glossary) on estimates of SCC is most striking. The 90th percentile SCC, for instance, is US$62/tC for a 3% pure rate of time preference, $165/tC for 1% and $1,610/tC for 0%. Stern (2007) calculated, on the basis of damage calculations described above, a mean estimate of the SCC in 2006 of US$85 per tonne of CO_2 (US$310 per tonne of carbon). Had it been included in the Tol (2005) survey, it would have fallen well above the 95th percentile, in large measure because of their adoption of a low 0.1% pure rate of time preference. Other estimates of the SCC run from less than US$1 per tonne to over US$1,500 per tonne of carbon. Downing et al. (2005) argued that this range reflects uncertainties in climate and impacts, coverage of sectors and extremes, and choices of decision variables. Tol (2005) concluded, using standard assumptions about discounting and aggregation, that the SCC is unlikely to exceed US$50/tC. In contrast, Downing et al. (2005) concluded that a lower benchmark of US$50/tC is reasonable for a global decision context committed to reducing the threat of dangerous climate change and including a modest level of aversion to extreme risks, relatively low discount rates and equity weighting.

Climate change is not caused by carbon dioxide alone, and integrated assessment models can calculate the social cost of each greenhouse gas under consistent assumptions. For instance, the mean estimate from the PAGE2002 model for the social cost of methane is US$105 per tonne emitted in 2001, in year 2000 dollars, with a 5 to 95% uncertainty range of US$25 to $250 per tonne. The estimate for the social cost of SF_6 is US$200,000 per tonne emitted in 2001 with a 5 to 95% range of US$45,000 to $450,000 per tonne. These are all higher than the corresponding US$19 per tonne estimate for SCC that is surrounded by a 5 to 95% range of US$4 to $50 per tonne (Hope, 2006b). It has been known since IPCC (1996) that the SCC will increase over time; current knowledge suggests a 2.4% per year rate of growth. The social cost of methane will grow 50% faster because of its shorter atmospheric lifetime. Unlike later emissions, any extra methane emitted today will have disappeared before the most severe climate-change impacts occur (Watkiss et al., 2005).

Tol (2005) finds that much of the uncertainty in the estimates of the SCC can be traced to two assumptions: one on the discount rate and the other on the equity weights that are used to aggregate monetised impacts over countries. In most other policy areas, the rich do not reveal as much concern for the poor as is implied by the equity weights used in many models. Downing et al. (2005) state that the extreme tails of the estimates of the SCC depend as much on decision values (such as discounting and equity weighting) as on the climate forcing and uncertainty in the underlying impact models. Integrated models are always simplified representations of reality. To be comprehensive, other social and cultural values need to be given comparable weights to economic values, and there are prototype integrated assessment models to demonstrate this (Rotmans and de Vries, 1997).

Table 20.2 shows the six major influences calculated by PAGE2002 and reported in Hope (2005). That the list can be divided into two scientific and four socio-economic parameters is another strong argument for the building of integrated assessment models (IAMs); models that are exclusively scientific, or exclusively economic, would omit parts of the climate-change problem which still contain profound uncertainties. The two top influences are the climate sensitivity and the pure rate of time preference. Climate sensitivity is positively correlated with the SCC, but the pure time preference rate is negatively correlated with the SCC. Non-economic impact ranks third and economic impact ranks sixth (Hope, 2005).

A few models have existed for long enough to trace the changes in their estimates of the SCC over time. Table 20.3 shows how the results from three integrated assessment models have evolved over the last 15 years. The DICE and PAGE estimates have not changed greatly over the years, but this gives a misleading impression of stability. The values from PAGE have changed little because several quite significant changes have approximately cancelled each other out. In the later studies, lower estimates for market-sector impacts in developed countries are offset by higher non-market impacts, equity weights and inclusion of estimates of the possible impacts of large-scale discontinuities (Tol, 2005).

Hitz and Smith (2004) found that the relationships between global mean temperature and impacts of the sort displayed in Figure 20.3 are not consistent across sectors for modest amounts of warming. Beyond an approximate 3 to 4°C increase in global mean temperature above pre-industrial levels, all sectors (except possibly forestry) show increasingly adverse impacts. Tol (2005) found that few studies cover non-market damages, the risk of potential extreme weather, socially contingent effects, or the potential for longer-term catastrophic events. Therefore, uncertainty in the value of the SCC is derived not only from the 'true' value of impacts that are covered by the models, but also from impacts that have not yet been quantified and valued. As argued in Watkiss et al. (2005) and displayed in Figure 20.4, existing estimates of SCC are products of work that spans only a sub-set of impacts for which complete estimates might be calculated. Nonetheless, current estimates do provide enough information to support meaningful discussions about reducing the emissions of CO_2, methane and other greenhouse gases, and the appropriate trade-off between gases.

Nonetheless, estimates of SCC offer a consistent way to internalise current knowledge about the impacts of climate change into development, mitigation and/or adaptation decisions that the private and public sector will be making over the near term (Morimoto and Hope, 2004). According to economic theory, if the social cost calculations were complete and markets were perfect, then efforts to cut back the emissions of greenhouse gases would continue as long as the marginal cost of the cutbacks were lower than the social cost of the impacts they cause. If taxes were used, then they should be set equal to the SCC. If tradable permits were used, then their price should be the same as the SCC. If their price turns out to be lower than the social cost, then the total allocation of permits would have been too large and *vice versa*. In any comparison between greenhouse gases, according to Pearce (2003), the SCC is the correct figure to use. For reference, spot prices for permits in the European Carbon Trading Scheme since its inception early in 2005 started out towards the bottom end of the range of the SCC, but they rose quickly to around US$100 per tonne of carbon before falling by about 50% in the early summer of 2006 amid concerns that the carbon allowances allocated by the European Commission at the start of the scheme had been too generous. In the real world, markets are not perfect, calculations of the SCC are far from complete, and both mask significant differences between regions and types of impacts.

Table 20.2. *Major factors causing uncertainty in the social cost of carbon. Relative importance is measured by the magnitude of the partial rank correlation coefficient between the parameter and the SCC, with the most important indexed to 100. A + sign shows that an increase in this parameter leads to an increase in the SCC and vice versa. Source: Hope (2005).*

Parameter	Definition	Sign	Range	Importance
Climate sensitivity	Equilibrium temperature rise for a doubling of CO_2 concentration	+	1.5 to 5°C	100
PTP rate	Pure time preference for consumption now rather than in 1 year's time	-	1 to 3% /yr	66
Non-economic impact	Valuation of non-economic impact for a 2.5°C temperature rise	+	0 to 1.5% of GDP	57
Equity weight	Negative of the elasticity of marginal utility with respect to income	-	0.5 to 1.5	50
Climate change half life	Half life in years of global response to an increase in radiative forcing	-	25 to 75 years	35
Economic impact	Valuation of economic impact for a 2.5°C temperature rise	+	-0.1 to 1.0% of GDP	32

Note: non-economic and economic impact ranges apply to Europe; impacts in other regions are expressed as a multiple of this.

Table 20.3. *Estimates of the social cost of carbon over time from three models (in constant 2000 US$). Sources: DICE best guesses of Nordhaus and Boyer (2000) are from Pearce (2003); FUND estimates are from Tol (1999), and 25 to 75% range with green book discounting and equity weights from Downing et al. (2005); PAGE 5th and 95th percentile ranges from Plambeck and Hope (1996), rebased to year 2000, and Hope (2006a).*

Date of estimate	1990	1995	2000	2005
DICE	$10	$7	$6	
FUND			$9 to $23	-$15 to $110
PAGE		$12 to $60		$4 to $51

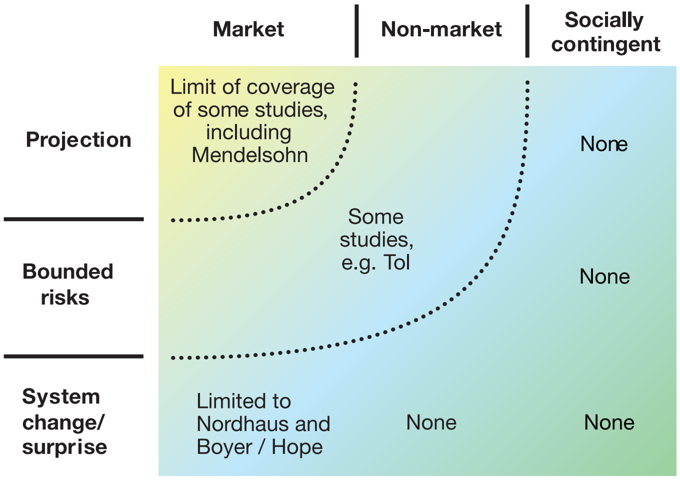

Figure 20.4. *Coverage of studies that compute estimates of the social cost of carbon against sources of climate-related risk. Coverage of most studies is limited to market-based sectors, and few of them move beyond the upper left corner to include bounded risks and abrupt system change. Source: Watkiss et al., 2005.*

20.6.2 Spatially-explicit methods: global impacts of climate change

Warren (2006) and Hitz and Smith (2004) observe that most impact assessments are conducted at the local scale. It is therefore extremely difficult to estimate impacts across the global domain from these localised studies. A small number of studies have used geographically-distributed impacts models to estimate the impacts of climate change across the global domain. The "Fast Track" studies (Arnell, 2004; Nicholls, 2004; Arnell et al., 2002; Levy et al., 2004; Parry et al., 2004; Van Lieshout et al., 2004) used a consistent set of scenarios and assumptions to estimate the effects of scenarios based on the HadCM3 climate model on water resource availability, food security, coastal flood risk, ecosystem change and exposure to malaria. Schroeter et al. (2005) used a similar approach in the ATEAM project to tabulate impacts across Europe using scenarios constructed from a larger number of climate models.

Both these sets of studies used a wide range of metrics that varied across sectors. Table 20.4 summarises some of the global-scale impacts of defined climate-change scenarios. Although the precise numbers depend on the climate model used and some key assumptions (particularly the effect of increased CO_2 concentrations on crop productivity), it is clear that the future impacts of climate change are dependent not only on the rate of climate change, but also on the future social, economic and technological state of the world. Impacts are greatest under an A2 world, for example, not because the climate change is greatest but because there are more people to be impacted. Impacts also vary regionally and Table 20.5 summarises impacts by major world region. The assumed effect of CO_2 enrichment on crop productivity has a major effect on estimated changes in population at risk of hunger (Chapter 5, Section 5.4.7).

Table 20.6 compares the global impacts of a 1% annual increase in CO_2 concentrations (i.e., the IS92a scenario, see IPCC, 1992) with the impacts of emissions trajectories stabilising at 750 (S750) and 550 (S550) ppm (Arnell et al., 2002). The results are not directly comparable to those reported in Table 20.4, because different population assumptions, methodologies and indicators were employed in their preparation. Nevertheless, the results suggest that aiming for stabilisation at 750 ppm has a relatively small effect on impacts in most sectors in comparison with 550 ppm stabilisation. The S550 pathway has a greater apparent impact on exposure to hunger because higher CO_2 concentrations under S750 result in a greater increase in crop productivity (but again, note that CO_2-enrichment effects are highly uncertain).

Each of these tables present *indicators* of impact which ignore adaptations that will occur over time. They can therefore be seen as indicative of the challenge to be overcome by adaptations to offset some of the impacts of climate change. Incorporating adaptation into global-scale assessments of the impacts of climate change is currently difficult for a number of reasons (including diversity of circumstances, diversity of potential objectives of adaptation, diversity of ways of meeting adaptation objectives and uncertainty over the effectiveness of adaptation options) and remains an area where more research is needed.

Table 20.4. *Global-scale impacts of climate change by 2080.*

	Climate and socio-economic scenario			
	A1FI	A2	B1	B2
Global temperature change (°C difference from the 1961-1990 period)	3.97	3.21 to 3.32	2.06	2.34 to 2.4
Millions of people at increased risk of hunger (Parry et al., 2004); no CO_2 effect	263	551	34	151
Millions of people at increased risk of hunger (Parry et al., 2004); with maximum direct CO_2 effect	28	-28 to -8	12	-12 to +5
Millions of people exposed to increased water resources stress (Arnell, 2004)	1256	2583 to 3210	1135	1196 to 1535
Additional numbers of people (millions) flooded in coastal floods each year, with lagged evolving protection (Nicholls, 2004)	7	29	2	16

Note: change in climate derived from the HadCM3 climate model. Impacts are compared to the situation in 2080 with no climate change. The range of impacts under the SRES A2 and B2 scenarios (Nakićenović and Swart, 2000) represents the range between different climate simulations. The figures for additional millions of people flooded in coastal floods assumes a low rate of subsidence and a low rate of population concentration in the coastal zone.

Table 20.5. *Regional-scale impacts of climate change by 2080 (millions of people).*

	Population living in watersheds with an increase in water-resources stress (Arnell, 2004)				Increase in average annual number of coastal flood victims (Nicholls, 2004)				Additional population at risk of hunger (Parry et al., 2004)[1] Figures in brackets assume maximum direct CO_2-enrichment effect			
	Climate and socio-economic scenario:											
	A1	A2	B1	B2	A1	A2	B1	B2	A1	A2	B1	B2
Europe	270	382-493	233	172-183	1.6	0.3	0.2	0.3	0	0	0	0
Asia	289	812-1197	302	327-608	1.3	14.7	0.5	1.4	78 (6)	266 (-21)	7 (2)	47 (-3)
North America	127	110-145	107	9-63	0.1	0.1	0	0	0	0	0	0
South America	163	430-469	97	130-186	0.6	0.4	0	0.1	27 (1)	85 (-4)	5 (2)	15 (-1)
Africa	408	691-909	397	492-559	2.8	12.8	0.6	13.6	157 (21)	200 (-2)	23 (8)	89 (-8)
Australasia	0	0	0	0	0	0	0	0	0	0	0	0

Note: change in climate derived from the HadCM3 climate model. Impacts are compared to the situation in 2080 with no climate change. The range of impacts under the SRES A2 and B2 scenarios (Nakićenović and Swart, 2000) represents the range between different climate simulations. The figures for additional millions of people flooded in coastal floods assumes a low rate of subsidence and a low rate of population concentration in the coastal zone.

[1] Analysis of project results carried out for this table.

Table 20.6. *Global-scale impacts under unmitigated and stabilisation pathways. Source: Arnell et al., 2002.*

	Unmitigated	2050 Scenario: S750	S550	Unmitigated	2050 Scenario: S750	S550
Approximate equivalent CO_2 concentration (ppm)	520	485	458	630	565	493
Approximate global temperature change (°C difference from 1961 to 1990)	2.0	1.3	1.1	2.9	1.7	1.2
Area potentially experiencing vegetation dieback (million km^2)	1.5 to 2.7	2	0.7	6.2 to 8	3.5	1.3
Millions of people exposed to increased water stress	200 to 3200	2100	1700	2830 to 3440	2920	760
Additional people flooded in coastal floods (millions/year)	20	13	10	79 to 81	21	5
Population at increased risk of hunger (millions)	-3 to 9	7	5	69 to 91	16	43

Note: climate scenarios based on HadCM2 simulations: the range with unmitigated emissions reflects variation between ensemble simulations.

Aggregation of impacts to regional and global scales is another key problem with such geographically-distributed impact assessments. Tables 20.4 to 20.6, for example, keep track of people living in watersheds who will face increased water-related stress. Of course, many people live in watersheds where climate change increases runoff and therefore may apparently see *reduced* water-related stress (if they see increased risk of flooding). Simply calculating the 'net' impact of climate change, however, is complicated, particularly where 'winners' and 'losers' live in different geographic regions, or where 'costs' and 'benefits' are not symmetrical. Watersheds with an increase in runoff, for example, are concentrated in east Asia, while watersheds with reduced runoff are much more widely distributed. Similarly, the adverse effects felt by 100 million people exposed to increased water stress could easily outweigh the 'benefits' of 100 million people with reduced stress.

The Defra Fast Track and ATEAM studies both describe impacts along defined scenarios, so it is difficult to infer the effects of different rates or degrees of climate change on different socio-economic worlds. A more generalised approach applies a wide range of climate scenarios representing different rates of change to estimate impacts for specific socio-economic contexts. Leemans and Eickhout (2004), for example, show that most species, ecosystems and landscapes would be impacted by increases of global temperature between 1 and 2°C above 2000 levels. Arnell (2006) showed that an increase in temperature of 2°C above the 1961 to 1990 mean by 2050 would result in between 550 and 900 million people suffering an increase in water-related stress in both the SRES (Special Report on Emissions Scenarios, Nakićenović and Swart, 2000) A1 and B1 worlds. In this case, the range between estimates represents the effect of different changes in rainfall patterns for a 2°C warming.

20.7 Implications for regional, sub-regional, local and sectoral development; access to resources and technology; equity

The first sub-section here addresses issues of equity and access to resources as measured by the likelihood of meeting Millennium Development Targets by 2015 and Millennium Development Goals until the middle of this century. Vulnerability to climate change is unlikely to be the dominant cause of trouble for most nations as they try to reach the 2015 Targets. However, an assortment of climate-related vulnerabilities will seriously impede progress in achieving the mid-century goals. The second sub-section considers the range of these vulnerabilities across regions and sectors in 2050 and 2100 before the last offers portraits of the global distribution of vulnerability with and without enhanced adaptive capacity and/or mitigation efforts.

20.7.1 Millennium Development Goals – a 2015 time slice

The Millennium Development Goals (MDGs) are the product of international consensus on a framework by which nations can assess tangible progress towards sustainable development; they are enumerated in Table 20.7. UN (2005) provides the most current documentation of the 8 MDGs, the 11 specific targets for progress by 2015 or 2020 and the 32 quantitative indicators that are being used as metrics. This chapter has made the point that sustainable development and adaptive capacity for coping with climate change have common determinants. It is easy, therefore, to conclude that climate change has the potential to affect the progress of nations and societies towards sustainability. MA (2005) supports this conclusion. Climate-change impacts on the timing, flow and amount of available freshwater resources could, for example, affect the ability of developing countries to increase access to potable water: Goal #7, Target #10, Indicator #30 (UN, 2005). It is conceivable that climate change could have measurable consequences, in some parts of the world at least, on the indicators of progress on food security: Goal #1, Target #2, Indicators #4 and #5 (UN, 2005). Climate-change impacts could possibly affect one indicator in Goal #6 (prevalence and death rates associated with malaria), over the medium term (UN, 2005). The list can be extended.

The anthropogenic drivers of climate change, *per se*, affect MDG indicators directly in only two ways: in terms of energy use per dollar GDP and CO_2 emissions per capita. While climate change may, with high confidence, have the potential for substantial effects on aspects of sustainability that are important for the MDGs, the literature is less conclusive on whether the metrics themselves will be sensitive to either the effects of climate change or to progress concerning its drivers, especially in the near term. The short-term targets of the MDGs (i.e., the 2015 to 2020 Targets) will be difficult to reach in any case. While climate impacts have now been observed with some levels of confidence in some places, it will be difficult to blame climate change for limited progress towards the Millennium Development Targets.

Table 20.7. *The Millennium Development Goals.*

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development
Source: http://www.un.org/millenniumgoals/documents.html

In the longer term, Arrow et al. (2004) argue that adaptation decisions can reduce the effective investment available to reach the MDGs. They thereby raise the issue of opportunity costs: perhaps investment in climate adaptation might retard efforts to achieve sustainable development. Because the determinants of adaptive capacity and of sustainable development overlap significantly; however, (see Section 20.2) it is also possible that a dollar spent on climate adaptation could strengthen progress towards sustainable development.

Whether synergistic effects or trade offs will dominate interactions between climate impacts, adaptation decisions and sustainable development decisions depend, at least in part, on the particular decisions that are made. Decisions on how countries will acquire sufficient energy to sustain growing demand will, for example, play crucial roles in determining the sustainability of economic development. If those demands are met by increasing fossil fuel combustion, then amplifying feedbacks to climate change should be expected. There are some indications that this is now occurring. Per capita emissions of CO_2 in developing countries rose from 1.7 tonnes of CO_2 per capita in 1990 to 2.1 tonnes per capita in 2002; they remained, though, far short of the 12.6 tonnes of CO_2 per capita consumed in developed countries (UN, 2005). Resources devoted to expanding fossil fuel generation could, therefore, be seen as a source of expanded climate-change impacts. On the other hand, investments in forestry and agricultural sectors designed to preserve and enhance soil fertility in support of improved food security MDGs (e.g., Goal #1) might have synergies for climate mitigation (through carbon sequestration) and for adaptation (because higher economic returns for local communities could be invested in adaptation). It is simply impossible to tell, *a priori*, which effect will dominate. Each situation must be analysed qualitatively and quantitatively.

These complexities make it clear that not all development paths will be equal with respect to either their consequences for climate change or their consequences for adaptive capacity. Moreover, the Millennium Ecosystem Assessment (MA, 2005) and others (e.g., AfDB et al., 2004) argue that climate change will be a significant hindrance to meeting the MDGs over the long term. There is no discrepancy here because stresses from climate change will grow over time. Some regions and countries are already lagging in their progress towards the MDGs and these tend to be in locations where climate vulnerabilities over the 21st century are likely to be high. For example, the proportion of land area covered by forests fell between 1990 and 2000 in sub-Saharan Africa, South-East Asia and Latin America and the Caribbean, while it appeared to stabilise in developed countries (UN, 2005). Energy use per unit of GDP fell between 1990 and 2002 in both developed and developing regions, but developed regions remained approximately 10% more efficient than developing regions (UN, 2005). In short, regions where ecosystem services and contributions to human well-being are already being eroded by multiple external stresses are more likely to have low adaptive capacity.

20.7.2 Sectoral and regional implications

The range of increase in global mean temperature that could be expected over the next several centuries is highly uncertain. The compounding diversity in the regional patterns of temperature change for selected changes in global mean temperature is depicted elsewhere in IPCC (2007b, Figure SPM.6); so, too, are illustrations of geographic diversity in changes in precipitation and model disagreement about even the sign of this change (IPCC, 2007b, Figure SPM.7). Earlier sections of this chapter have also underscored the difficulty in anticipating the development of adaptive capacity and the ability of communities to take advantage of the incumbent opportunities. Despite all of this complexity, however, it is possible to offer some conclusions about vulnerability across regions and sectors as reported throughout this report.

Locating the anticipated impacts of climate change on a map is perhaps the simplest way to see this point. Figure 9.5, for example, shows the spatial distribution of the projected impacts that are reported for Africa in Chapter 9. The power of maps like this lies in their ability to show how the various manifestations of climate change can be geographically concentrated. It is clear, as a result, that climate change can, by virtue of its multiple dimensions, be its own source of multiple stresses. It follows immediately that vulnerability to climate change can easily be amplified (in the sense that total vulnerability to climate change is greater than the sum of vulnerabilities to specific impacts) in regions like the south-eastern coast of Africa and Madagascar.

Maps of this sort do not, however, capture sensitivities to larger indices of climate change (such as increases in global mean temperature); nor do they not offer any insight into the timing of increased vulnerabilities.

Tables 20.8 and 20.9 address these deficiencies by summarising estimated impacts at global and regional scales against a range of changes in global average temperature. Each entry is drawn from earlier chapters in this report, and assessed levels of confidence are indicated. The entries have been selected by authors of the chapters and the selection is intended to illustrate impacts that are important for human welfare. The criteria for judging this importance include the magnitude, rate, timing and persistence/irreversibility of impacts, and the capacity to adapt to them. Where possible, the entries give an indication of impact trend and its quantitative level. In a few cases, quantitative measures of impact have now been estimated for different amounts of climate change, thus pointing toward different levels of the same impact that might be avoided by not exceeding given amounts of global temperature change.

The time dimension is captured by the bars drawn at the top of Table 20.8; they indicate the range of global average temperature increase that could be expected during the 2020s, the 2050s and the 2080s among the SRES collection of unmitigated scenarios as well as a range of alternative stabilisation pathways (Nakićenović and Swart, 2000). The real message to be drawn from their inclusion is that no temperature threshold associated with any subjective judgment of what might constitute 'dangerous' climate change can be guaranteed by anything but the most stringent of mitigation interventions, at least not on the basis of current knowledge. Moreover, there is an estimated commitment to warming of 0.6°C due to past emissions, from which impacts must be expected, regardless of any future efforts to reduce emissions in the future.

20.7.3 The complementarity roles of mitigation and enhanced adaptive capacity

IPCC (2001a) focused minimal attention on the co-benefits of mitigation and adaptation, but this report has added a chapter-length assessment of current knowledge at the nexus of adaptation and mitigation. An emphasis on constructing a "portfolio of adaptation and mitigation actions" has emerged (Chapter 18, Sections 18.4 and 18.7). Moreover, the capacities to respond in either dimension are supported by 'similar sets of factors' (Chapter 18, Section 18.6). These factors are, of course, themselves determined by underlying socio-economic and technological development paths that are location and time specific.

Yohe et al. (2006a, b) offer suggestive illustrations of potential synergies within the adaptation/mitigation portfolio; complementarity in the economic sense that one makes the other more productive. Figures 20.5 and 20.6 display the geographic distribution of these synergies in terms of a national vulnerability index with and without mitigation, and with and without enhanced adaptive capacity by 2050 and 2100, respectively. Vulnerabilities that were assigned to specific countries on the basis of a vulnerability index derived from national estimates of adaptive capacity provided by Brenkert and Malone (2005) and the geographic distribution of temperature change derived from a small ensemble of global circulation models. The upper left panels of Figures 20.5 and 20.6 present geographical distributions of vulnerability in 2050 and 2100, respectively, along the SRES A2 emissions scenario with a climate sensitivity of 5.5°C under the limiting assumption that adaptive capacities are fixed at current levels; global mean temperature climbs by 1.6°C and 4.9°C above 1990 levels by 2050 and 2100, respectively. These two panels are benchmarks of maximum vulnerability against which other options can be assessed. Notice that most of Africa plus China display the largest vulnerabilities in 2050 and that nearly every nation displays extreme vulnerability by 2100. A2 was chosen for illustrative clarity with reference to temperature change only. Moreover, none of the interpretations depend on the underlying storyline of the A2 scenario; Yohe et al. (2006b) describes comparable results for other scenarios.

The upper right panels present comparable geographic distributions under the assumption that adaptive capacity improves everywhere with special emphasis on developing countries; their capacities are assumed to advance to the current global mean by 2050 and 2100 for Figures 20.5 and 20.6,

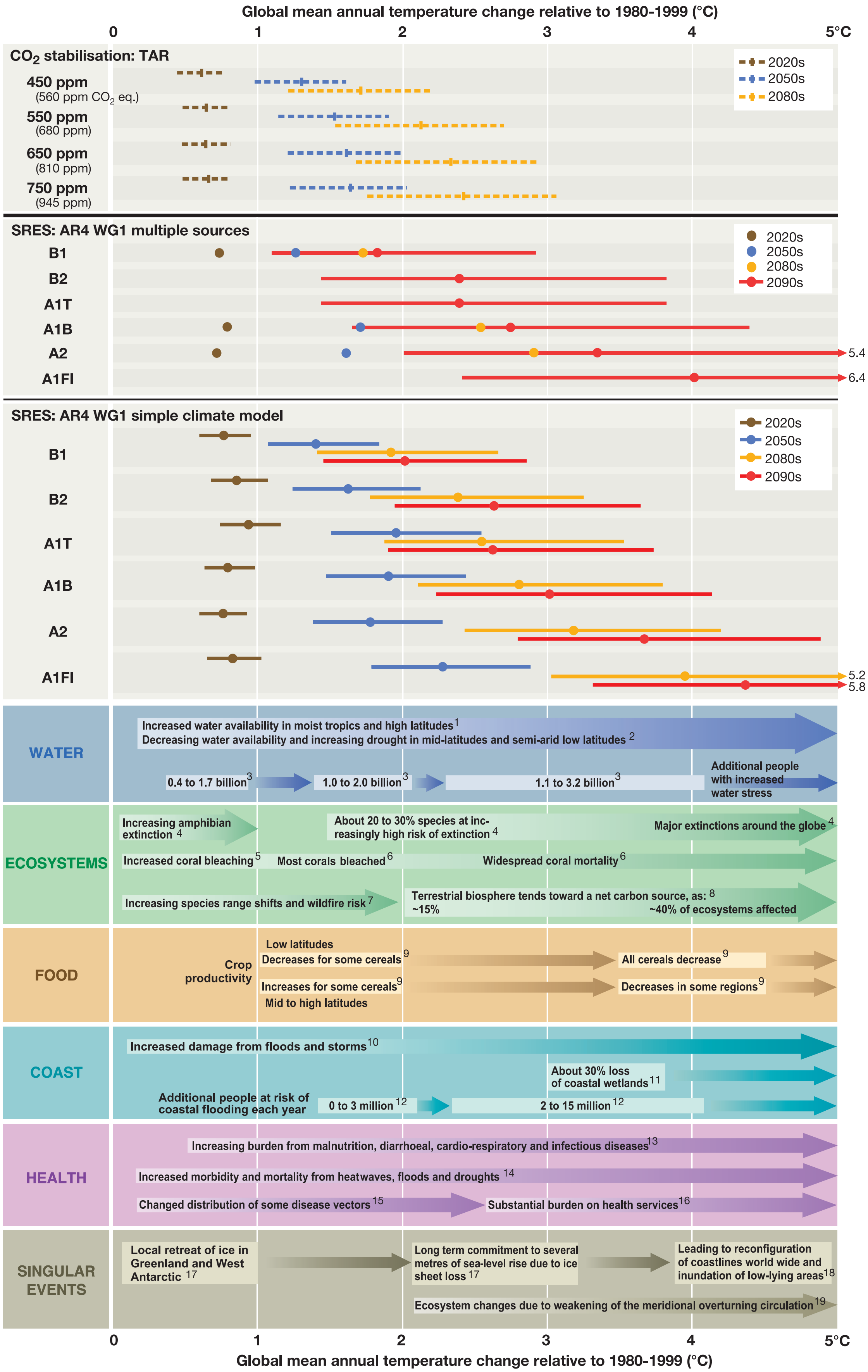

Table 20.8. *Examples of global impacts projected for changes in climate (and sea level and atmospheric CO_2 where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. This is a selection of some estimates currently available. All entries are from published studies in the chapters of the Assessment. (Continues below Table 20.9)*

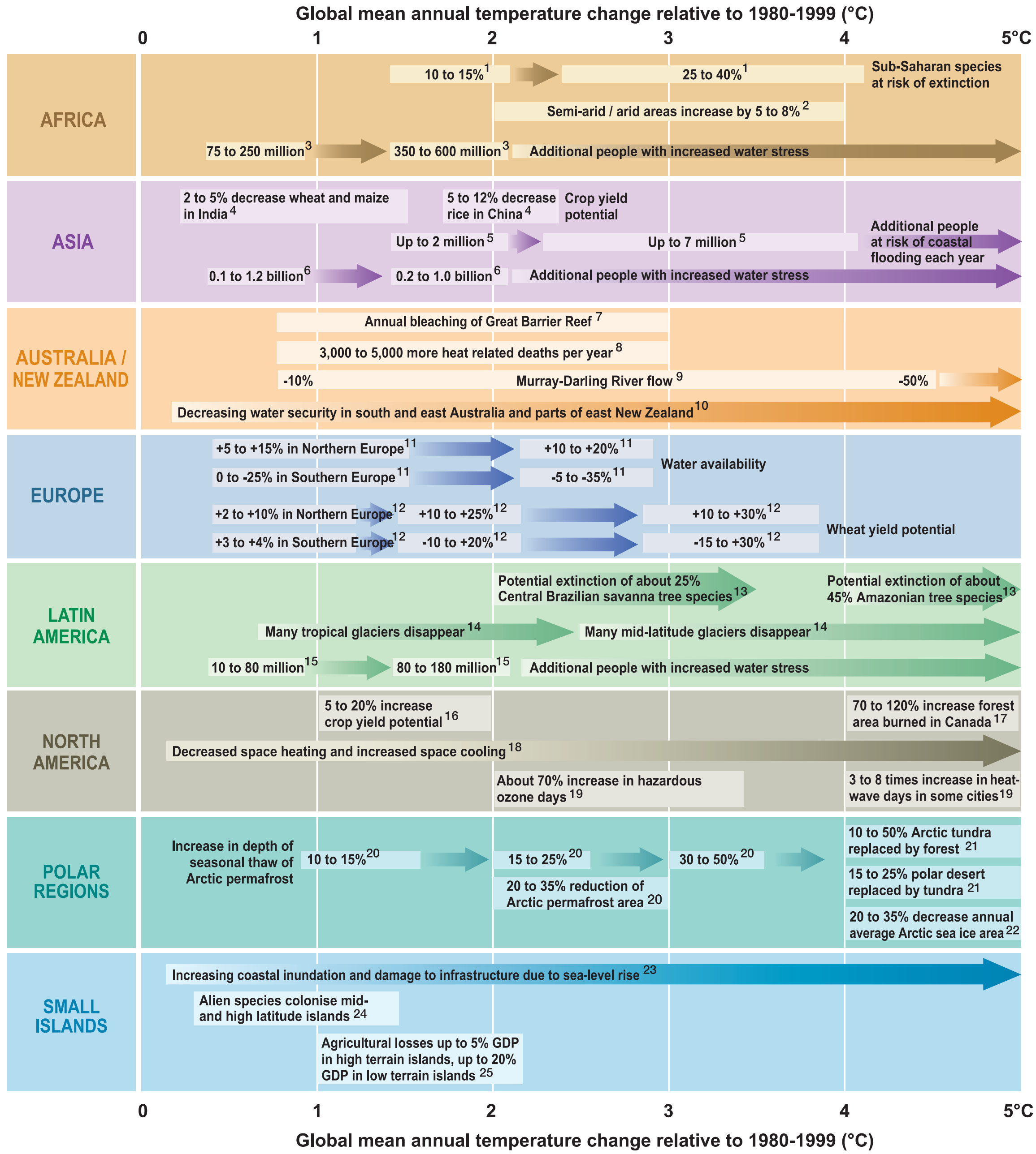

Table 20.9. *Examples of regional impacts. See caption for Table 20.8.*

Table 20.8. (cont.) *Edges of boxes and placing of text indicate the range of temperature change to which the impacts relate. Arrows between boxes indicate increasing levels of impacts between estimations. Other arrows indicate trends in impacts. All entries for water stress and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES scenarios A1FI, A2, B1 and B2. Adaptation to climate change is not included in these estimations. For extinctions, 'major' means ~40 to ~70% of assessed species.*

The table also shows global temperature changes for selected time periods, relative to 1980-1999, projected for SRES and stabilisation scenarios. To express the temperature change relative to 1850-1899, add 0.5°C. More detail is provided in Chapter 2 [Box 2.8]. Estimates are for the 2020s, 2050s and 2080s, (the time periods used by the IPCC Data Distribution Centre and therefore in many impact studies) and for the 2090s. SRES-based projections are shown using two different approaches. ***Middle panel:*** *projections from the WGI AR4 SPM based on multiple sources. Best estimates are based on AOGCMs (coloured dots). Uncertainty ranges, available only for the 2090s, are based on models, observational constraints and expert judgement.* ***Lower panel:*** *best estimates and uncertainty ranges based on a simple climate model (SCM), also from WGI AR4 (Chapter 10).* ***Upper panel:*** *best estimates and uncertainty ranges for four CO_2-stabilisation scenarios using an SCM. Results are from the TAR because comparable projections for the 21st century are not available in the AR4. However, estimates of equilibrium warming are reported in the WGI AR4 for CO_2-equivalent stabilisation[a]. Note that equilibrium temperatures would not be reached until decades or centuries after greenhouse gas stabilisation.*

Table 20.8. Sources: 1, 3.4.1; **2,** 3.4.1, 3.4.3; **3,** 3.5.1; **4,** 4.4.11; **5,** 4.4.9, 4.4.11, 6.2.5, 6.4.1; **6,** 4.4.9, 4.4.11, 6.4.1; **7,** 4.2.2, 4.4.1, 4.4.4 to 4.4.6, 4.4.10; **8,** 4.4.1, 4.4.11; **9,** 5.4.2; **10,** 6.3.2, 6.4.1, 6.4.2; **11,** 6.4.1; **12,** 6.4.2; **13,** 8.4, 8.7; **14,** 8.2, 8.4, 8.7; **15,** 8.2, 8.4, 8.7; **16,** 8.6.1; **17,** 19.3.1; **18,** 19.3.1, 19.3.5; **19,** 19.3.5
Table 20.9. Sources: 1, 9.4.5; **2,** 9.4.4; **3,** 9.4.1; **4,** 10.4.1; **5,** 6.4.2; **6,** 10.4.2; **7,** 11.6; **8,** 11.4.12; **9,** 11.4.1, 11.4.12; **10,** 11.4.1, 11.4.12; **11,** 12.4.1; 12, 12.4.7; **13,** 13.4.1; **14,** 13.2.4; **15,** 13.4.3; **16,** 14.4.4; **17,** 5.4.5, 14.4.4; **18,** 14.4.8; **19,** 14.4.5; **20,** 15.3.4, **21,** 15.4.2; **22,** 15.3.3; **23,** 16.4.7; **24,** 16.4.4; **25,** 16.4.3

[a] Best estimate and likely range of equilibrium warming for seven levels of CO_2-equivalent stabilisation from WGI AR4 are: 350 ppm, 1.0°C [0.6–1.4]; 450 ppm, 2.1°C [1.4–3.1]; 550 ppm, 2.9°C [1.9–4.4]; 650 ppm, 3.6°C [2.4–5.5]; 750 ppm, 4.3°C [2.8–6.4]; 1,000 ppm, 5.5°C [3.7–8.3] and 1,200 ppm, 6.3°C [4.2–9.4].

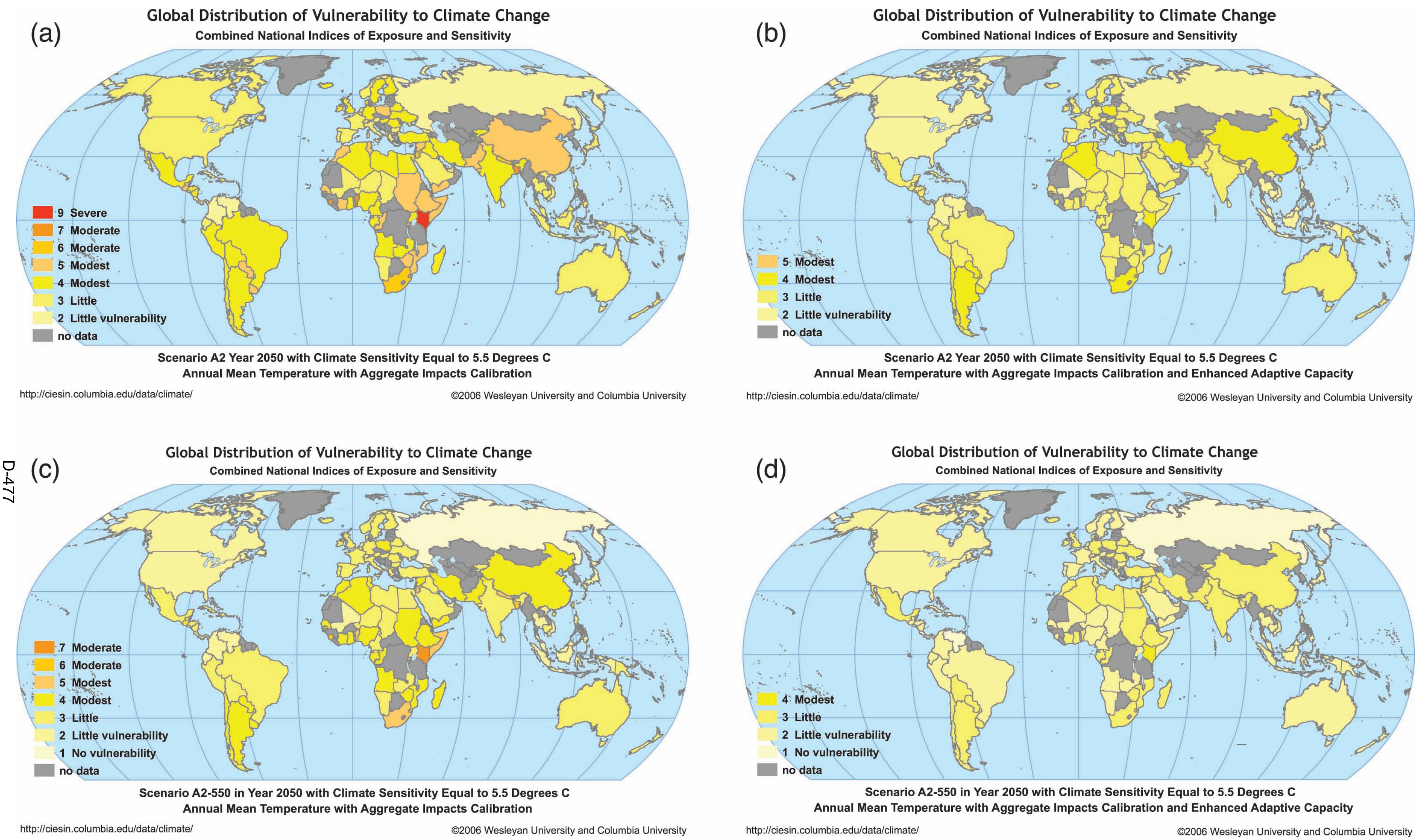

Figure 20.5. *Geographical distribution of vulnerability in 2050 with and without mitigation along an SRES A2 emissions scenario with a climate sensitivity of 5.5°C. (a) portrays vulnerability with a static representation of current adaptive capacity. (b) shows vulnerability with enhanced adaptive capacity worldwide. (c) displays the geographical implications of mitigation designed to cap effective atmospheric concentrations of greenhouse gases at 550 ppm. (d) offers a portrait of the combined complementary effects of mitigation to the same 550 ppm concentration limit and enhanced adaptive capacity. Source: Yohe et al., 2006b.*

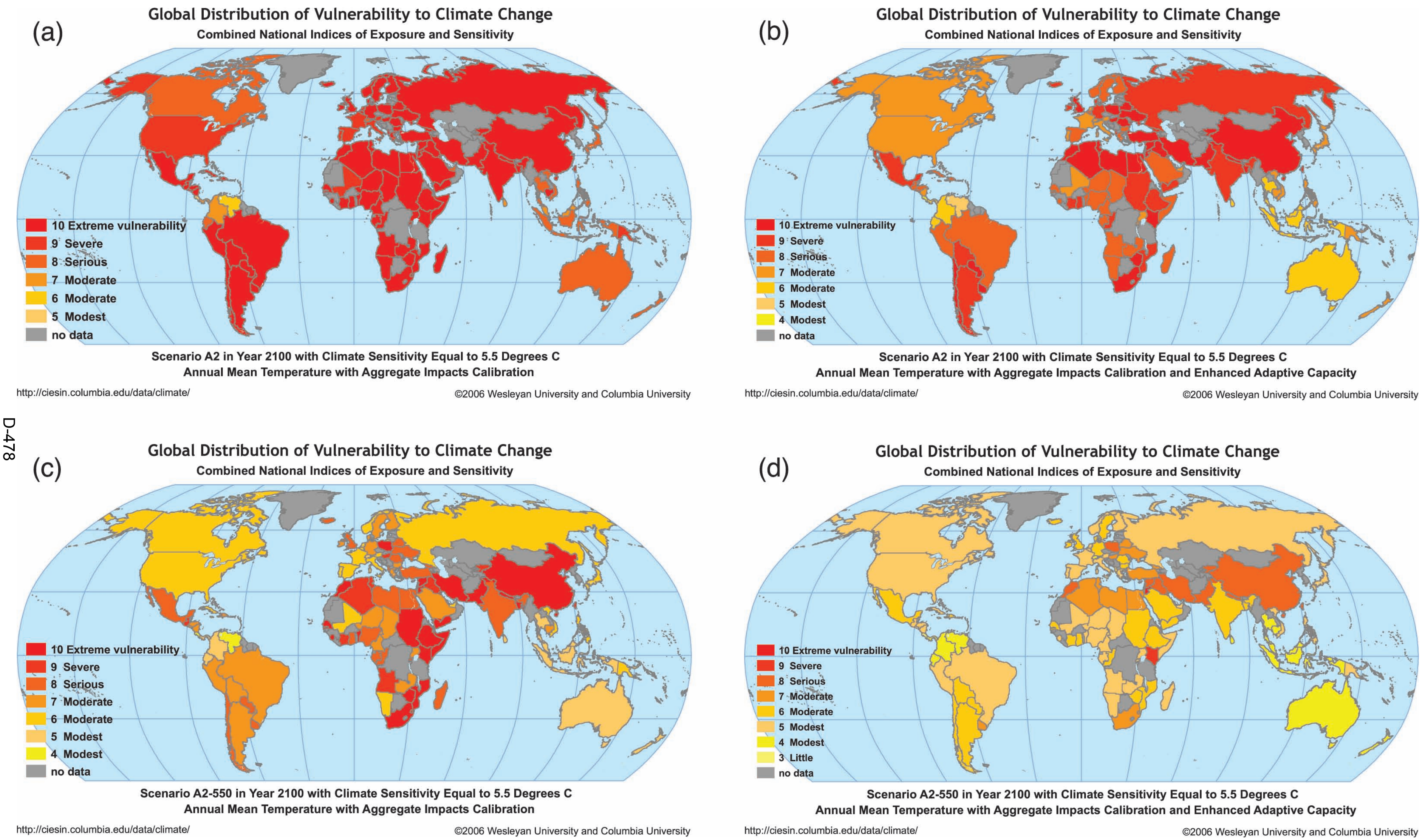

Figure 20.6. *Geographical distribution of vulnerability in 2100 with and without mitigation along an SRES A2 emissions scenario with a climate sensitivity of 5.5°C. (a) portrays vulnerability with a static representation of current adaptive capacity. (b) shows vulnerability with enhanced adaptive capacity worldwide. (c) displays the geographical implications of mitigation designed to cap effective atmospheric concentrations of greenhouse gases at 550 ppm. (d) offers a portrait of the combined complementary effects of mitigation to the same 550 ppm concentration limit and enhanced adaptive capacity. Source: Yohe et al., 2006b.*

respectively. Significant improvement is seen in 2050, but adaptation alone still cannot reduce extreme vulnerability worldwide in 2100. The lower panels present the effect of limiting atmospheric concentrations of greenhouse gases to 550 ppm along least-cost emissions trajectories; global mean temperature is 1.3°C and 3.1°C higher than 1990 levels by 2050 and 2100 in this case. In the lower left panels, adaptive capacity is again held constant at current levels. Mitigation reduces vulnerability across much of the world in 2050, but extreme vulnerability persists in developing countries and threatens developed countries in 2100. Mitigation alone cannot overcome climate risk. Finally, the lower right panels show the combined effects of investments in enhanced adaptive capacity and mitigation. Climate risks are substantially reduced in 2050, but significant vulnerabilities reappear by 2100. Developing countries are still most vulnerable. Developed countries are also vulnerable, but they see noticeable benefits from the complementary effects of the policy portfolio. These results suggest that global mitigation efforts up to 2050 would benefit developing countries more than developed countries when combined with enhanced adaptation. By 2100, however, climate change would produce significant vulnerabilities ubiquitously even if a relatively restrictive concentration cap were implemented in combination with a programme designed to enhance adaptive capacity significantly.

20.8 Opportunities, co-benefits and challenges for adaptation

This section extends some of the ideas outlined in Najam et al. (2003); they focus on mainstreaming climate-change adaptation into planning and development decisions with particular emphasis on participatory processes.

20.8.1 Challenges and opportunities for mainstreaming adaptation into national, regional and local development processes

An international opportunity for mainstreaming adaptation into national, regional and local development processes has recently emerged with the community approach to disaster management adopted by the World Conference on Disaster Reduction held in Kobe, Hyogo, Japan in January 2005 (Hyogo Declaration, 2005). This approach is described in, for example, UNCRD (2003). The results of an action research and pilot activity undertaken during 2002 to 2004 (APJED, 2004) have been reported, albeit on a limited scale in Bangladesh, India and Nepal, with support from World Meteorological Organization (WMO) and Global Water Partnership (GWP). The pilot activity focused on community approaches to flood management, and found that a community flood management committee formed in a local area, working in co-operation with the relevant local government and supported by national government policy, can significantly reduce adverse consequences of floods. There are, however, many challenges. Progress in carrying out analyses and identifying what needs to be and can be done can be documented, but action on the ground to mainstream adaptation to climate change remains limited, particularly in the least developed countries. National policy making in this context remains a major challenge that can only be met with increased international funding for adaptation and disaster management (Ahmad and Ahmed, 2002; Jegillos, 2003; Huq et al., 2006).

Socio-economic and even environmental policy agendas of developing countries do not yet prominently embrace climate change (Beg et al., 2002) even though most developing countries participate in various international protocols and conventions relating to climate change and sustainable development and most have adopted national environmental conservation and natural disaster management policies. Watson International Scholars of the Environment (2006) has offered some suggestions for improved mainstreaming within multilateral environmental agreements; they include fostering links with poverty reduction and increasing support designed to engage professionals, researchers and governments at local levels in developing countries more directly.

Even as economic growth is pursued, progress towards health, education, training and access to safe water and sanitation, and other indicators of social and environmental progress including adaptive capacity remains a significant challenge. It can be addressed through appropriate policies and commitment to ending poverty (WSSD, 2002; Sachs, 2005). Strengthened linkages between government and people, and the consequent capacity building at local levels, are key factors for robust progress towards sustainability at the grassroots (Jegillos, 2003). Social and environmental (climate change) issues are, however, often left resource-constrained and without effective institutional support when economic growth takes precedence (UNSEA, 2005).

20.8.2 Participatory processes in research and practice

Participatory processes can help to create dialogues that link and mutually instruct researchers, practitioners, communities and governments. There are, however, challenges in applying these processes as a methodology for using dialogue and narrative (i.e., communication of quantitative and qualitative information) to influence social learning and decision-making, including governance.

Knowledge about climate-change adaptation and sustainable development can be translated into public policy through processes that generate usable knowledge. The idea of usable knowledge in climate assessments stems from the experiences of national and international bodies (academies, boards, committees, panels, etc.) that offer credible and legitimate information to policymakers through transparent multi-disciplinary processes (Lemos and Morehouse, 2005). It requires the inclusion of local knowledge, including indigenous knowledge (see Box 20.1), to complement more formal technical understanding generated through scientific research and the consideration of the role that institutions and governance play in the translation of scientific information into effective action.

Box 20.1. Role of local and indigenous knowledge in adaptation and sustainability research

Research on indigenous environmental knowledge has been undertaken in many countries, often in the context of understanding local oral histories and cultural attachment to place. A survey of research during the 1980s and early 1990s was produced by Johnson (1992). Reid et al. (2006) outline the many technical and social issues related to the intersection of different knowledge systems, and the challenge of linking the scales and contexts associated with these forms of knowledge. With the increased interest in climate change and global environmental change, recent studies have emerged that explore how indigenous knowledge can become part of a shared learning effort to address climate-change impacts and adaptation, and its links with sustainability. Some examples are indicated here.

Sutherland et al. (2005) describe a community-based vulnerability assessment in Samoa, addressing both future changes in climate-related exposure and future challenges for improving adaptive capacity. Twinomugisha (2005) describes the dangers of not considering local knowledge in dialogues on food security in Uganda.

A scenario-building exercise in Costa Rica has been undertaken as part of the Millennium Ecosystem Assessment (MA, 2005). This was a collaborative study in which indigenous communities and scientists developed common visions of future development. Two pilot five-year storylines were constructed, incorporating aspects of coping with external drivers of development (Bennett and Zurek, 2006). Although this was not directly addressing climate change, it demonstrates the potential for joint scenario-building incorporating different forms of knowledge.

In Arctic Canada, traditional knowledge was used as part of an assessment which recognised the implications of climate change for the ecological integrity of a large freshwater delta (NRBS, 1996). In another case, an environmental assessment of a proposed mine was produced through a partnership with governments and indigenous peoples. Knowledge to facilitate sustainable development was identified as an explicit goal of the assessment, and climate-change impacts were listed as one of the long-term concerns for the region (WKSS, 2001).

Vlassova (2006) describes results of interviews of indigenous peoples of the Russian North on climate and environmental trends within the Russian boreal forest. Additional examples from the Arctic are described in ACIA (2005), Reidlinger and Berkes (2001), Krupnik and Jolly (2002), Furgal et al. (2006) and Chapter 15.

Social learning of complex issues like climate change emerges through consensus that includes both scientific discourse and policy debate. In the case of climate change, participatory processes encourage local practitioners from climate-sensitive endeavours (water management, land-use planning, etc.) to become engaged so that past experiences can be included in the study of (and the planning for) future climate change and development pressures. Processes designed to integrate various dimensions of knowledge about how regional resource systems operate are essential; so is understanding of how resource systems are affected by biophysical and socio-economic forces including a wide range of possible future changes in climate. This requirement has led to increased interest in a number of participatory processes like participatory integrated assessment (PIA) and participatory mapping (using, for example, specially designed geographic information systems – GIS).

PIA is an umbrella term describing approaches in which non-researchers play an active role in integrated assessment (Rotmans and van Asselt, 2002). Participatory processes can be used to facilitate the integration of biophysical and socio-economic aspects of climate-change adaptation and development by creating opportunities for shared experiences in learning, problem definition and design of potential solutions (Hisschemöller et al., 2001). Van Asselt and Rijkens-Klomp (2002) identify several approaches, including methods for mapping diversity of opinion (e.g., focus groups, participatory modelling) and reaching consensus (e.g., citizens' juries, participatory planning). Kangur (2004) reported on a recent exercise on water policy that employed citizens' juries. PIA has also been used to facilitate the development of integrated models (e.g., Turnpenny et al., 2004) and to use models to facilitate policy dialogue (e.g., van de Kerkhof, 2004).

Participatory mapping is a process by which local information, including indigenous knowledge, is incorporated into information management systems (Corbett et al., 2006). Ranging from paper to GIS, it is becoming more popular, and it has contributed to the increased application of Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) as techniques to support rural development (Chambers, 2006). Maps have displayed natural resources, social patterns and mobility, and they have been used to identify landscape changes, tenure, boundaries and places of cultural significance (Rambaldi et al., 2006). With the advent of modern GIS technologies, concerns have been raised regarding disempowerment of communities from lack of training. Questions related to who owns the maps and to who controls their use have also been raised (Corbett et al., 2006; Rambaldi et al., 2006).

The long-term sustainability of dialogue processes is critical to the success of participatory approaches. For PIA, PRA, participatory GIS and similar processes to be successful as shared learning experiences, they have to be inclusive and transparent. Haas (2004) describes examples of experiences in social learning on sustainable development and climate change, noting the importance of sustaining the learning process over the long term, and maintaining distance between science and policy while still promoting focused science-policy interactions. Applications of focus group and other techniques for stakeholder engagement are described for several studies in Europe (Welp et al., 2006) and Africa (Conde and Lonsdale, 2004). However, there has been particular concern regarding its application within development processes and hazard management in poor countries. Cooke and Kothari (2001) and Garande and Dagg (2005) document some problems, including hindering empowerment of local scale interests, reinforcing existing power structures and constraining how local knowledge is expressed. Barriers include uneven gains from cross-scale interactions (Adger et al., 2005; Young, 2006) and increased responsibility without increased capacity (Allen, 2006). There can be difficulties in reaching consensus on identifying and engaging participants (Bulkeley and Mol, 2003; Parkins and Mitchell, 2005), and in interpreting the results of dialogue within variations in cultural and epistemological contexts (e.g., Huntington et al., 2006). There are also challenges in measuring the quality of dialogue (debate, argument), particularly the transparency of process, promotion of learning and indicators of influence (van de Kerkhof, 2004; Rowe and Frewer, 2000).

Participatory governance is part of a growing global movement to decentralise many aspects of natural resources management. Hickey and Mohan (2004) offer several examples of the convergence of participatory development and participatory governance with empowerment for marginalised communities. Other examples include agrarian reform in the Philippines, the Popular Participation Law in Bolivia (Schneider, 1999; Iwanciw, 2004) and the appointment of an 'exploratory committee' for addressing water resources concerns in Nagoya, Japan (Kabat et al., 2002). In each case, the point is to improve access to resources and enhance social capital (Larson and Ribot, 2004a and 2004b). Unfortunately, broadening decision-making can work to exacerbate vulnerabilities. For example, there have been cases emerging from Latin America describing difficulties in building national adaptive capacity as national and local institutions change their roles in governance. Although the language of sustainability and shared governance is widely accepted, obtaining benefits from globalisation in enhanced adaptive capacity is difficult (Eakin and Lemos, 2006).

Dialogue processes in assessment and appraisal are becoming important tools in the support of participatory processes. Although they may be seen as relatively similar activities, PIA and PRA have different mandates. The latter is directly within a policy process (selecting among development options), while the former is a research method that assesses complex problems (e.g., environmental impact of development, climate-change impacts/adaptation), producing results that can have policy implications. This chapter's discussion on PIA is offered as a complement to integrated modelling results reported in Sections 20.6 and 20.7 to suggest that PIA may assist in providing regional-scale technical support to match the scale of information needs of decentralised governance.

An agricultural example of a PIA of climate-change adaptation can be found in the eastern United Kingdom (Lorenzoni et al., 2001). Adaptation options are identified (e.g., shifting cultivation times, modifying soil management to improve water retention and avoid compaction), but questions about how a climate component can be built into the way non-climate issues are currently addressed emerge. Long-term strategies may have to include greater fluctuations in crop yields across a region; as a result, farm operations may have to diversity if they are to maintain incomes and employment. The compartmentalisation of regional decision-making is seen as a barrier to encouraging more sustainable land management over the periods in which climate change evolves. In an example from Canada, Cohen and Neale (2006) and Cohen et al. (2004) illustrate the linkages between water management and scenarios of population growth and climate change in the Okanagan region (see also Chapter 3, Box 3.1). Planners in one district have responded by incorporating adaptation to climate change into long-term water plans (Summit Environmental Consultants Ltd., 2004) even though governance-related obstacles to proactive implementation of innovative measures to manage water demand have appeared in the past (Shepherd et al., 2006).

A comprehensive understanding of the implications of extreme climate change requires an in-depth exploration of the perceptions and reactions of the affected stakeholder groups and the lay public. Toth and Hizsnyik (2005) describe how participatory techniques might be applied to inform decisions in the context of possible abrupt climate change. Their project has studied one such case, the collapse of the West Antarctic Ice Sheet and a subsequent 5 to 6 m sea-level rise. Possible methods for assessing the societal consequences of impacts and adaptations include simulation-gaming techniques, a policy exercise approach, as well as directed focus-group conversations. Each approach can be designed to explore adaptation as a local response to a global phenomenon. As a result, each sees adaptation being informed by a fusion of top-down descriptions of impacts from global climate change and bottom-up deliberations rooted in local, national and regional experiences (see Chapter 2, Section 2.2.1).

20.8.3 Bringing climate-change adaptation and development communities together to promote sustainable development

The Millennium Development Goals (MDGs) are the latest international articulation of approaching poverty eradication and related goals in the developing world (see Section 20.7.1). Economic growth is necessary for poverty reduction and promoting other millennium goals; but, unless the growth achieved is equitably distributed, the result is a lopsided development where inequality increases. Many countries face intensifying poverty and inequality predicaments in the wake of undertaking free market policies (UNDP, 2003; UNSEA, 2005). As noted above, however, climate change is represented in the Millennium goals solely by indicators of changes in energy use per unit of GDP and/or by total or per capita emissions of CO_2. Tracking indicators of protected areas for biological diversity, changes in forests and access to water all appear in the goals, but they are not linked to climate-change impacts or adaptation; nor are they identified as part of a country's capacity to adapt to climate change.

Other issues of particular concern include ensuring energy services, promoting agriculture and industrialisation, promoting trade and upgrading technologies. Sustainable natural-resource management is a key to sustained economic growth and poverty reduction. It calls for clean energy sources; and the nature and pattern of agriculture, industry and trade should not unduly impinge on ecological health and resilience. Otherwise, the very basis of economic growth will be shattered through environmental degradation, more so as a consequence of climate change (Sachs, 2005). Put another way by Swaminathan (2005), developing and employing 'eco-technologies' (based on an integration of traditional and frontier technologies including bio-technologies, renewable energy and modern management techniques) is a critical ingredient rooted in the principles of economics, gender, social equity and employment generation with due emphasis given to climate change.

For environmentally-sustainable economic growth and social progress, therefore, development policy issues must inform the work of the climate-change community such that the two communities bring their perspectives to bear on the formulation and implementation of integrated approaches and processes that recognise how persistent poverty and environmental needs exacerbate the adverse consequences of climate change. In this process, science has a critical role to play in assessing the prevailing realities and likely future scenarios, and identifying policies and cost-effective methods to address various aspects of development and climate change; and it is important that all relevant stakeholders are involved in science-based dialogues (Welp et al., 2006). In order to go down this integrated and participatory road, a strong political will and public commitment to promoting sustainable development is needed, focusing simultaneously on economic growth, social progress, environmental conservation and adaptation to climate change (World Bank, 1998; AfDB et al., 2003). It is also important that private and public sectors work together within a framework of identified roles of each, with economic, social and climate-change perspectives built into the process. Further, co-ordination among national development and climate-change communities, as well as co-ordination among appropriate national and international institutions, is imperative.

This raises an important question regarding the process for bringing climate change and sustainable development together. Growing interest in these linkages is evident in a series of recent publications, including Toth (1999), Yamin (2004), Collier and Löfstedt (1997), Jepma and Munasinghe (1998), Munasinghe and Swart (2000, 2005), Abaza and Baranzini (2002), Markandya and Halsnaes (2002), Cohen et al. (1998), Kok et al. (2002), Swart et al. (2003). A number of themes that are particularly relevant to adaptation run through this literature. They include the need for equity between developed and developing countries in the delineation of rights and responsibilities within any climate-change response framework. Shue (1999), Thomas and Twyman (2004) and Paavola and Adger (2006) point, as well, to the need for equity across vulnerable groups that are disproportionately exposed to climate-change impacts. Hasselman (1999), Gardiner (2004) and Kemfert and Tol (2002) identify some examples from economics which raise concerns for intergenerational ethics; i.e., the degree to which the interests of future generations are given relatively lower weighting in favour of short-term concerns. Intergenerational justice implications, for individuals and collectives (e.g., indigenous cultures) are described in Page (1999). Masika (2002) specifically outlines gender aspects of differential vulnerabilities. Swart et al. (2003) identify the need to describe potential changes in vulnerability and adaptive capacity within the SRES storylines.

Although linkages between climate-change adaptation and sustainable development should appear to be self evident, it has been difficult to act on them in practice. Beg et al. (2002) identify potential synergies between climate change and other policies that could facilitate adaptation, such as those that address desertification and biodiversity. Ethical guidance from various spiritual and religious sources is reviewed in Coward (2004). However, an 'adaptation deficit' exists. Burton and May (2004) identify this as the gap between current and optimal levels of adaptation to climate-related events (including extremes); it is expected that climate change and poor development decisions will lead to an increased adaptation deficit in the future. While mitigation within the UNFCCC includes clearly defined objectives, measures, costs and instruments, this is not the case for adaptation. Agrawala (2005) indicates that much less attention has been paid to how development could be made more resilient to climate-change impacts, and identifies a number of barriers to mainstreaming climate-change adaptation within development activity (see, as well Chapter 17, Section 17.3).

The existence of these barriers does not mean that the development community does not recognise the linkage between development and climate-change adaptation. Climate change is identified as a serious risk to poverty reduction in developing countries, particularly because these countries have a limited capacity to cope with current climate variability and extremes not to mention future climate change (Schipper and Pelling, 2006). Adaptation measures will need to be integrated into strategies of poverty reduction to ensure sustainable development, and this will require improved governance, mainstreaming of climate-change measures, and the integration of climate-change impacts information into national economic projections (AfDB et al., 2003; Davidson et al., 2003). Brooks et al. (2005) offer an extensive list of potential proxy indicators for national-level vulnerability to climate change, including health, governance and technology indicators. Agrawala (2005) describes case studies of natural resources management in Nepal, Bangladesh, Egypt, Fiji, Uruguay and Tanzania, and recommends several priority actions for overcoming barriers to mainstreaming, including project screening for climate-related risk, inclusion of climate impacts in environmental impact assessments , and shifting emphasis from creating new plans to better implementation of existing measures. Approaches for integration of adaptation with development are outlined for East Africa (Orindi and Murray, 2005). The Commission for Africa (2005) explicitly links the need to address climate-change risks with achievement of poverty reduction and sustainable growth.

In recent years, new mechanisms have been established to support adaptation, including the Lesser Developed Countries (LDC) Fund, Special Climate Change Fund and the Adaptation Fund (Huq, 2002; Brander, 2003; Desanker, 2004; Huq, 2006; Huq et al., 2006). They have provided visibility and opportunity to mainstream adaptation into local/regional development activities. However, there are technical challenges associated with defining adaptation benefits for particular actions within UNFCCC mechanisms such as the Global Environmental Facility (GEF). For example, Burton (2004) and Huq and Reid (2004) note that the calculation of costs of adapting to future climate change (as opposed to current climate variability), as well as the local nature of resulting benefits, are both problematic *vis-à-vis* GEF requirements for defining global environmental benefits. On the other hand, there are opportunities. Dang et al. (2003) illustrate how including "adaptation benefits of mitigation" in Vietnam offers a way of linking both criteria in the analysis of potential projects for inclusion in the Clean Development Mechanism. Bouwer and Aerts (2006) and Schipper and Pelling (2006) identify opportunities for integrating climate-change adaptation and disaster risk management through insurance mechanisms, official development assistance and ongoing risk management programmes. Niang-Diop and Bosch (2004) outline methods for linking adaptation strategies with sustainable development at national and local scales, as part of National Adaptation Programmes of Action (NAPAs). As of the autumn of 2006, the LDC Fund was operational in its support of NAPAs in LDCs and both the Conference of Parties (COP) and GEF were in the process of defining how the implementation of adaptation activities highlighted in NAPAs could be funded (Huq et al., 2006).

20.9 Uncertainties, unknowns and priorities for research

Uncertainties, unknowns and priorities for research illuminate the confidence statements that modify scientific conclusions delivered to members of the policy community. For the research community, however, they can be translated into tasks designed to improve understanding and elaborate sources confidence. This section is therefore organised as a series of tasks.

Expand understanding of the synergies in and/or obstacles to simultaneous progress in promoting enhanced adaptive capacity and sustainable development. The current state of knowledge in casting adaptive capacity and vulnerability into the future is primitive. More thorough understandings of the process by which adaptive capacity and vulnerability evolve over time along specific development pathways are required. Commonalities exist across the determinants of adaptive capacity, mitigative capacity and the factors that support sustainable development, but current understanding of how they can be recognised and exploited is minimal.

Integrate more closely current work in the development and climate-change communities. Synergies exist between practitioners and researchers in the sustainable development and climate-change communities, but there is a need to develop means by which these communities can integrate their efforts more productively. The relative efficacies of dialogue processes and new tools required to promote this integration, and the various participatory and/or model-based approaches required to support their efforts must be refined or developed from scratch. Opportunities for shared learning should be identified, explored and exploited.

Search for common ground between spatially explicit analyses of vulnerability and aggregate integrated assessment models. Geographical and temporal scales of development and climate initiatives vary widely. The interaction and intersection between spatially explicit and aggregate integrated assessment models has yet to be explored rigorously. For example, representations of adaptive capacities and resulting vulnerabilities in aggregate integrated assessment models are still rudimentary. As progress is encouraged in improving their abilities to depict reality, research initiatives must also recognise and work to overcome difficulties in matching the scales at which models are constructed and exercised with the scales at which decisions are made. New tools are required to handle these differences, particularly between the local and national, short-to-medium-term scales of adaptation and development programmes and projects and the global, medium-to-long-term scale of mitigation.

Recognise that uncertainties will continue to be pervasive and persistent, and develop or refine new decision-support mechanisms that can identify robust coping strategies even in the face of this uncertainty. Significant uncertainties in estimating the social cost of greenhouse gases exist, and many of their sources have been identified; indeed many of their sources reside in the research needs listed above. Reducing these uncertainties would certainly be productive, but it cannot be guaranteed that future research will make much progress in this regard. It follows that concurrent improvement in our ability to use existing decision-support tools and to design new approaches to cope with uncertainties and associated risks that will be required over the foreseeable future is even more essential. In short, identify appropriate decision-support tools and clarify the criteria that they can inform in an uncertain world.

Characterise the full range of possible climate futures and the paths that might bring them forward. The research communities in both climate and development must, along with practitioners and decision-makers, be informed not only about the central tendencies of climate change and its ramifications, but also about the outlier possibilities about which the natural-science community is less sanguine. It is simply impossible to comprehend the risks associated with high-consequence outcomes with low probabilities if neither their character nor their likelihood has been described.

This chapter has offered a glimpse into where to turn for guidance in confronting and managing the risks associated with climate change and climate variability. Indeed, the climate problem is a classic risk management problem of the sort with which decision-makers are already familiar. It is critical to see risk as the product of likelihood and consequence, to recognise that the likelihood of a climate impact is dependent on natural and human systems, and to understand that the consequence of that impact can be measured in terms of a multitude of numeraires (currency, millions at risk, species extinction, abrupt physical changes and so on). These expressions of risk are determined fundamentally by location in time and space.

This chapter also points to synergies that exist at the nexus of sustainable development and adaptive capacity, primarily by noting for the first time that many of the goals of sustainable development match the determinants of adaptive capacity (and, for that matter, mitigative capacity). Planners in the decision-intensive ministries around the world are therefore already familiar with the generic mechanisms by which including climate change into their risk assessments of development programmes can complicate their decisions. Adding climate to the list of multiple stresses which can impede progress in meeting their goals in their specific context is thus not a new problem. Climate change, even when its impacts are amplified by the effects of other stresses, is just one more thing: one more problem to confront, but also one more reason to act in ways that promote progress along multiple fronts. Exploitation of the synergies is not automatic, so care must be taken to avoid development activities that can exacerbate climate change or impacts just as care must be taken to take explicit account of climate risks.

The United Nations Framework Convention on Climate Change commits governments to avoiding "dangerous anthropogenic interference with the climate system", but governments will be informed in their deliberations of what is or is not 'dangerous' only by an approach that explicitly reflects the rich diversity of climate risk across the globe and into the coming decades instead of burying this diversity into incomplete aggregate indices of damages. Risk management techniques have been designed for such tasks; but it is important to note that risk-based approaches require exploration of the implications of not only the central tendencies of climate change that are the focus of consensus-driven assessments of the literature, but also the uncomfortable (or more benign) futures that reside in the 'tails' of current understanding. Viewing the climate issue from a risk perspective can offer climate policy deliberations and negotiations new insight into the synergies by which governments can promote sustainable development, reduce the risk of climate-related damages and take advantage of climate-related opportunities.

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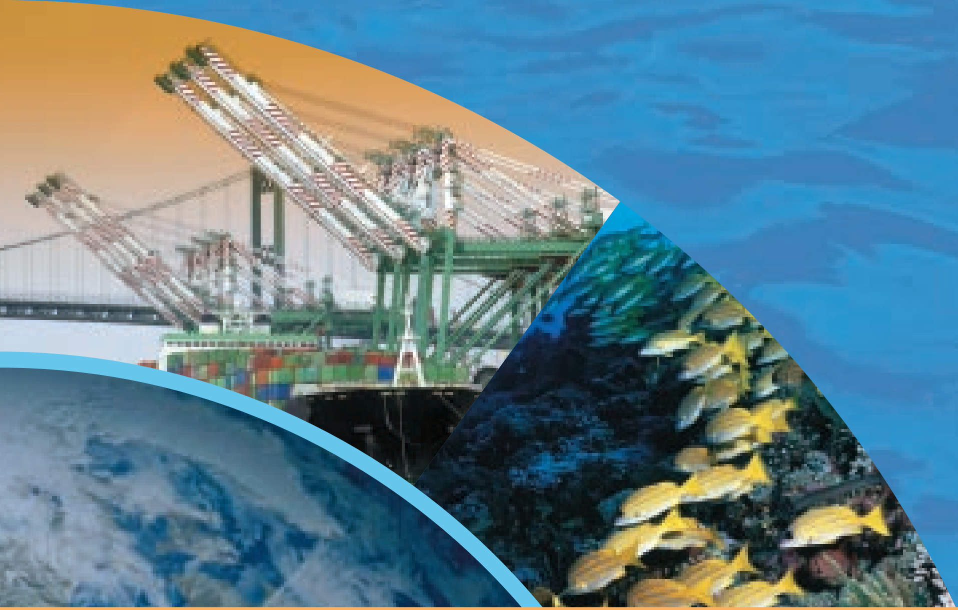
FINAL REPORT



AN OCEAN BLUEPRINT
FOR THE 21st CENTURY

U.S. COMMISSION ON
OCEAN POLICY

FINAL REPORT

AN OCEAN BLUEPRINT

FOR THE 21st CENTURY

U.S. COMMISSION ON OCEAN POLICY

D-1160

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This document may be cited as follows:
U.S. Commission on Ocean Policy.
An Ocean Blueprint for the 21st Century.
Final Report.
Washington, DC, 2004
ISBN#0–9759462–0–X

THE UNITED STATES IS AN OCEAN NATION

The U.S. exclusive economic zone (EEZ) extends 200 nautical miles offshore, encompassing diverse ecosystems and vast natural resources, such as fisheries and energy and other mineral resources. The U.S. EEZ is the largest in the world, spanning over 13,000 miles of coastline and containing 3.4 million square nautical miles of ocean—larger than the combined land area of all fifty states. (A square nautical mile is equal to 1.3 square miles.)

U.S. states also have jurisdiction over a significant portion of the Great Lakes. This chain of freshwater lakes and its tributaries constitute the largest reservoir of fresh surface water on the planet, containing 6.5 quadrillion gallons of fresh water and covering an area of about 72,000 square nautical miles. The Great Lakes' U.S. coastline borders eight states and is roughly the same length as the entire Atlantic Coast.

D-1162

U.S. Commission on Ocean Policy

July 22, 2004

The Members of the U.S. Commission on Ocean Policy,
directed by the United States Congress and appointed by the President
under the Oceans Act of 2000 (Public Law 106–256) to
make recommendations for a coordinated and comprehensive
national ocean policy, hereby approve

An Ocean Blueprint for the 21st Century,

the final report of the Commission's findings and recommendations in
fulfillment of our responsibilities and obligations under such Act.

Admiral James D. Watkins, USN (Ret.), Chairman

Robert Ballard, Ph.D.

Mr. Lawrence Dickerson

Dr. Frank Muller-Karger

Mr. Ted A. Beattie

Vice Admiral Paul G. Gaffney II, USN (Ret.)

Mr. Edward B. Rasmuson

Mrs. Lillian Borrone

Professor Marc J. Hershman

Dr. Andrew A. Rosenberg

Dr. James M. Coleman

Mr. Paul L. Kelly

Mr. William D. Ruckelshaus

Ms. Ann D'Amato

Mr. Christopher Koch

Dr. Paul A. Sandifer

U.S. COMMISSION ON
OCEAN POLICY

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September 2004

The President
The White House
Washington, D.C. 20500

Dear Mr. President:

I am pleased to submit for your consideration *An Ocean Blueprint for the 21st Century,* the final report of the U.S. Commission on Ocean Policy. As mandated by the Oceans Act of 2000, this report contains balanced and practical proposals for the establishment of a comprehensive and coordinated ocean policy for our nation. The sixteen Commissioners you appointed, representing diverse interests and experience, unanimously support the Commissions' findings, recommendations and vision for the future.

The value of the oceans and coasts to the nation is immense and their full potential remains unrealized. Over half the U.S. population lives in coastal watershed counties and roughly one-half of the nation's gross domestic product ($4.5 trillion in 2000) is generated in those counties and in adjacent ocean waters.

However, there is widespread agreement that our oceans and marine resources are in serious trouble, increasingly affected by rapid growth along our coasts, land and air pollution, unsustainable exploitation of too many of our fishery resources, and frequently ineffective management. The consistent message we heard throughout the country is that we must act now to halt continuing degradation.

We believe that a historic opportunity is at hand to make positive and lasting changes in the way we manage our oceans. The comments we received from Governors of states and territories, tribal leaders, industry, nongovernmental organizations, and the public at large were strongly supportive of our assessment of declining ocean and coastal conditions, the need for a new management approach, and our call for immediate action.

A comprehensive and coordinated national ocean policy requires moving away from the current fragmented, single-issue way of doing business and toward ecosystem-based management. This new approach considers the relationships among all ecosystem components, and will lead to better decisions that protect the environment while promoting the economy and balancing multiple uses of our oceans and coasts.

The Commission, therefore, considers the following actions essential. First, a new national ocean policy framework must be established to improve federal coordination and effectiveness. An important part of this new framework is strengthening support for state, territorial, tribal, and local efforts to identify and resolve issues at the regional level. Second, it is also critical that decisions about ocean and coastal resources be based on the most current, credible, and unbiased scientific data and information. Finally, formal and informal ocean education should be strengthened to better engage the general public, cultivate a broad stewardship ethic, and prepare a new generation of leaders to meet future ocean policy challenges.

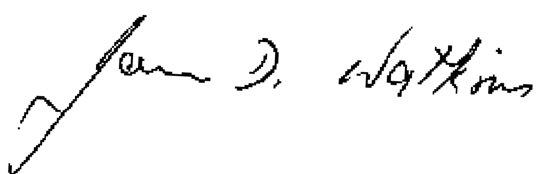
Implementation of the Commission's recommendations, which will require a new and modest investment over current funding levels, can create a system that sustains our resources and generates significantly greater benefits for our nation. We have recommended creation of an Ocean Policy Trust Fund that will dedicate funds generated from ocean activities to implement our Ocean Blueprint for the 21st Century.

The urgent need for action is clear. It is equally clear that, by rising to the challenge today and addressing the many activities that are affecting our continent at its edges, our nation can protect the ocean environment, create jobs, increase revenues, enhance security, expand trade, and ensure ample supplies of energy, minerals, food, and life-saving drugs.

Our report is just the beginning of what must be a sustained effort. The Commission encourages you to work with Congress, the Governors and other stakeholders, and, where appropriate, to use existing Presidential authorities to commence implementation of our recommendations at an early date.

On behalf of all sixteen Commissioners, I would like to thank you for the opportunity to serve our nation as members of the U.S. Commission on Ocean Policy. It has been a privilege to contribute to a new age of ocean awareness and stewardship. Although our work officially ends ninety days after submission of this report, we stand ready now and in the future to assist in the implementation of our recommendations and achievement of our vision—one in which our oceans and coasts are clean, safe, sustainably managed, and preserved for the benefit and enjoyment of future generations.

Respectfully,



James D. Watkins
Admiral, U.S. Navy (Retired)
Chairman

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September 2004

The Honorable William H. Frist, M.D.
Majority Leader
United States Senate
Washington, D.C. 20510

Dear Mr. Leader:

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Sincerely,

James D. Watkins
Admiral, U.S. Navy (Retired)
Chairman

cc: The Honorable Tom Daschle

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September 2004

The Honorable J. Dennis Hastert
Speaker of the House of Representatives
Washington, D.C. 20515

Dear Mr. Speaker:

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Sincerely,

James D. Watkins
Admiral, U.S. Navy (Retired)
Chairman

cc: The Honorable Nancy Pelosi

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Acknowledgements

An effort of this magnitude could not have been completed without the help of many dedicated people. The Commission is deeply grateful to the scores of individuals who provided testimony, technical input, insightful comments, figures and photographs, production help, and many other forms of assistance in completing this momentous task.

A complete record of testimony presented to the Commission can be found in Appendices 1 and 2, and on the Commission's Web site at www.oceancommission.gov. These presentations were invaluable in communicating the problems facing our oceans and coasts—and suggesting positive solutions.

A number of consultants were instrumental in helping the Commission conduct its meetings and complete its report, particularly in the following areas:

> *Meeting facilitation, strategy, and advice*—John Ehrmann and Jay West of the Meridian Institute, and Philip Angell.
>
> *Research, writing, and editing*—Charles Colgan, M. Richard DeVoe, Peter Fippinger, Jeremy Firestone, Gabriela Goldfarb, Montserrat Gorina-Ysern, Ray Kammer, Fredrika Moser, Joan O'Callaghan, Julie Phillips, Ellen Prager, Robert Wayland III, and Bill Woodward.
>
> *Public relations*—Scott Treibitz, David Roscow, Victoria Sackett, and Dean Tinnin of Tricom Associates, and Herbert Rosen.
>
> *Report design and production*—Cynthia Cliff, James Durham, and Lisa Wells of Janin/Cliff Design, Inc.
>
> *Web site development and maintenance*—Tom LaPoint, Jerry Lau, and Davida Remer of the National Oceanic and Atmospheric Administration's National Ocean Service.

The members of the Commission's Science Advisory Panel (listed in the preceding pages) were at our side from start to finish, answering questions, clarifying technical points, preparing and reviewing written materials, and generally sharing their decades of collective wisdom. In addition, we extend our thanks to the following individuals who served as researchers, reviewers, and wise advisors, or helped in dozens of other ways:

Craig Allen, Donald Anderson, Anthony Andrady, Lori Arguellas, Stefano Belfiore, Joan Myers Bondareff, Nicole Breznock, Richard Brill, David Brower, R. Steven Brown, Joedy Cambridge, James Carlton, Thomas Chase, David Colson, James Corbett, Barry Costa-Pierce, Penelope Dalton, Shelley Dawicki, Richard Delaney, Jessica Demian, Alex Echols, Carolyn Elefant, Amanda Enser, Karen Foerstel, Kim Fulton-Bennett, Marc Gaden, Joseph Geraci, Roger Germann, W. Rockwell Geyer, Suzanne Giles, David Godschalk, James Good, Shannon Gordon, Dale Green, Karl Gustavson, Kathryn Hayes, Amy Heywood, Barbara Hinthorn, Robert Hofman, Edward Houde, John Justus, Geri Kantor, Jill Karsten, David Keeley, Jim Kent, Joanna Knight, Robert Knox, Kei Koizumi, Jennie Kopelson, Judith Krauthamer, Stephen Leatherman, James R. Lyons, Tony MacDonald, Elizabeth Martin, Emily McBride, Tom McCann, Shannon McCoy, David McGrath, James Murley, Savithri Narayanan, Scott Newsham, John Ogden, Rafael Olivieri, Joan Oltman-Shay, John O'Shea, Edward Page, Richard Pittenger, Eugene Proulx, Timothy Ragen, Andrew Read, Robert Richmond, Robert Ross, Amy Schick, Sarah Schoedinger, Gerry Schubel, Richard Seymour, Seba Sheavly, Rexford Sherman, Andrea Sanico, Judson Starr, Denise Stephenson-Hawk, Robert Stickney, Maurice Tarares, Joanne Tromp, Nicole Vickey, Daniel Walker, Ferris Webster, Robert Weller, and Art Wong.

The members and staff of the Pew Oceans Commission, led by the Honorable Leon Panetta, also deserve our recognition and thanks for their contributions to the development of a new national ocean policy and their steadfast support for the work of this Commission.

Input from Governors and other state-level representatives and groups were invaluable to the development of this report. The official comments from thirty-seven state and territorial Governors and five tribal leaders can be found in the Special Addendum to this report, and on the Commission's Web site at www.oceancommission.gov. Special thanks go to the members and staff of the Coastal States Organization and the National Governors Association for their critical roles in conveying state level interests and perspectives.

Although too numerous to list by name, the Commission extends its heartfelt appreciation to the many knowledgeable and dedicated federal agency employees who supplied detailed information, answered a barrage of questions, and offered excellent advice. Particular thanks go to the Council on Environmental Quality for its role as the Administration's chief liaison to the Commission.

We also appreciate the support provided to the Commission by the Members of Congress and their staffs, in particular those who serve on committees with key jurisdiction over ocean and coastal issues and who have closely followed the progress of the Commission's work. This includes the Members and staff of the Senate Committee on Commerce, Science and Transportation, and the Committee on Appropriations, as well as the House Committees on Science, Resources, and Transportation and Infrastructure. Additional thanks are extended to the Members of the House Oceans Caucus and their staff.

Finally, the work reflected in this report would simply not have been possible without the support and dedication of a talented group of professionals, the members of the Commission staff, to whom we extend our deepest gratitude for their tireless effort on behalf of a new national ocean policy.

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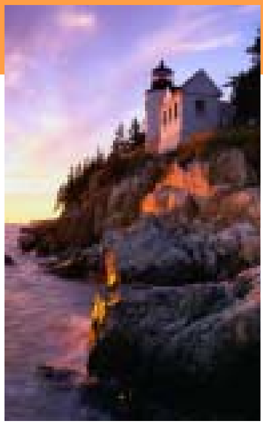
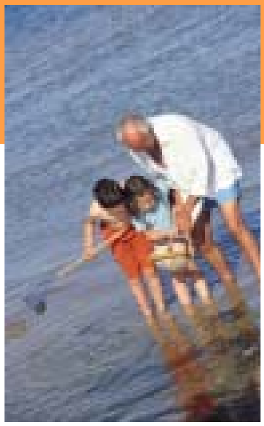


PART II

BLUEPRINT FOR CHANGE: A NEW NATIONAL OCEAN POLICY FRAMEWORK



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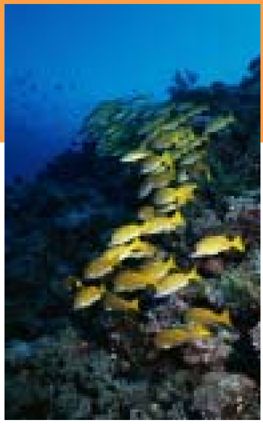

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Printed as Separate Documents:
Available Electronically on CD or at www.oceancommission.gov

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Executive Summary

America is a nation intrinsically connected to and immensely reliant on the ocean. All citizens—whether they reside in the country's farmlands or mountains, in its cities or along the coast—affect and are affected by the sea. Our grocery stores and restaurants are stocked with seafood and our docks are bustling with seaborne cargo. Millions of visitors annually flock to the nation's shores, creating jobs and contributing substantially to the U.S. economy through one of the country's largest and most rapidly growing economic sectors: tourism and recreation.

The offshore ocean area under U.S. jurisdiction is larger than its total land mass, providing a vast expanse for commerce, trade, energy and mineral resources, and a buffer for security. Born of the sea are clouds that bring life-sustaining water to our fields and aquifers, and drifting microscopic plants that generate much of the oxygen we breathe. Energy from beneath the seabed helps fuel our economy and sustain our high quality of life. The oceans host great biological diversity with vast medical potential and are a frontier for exciting exploration and effective education. The importance of our oceans, coasts, and Great Lakes cannot be overstated; they are critical to the very existence and well-being of the nation and its people. Yet, as the 21st century dawns, it is clear that these invaluable and life-sustaining assets are vulnerable to the activities of humans.

Human ingenuity and ever-improving technologies have enabled us to exploit—and significantly alter—the ocean's bounty to meet society's escalating needs. Pollution runs off the land, degrading coastal waters and harming marine life. Many fish populations are declining and some of our ocean's most majestic creatures have nearly disappeared. Along our coasts, habitats that are essential to fish and wildlife and provide valuable services to humanity continue to suffer significant losses. Non-native species are being introduced, both intentionally and accidentally, into distant areas, often resulting in significant economic costs, risks to human health, and ecological consequences that we are only beginning to comprehend.

Yet all is not lost. This is a moment of unprecedented opportunity. Today, as never before, we recognize the links among the land, air, oceans, and human activities. We have access to advanced technology and timely information on a wide variety of scales. We recognize the detrimental impacts wrought by human influences. The time has come for us to alter our course and set sail for a new vision for America, one in which the oceans, coasts, and Great Lakes are healthy and productive, and our use of their resources is both profitable and sustainable.

It has been thirty-five years since this nation's management of the oceans, coasts, and Great Lakes was comprehensively reviewed. In that time, significant changes have occurred in how we use marine assets and in our understanding of the consequences of our actions. This report from the U.S. Commission on Ocean Policy provides a blueprint for change in the 21st century, with recommendations for creation of an effective national ocean policy that ensures sustainable use and protection of our oceans, coasts, and Great Lakes for today and far into the future.

The Value of the Oceans and Coasts

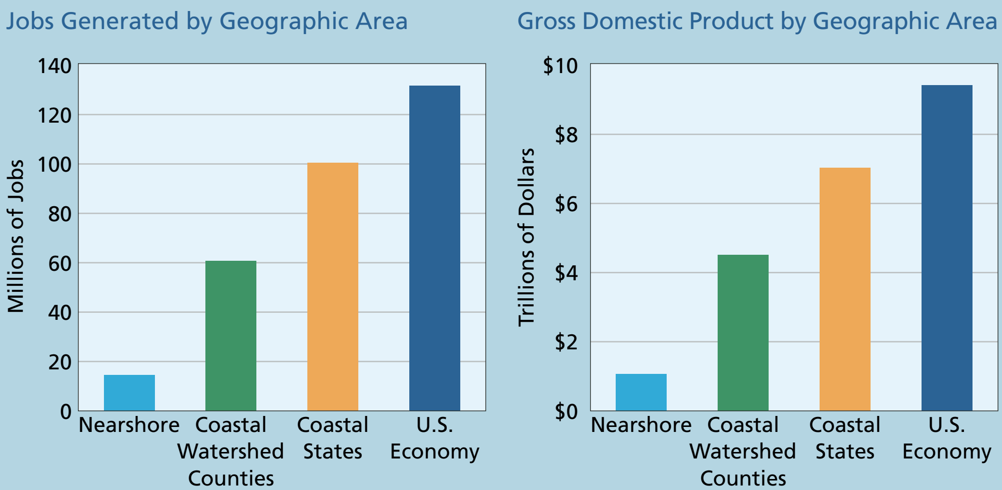
America's oceans, coasts, and Great Lakes provide tremendous value to our economy. Based on estimates in 2000, ocean-related activities directly contributed more than $117 billion to American prosperity and supported well over two million jobs. By including coastal activities, the numbers become even more impressive; more than $1 trillion, or one-tenth of the nation's annual gross domestic product, is generated within the relatively narrow strip of land immediately adjacent to the coast that we call the nearshore zone (Figure ES.1). When the economies throughout coastal watershed counties are considered, the contribution swells to over $4.5 trillion, fully half of the nation's gross domestic product, accounting for some 60 million jobs.

The United States uses the sea as a highway for transporting goods and people and as a source of energy and potentially lifesaving drugs. Annually, the nation's ports handle more than $700 billion in merchandise, while the cruise industry and its passengers account for another $12 billion in spending. More than thirteen million jobs are connected to maritime trade. With offshore oil and gas operations expanding into ever deeper waters, annual production is now valued at $25–$40 billion, and yearly bonus bid and royalty payments contribute approximately $5 billion to the U.S. Treasury. Ocean exploration has also led to a growing and potentially multi-billion dollar industry in marine-based bioproducts and pharmaceuticals.

Fisheries are another important source of economic revenue and jobs and provide a critical supply of healthy protein. They also constitute an important cultural heritage for fishing communities. The commercial fishing industry's total annual value exceeds $28 billion, with the recreational saltwater fishing industry valued at around $20 billion, and the annual U.S. retail trade in ornamental fish worth another $3 billion.

Every year, hundreds of millions of people visit America's coasts to enjoy the oceans, spending billions of dollars and directly supporting millions of jobs. Nationwide, retail expenditures on recreational boating alone exceeded $30 billion in 2002. In fact, tourism and recreation is one of the nation's fastest-growing business sectors, enriching economies and supporting jobs in communities virtually everywhere along the shores of the United States and its territories. Over half of the U.S. population lives in coastal watersheds,

Figure ES.1 The Value of the Coasts



Coastal watershed counties, which account for less than a quarter of U.S. land area, are significant contributors to the U.S. economy. In 2000, they were home to nearly half of the nation's jobs and generated a similar proportion of the nation's gross domestic product.

Source: Living Near… and Making a Living from… the Nation's Coasts and Oceans, Appendix C.

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and more than 37 million people and 19 million homes have been added to coastal areas during the last three decades, driving up real estate values and requiring ever greater support services.

These concrete, quantifiable contributions are just one measure of the value of the nation's oceans, coasts, and Great Lakes. There are many even more important attributes that cannot be given a price tag, such as global climate control, life support, cultural heritage, and the aesthetic value of the ocean with its intrinsic power to relax, rejuvenate, and inspire.

Trouble in Paradise

Unfortunately, our use and enjoyment of the ocean and its resources have come with costs, and we are only now discovering the full extent of the consequences of our actions. In 2001, 23 percent of the nation's estuarine areas were considered impaired for swimming, fishing, or supporting marine species. In 2003, there were more than 18,000 days of closings and advisories at ocean and Great Lakes beaches, most due to the presence of bacteria associated with fecal contamination. Across the globe, marine toxins afflict more than 90,000 people annually and are responsible for an estimated 62 percent of all seafood-related illnesses. Harmful algal blooms appear to be occurring more frequently in our coastal waters and non-native species are increasingly invading marine ecosystems. Experts estimate that 25 to 30 percent of the world's major fish stocks are overexploited, and many U.S. fisheries are experiencing serious difficulties. Since the Pilgrims first arrived at Plymouth Rock, over half of our fresh and saltwater wetlands—more than 110 million acres—have been lost.

Coastal waters are one of the nation's greatest assets, yet they are being bombarded with pollutants from a variety of sources. While progress has been made in reducing point sources of pollution, nonpoint source pollution has increased and is the primary cause of nutrient enrichment, hypoxia, harmful algal blooms, toxic contamination, and other problems that plague coastal waters. Nonpoint source pollution occurs when rainfall and snowmelt wash pollutants such as fertilizers, pesticides, bacteria, viruses, pet waste, sediments, oil, chemicals, and litter into our rivers and coastal waters. Other pollutants, such as mercury and some organic chemicals, can be carried vast distances through the atmosphere before settling into ocean waters.

Our failure to properly manage the human activities that affect the nation's oceans, coasts, and Great Lakes is compromising their ecological integrity, diminishing our ability to fully realize their potential, costing us jobs and revenue, threatening human health, and putting our future at risk.

The Work of the U.S. Commission on Ocean Policy

Congress clearly recognized both the promise of the oceans and the threats to them when it passed the Oceans Act of 2000, calling for establishment of a Commission on Ocean Policy to establish findings and develop recommendations for a coordinated and comprehensive national ocean policy. Pursuant to that Act, the President appointed sixteen Commission members drawn from diverse backgrounds, including individuals nominated by the leadership in the United States Senate and House of Representatives.

The Commission held sixteen public meetings around the country and conducted eighteen regional site visits, receiving testimony, both oral and written, from hundreds of people. Overall, the Commission heard from some 447 witnesses, including over 275 invited presentations and an additional 172 comments from the public, resulting in nearly 1,900 pages of testimony.

The message from both experts and the public alike was clear: our oceans, coasts, and Great Lakes are in trouble and major changes are urgently needed in the way we manage them. The Commission learned about new scientific findings that demonstrate the complexity and interconnectedness of natural systems. It also confirmed that our management approaches have not been updated to reflect this complexity, with responsibilities remaining dispersed among a confusing array of agencies at the federal, state, and local levels. Managers, decision makers, and the public cried out for improved and timely access to reliable data and solid scientific information that have been translated into useful results and products. Another steady theme heard around the country was the plea for additional federal support, citing decades of underinvestment in the study, exploration, protection, and management of our oceans, coasts, and Great Lakes. Finally, the point was made that we must enhance ocean-related education so that all citizens recognize the role of the oceans, coasts, and Great Lakes in their own lives and the impacts they themselves have on these environments.

Following extensive consideration, and deliberation of a broad array of potential solutions, the Commission presented a preliminary report in early 2004. Comments were solicited from state and territorial governors, tribal leaders, and the public; the response was overwhelming. Thoughtful, constructive feedback was received from thirty-seven governors (including 33 of the 34 coastal state governors), five tribal leaders, and a multitude of other organizations and individuals—over one thousand pages in all. Commenters were nearly unanimous in praising the report, agreeing that our oceans are in trouble, and supporting the call for action to rectify the situation. Where governors and others offered corrections or suggestions for improvement, the Commission paid close attention and made changes as needed.

This final report lays out the Commission's conclusions and detailed recommendations for reform—reform that needs to start now, while it is still possible to reverse distressing declines, seize exciting opportunities, and sustain the oceans and their valuable assets for future generations.

A Vision and Strategy for the 21st Century and Beyond

The Commission began by envisioning a desirable future. In this future, the oceans, coasts, and Great Lakes are clean, safe, prospering, and sustainably managed. They contribute significantly to the economy, supporting multiple, beneficial uses such as food production, development of energy and mineral resources, recreation and tourism, transportation of goods and people, and the discovery of novel medicines, while preserving a high level of biodiversity and a wide range of critical natural habitats.

In this future, the coasts are attractive places to live, work, and play, with clean water and beaches, easy public access, sustainable and strong economies, safe bustling harbors and ports, adequate roads and services, and special protection for sensitive habitats and threatened species. Beach closings, toxic algal blooms, proliferation of invasive species, and vanishing native species are rare. Better land-use planning and improved predictions of severe weather and other natural hazards save lives and money.

In this future, the management of our impacts on the oceans, coasts, and Great Lakes has also changed. Management boundaries correspond with ecosystem regions, and policies consider interactions among all ecosystem components. In the face of scientific uncertainty, managers balance competing considerations and proceed with caution. Ocean governance is effective, participatory, and well coordinated among government agencies, the private sector, and the public.

The Commission envisions a time when the importance of reliable data and sound science is widely recognized and strong support is provided for physical, biological, social, and economic research, as well as ocean exploration. The nation invests in the needed scientific tools and technologies, including ample, well-equipped surface and underwater research vessels, reliable, sustained satellites, state-of-the-art computing facilities, and innovative sensors that can withstand harsh ocean conditions. A widespread network of observing and monitoring stations provides a steady stream of data, and scientific findings are translated into practical information and products for decision makers, vessel operators, educators, and the public.

In this hoped-for future, better education is a cornerstone of national ocean policy, with the United States once again joining the top ranks in math, science, and technology achievement. An audacious program to explore unknown reaches of the ocean inspires and engages people of all ages. An ample, diverse, well-trained, and motivated workforce is available to study the oceans, set wise policies, develop and apply technological advances, and engineer new solutions. An effective team of educators works closely with scientists to learn and teach about the oceans—its value, beauty, and critical role on the planet. And, as a result of lifelong education, all citizens are better stewards of the nation's resources and marine environment.

Finally, the Commission's vision sees the United States as an exemplary leader and full partner globally, eagerly exchanging science, engineering, technology, and policy expertise with others, particularly those in developing countries, to facilitate the achievement of sustainable ocean management on an international level.

While progress has been made in a number of areas, the nation's existing system for managing our oceans, coasts, and Great Lakes is simply unable to effectively implement the appropriate guiding principles (see next page) and realize a positive long-term vision.

The Commission recommends moving toward an ecosystem-based management approach by focusing on three cross-cutting themes: (1) a new, coordinated national ocean policy framework to improve decision making; (2) cutting edge ocean data and science translated into high-quality information for managers; and (3) lifelong ocean-related education to create well-informed citizens with a strong stewardship ethic. These themes are woven throughout the report, appearing again and again in chapters dealing with a wide variety of ocean challenges.

A New National Ocean Policy Framework

To improve decision making, promote effective coordination, and move toward an ecosystem-based management approach, a new National Ocean Policy Framework is needed. While this framework is intended to produce strong, national leadership, it is also designed to support and enhance the critical roles of state, territorial, tribal, and local decision makers.

Improved National Coordination and Leadership

At the federal level, eleven of fifteen cabinet-level departments and four independent agencies play important roles in the development of ocean and coastal policy. These agencies interact with one another and with state, territorial, tribal, and local authorities in sometimes haphazard ways. Improved communication and coordination would greatly enhance the effectiveness of the nation's ocean policy.

Within the Executive Office of the President, three entities have some responsibilities relevant to oceans: the Office of Science and Technology Policy addresses government-wide science and technology issues and includes an ocean subcommittee; the Council on Environmental Quality (CEQ) oversees broad federal environmental efforts and implementation of the National Environmental Policy Act; and the National Security Council's

Guiding Principles

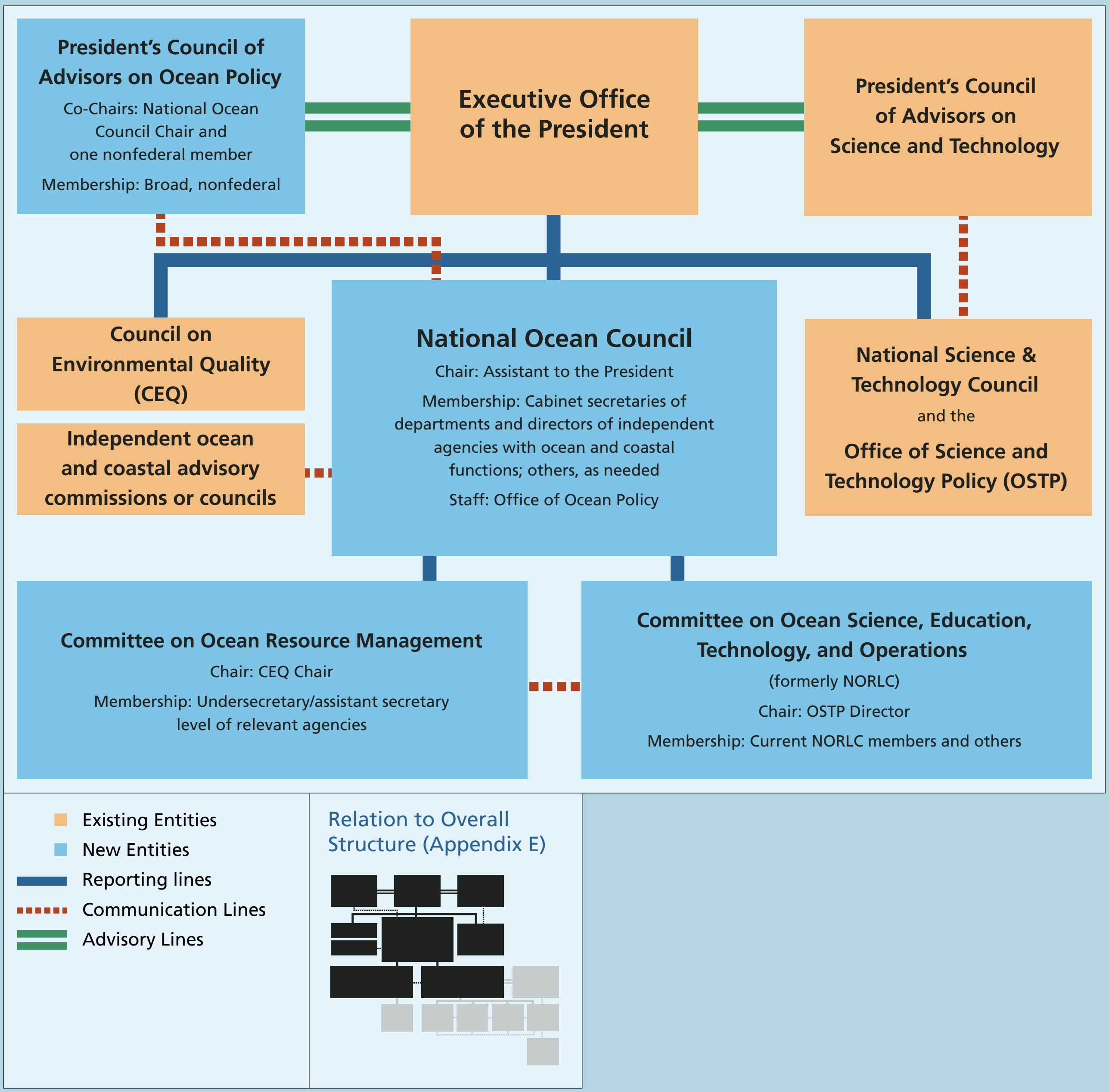
The Commission believes its vision for the future is both practical and attainable. To achieve it, however, an overarching set of principles should guide national ocean policy.

- **Sustainability:** Ocean policy should be designed to meet the needs of the present generation without compromising the ability of future generations to meet their needs.
- **Stewardship:** The principle of stewardship applies both to the government and to every citizen. The U.S. government holds ocean and coastal resources in the public trust—a special responsibility that necessitates balancing different uses of those resources for the continued benefit of all Americans. Just as important, every member of the public should recognize the value of the oceans and coasts, supporting appropriate policies and acting responsibly while minimizing negative environmental impacts.
- **Ocean–Land–Atmosphere Connections:** Ocean policies should be based on the recognition that the oceans, land, and atmosphere are inextricably intertwined and that actions that affect one Earth system component are likely to affect another.
- **Ecosystem-based Management:** U.S. ocean and coastal resources should be managed to reflect the relationships among all ecosystem components, including humans and nonhuman species and the environments in which they live. Applying this principle will require defining relevant geographic management areas based on ecosystem, rather than political, boundaries.
- **Multiple Use Management:** The many potentially beneficial uses of ocean and coastal resources should be acknowledged and managed in a way that balances competing uses while preserving and protecting the overall integrity of the ocean and coastal environments.
- **Preservation of Marine Biodiversity:** Downward trends in marine biodiversity should be reversed where they exist, with a desired end of maintaining or recovering natural levels of biological diversity and ecosystem services.
- **Best Available Science and Information:** Ocean policy decisions should be based on the best available understanding of the natural, social, and economic processes that affect ocean and coastal environments. Decision makers should be able to obtain and understand quality science and information in a way that facilitates successful management of ocean and coastal resources.
- **Adaptive Management:** Ocean management programs should be designed to meet clear goals and provide new information to continually improve the scientific basis for future management. Periodic reevaluation of the goals and effectiveness of management measures, and incorporation of new information in implementing future management, are essential.
- **Understandable Laws and Clear Decisions:** Laws governing uses of ocean and coastal resources should be clear, coordinated, and accessible to the nation's citizens to facilitate compliance. Policy decisions and the reasoning behind them should also be clear and available to all interested parties.
- **Participatory Governance:** Governance of ocean uses should ensure widespread participation by all citizens on issues that affect them.
- **Timeliness:** Ocean governance systems should operate with as much efficiency and predictability as possible.
- **Accountability:** Decision makers and members of the public should be accountable for the actions they take that affect ocean and coastal resources.
- **International Responsibility:** The United States should act cooperatively with other nations in developing and implementing international ocean policy, reflecting the deep connections between U.S. interests and the global ocean.

Global Environment Policy Coordinating Committee includes a subcommittee to deal with international ocean issues. But there is no multi-issue, interagency mechanism to guide, oversee, and coordinate all aspects of ocean and coastal science and policy.

As part of a new National Ocean Policy Framework, the Commission recommends that Congress establish a National Ocean Council (NOC) within the Executive Office of the President, chaired by an Assistant to the President and composed of cabinet secretaries of departments and administrators of independent agencies with relevant ocean- and coastal-related responsibilities (Figure ES.2). The NOC should provide high-level attention to ocean, coastal, and Great Lakes issues, develop and guide the implementation of

Figure ES.2 Proposed Structure for Coordination of Federal Ocean Activities



Shown here are the institutional components that should be established in the Executive Office of the President (EOP) to improve federal leadership and coordination of the nation's oceans and coasts. This diagram also illustrates the organizational relationship between these new components and existing units in the EOP.

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appropriate national policies, and coordinate the many federal departments and agencies with ocean and coastal responsibilities. The Assistant to the President should also advise OMB and the agencies on appropriate funding levels for important ocean- and coastal-related activities, and prepare a biennial report as mandated by Section 5 of the Oceans Act of 2000. A Committee on Ocean Science, Education, Technology, and Operations and a Committee on Ocean Resource Management should be created under the NOC to support its coordination and planning functions.

A President's Council of Advisors on Ocean Policy, consisting of representatives from state, territorial, tribal, and local governments and academic, public interest, and private sector organizations, should also be established to ensure a formal structure for nonfederal input to the NOC and the President on ocean and coastal policy matters.

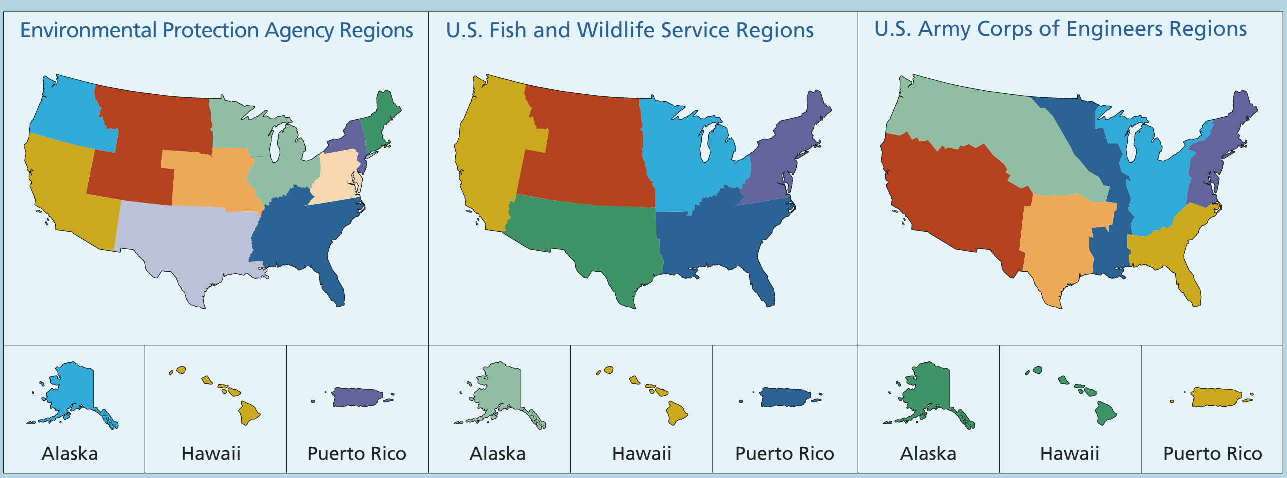
A small Office of Ocean Policy should provide staff support to all the bodies discussed above. Pending congressional action, the Commission recommends that the President put this structure in place through an executive order.

An Enhanced Regional Approach

Ensuring full state, territorial, tribal, and local participation in ocean policy development and implementation is a critical element of the new National Ocean Policy Framework. Many of the nation's most pressing ocean and coastal issues are local or regional in nature and their resolution requires the active involvement of state and local policy makers, as well as a wide range of stakeholders.

One of the priority tasks for the new National Ocean Council should be to develop and promote a flexible, voluntary process that groups of states could use to establish regional ocean councils. These regional ocean councils would then serve as focal points for discussion, cooperation, and coordination. They would improve the nation's ability to respond to issues that cross jurisdictional boundaries and would help policy makers address the large-scale connections and conflicts among watershed, coastal, and offshore uses. To complement and support this effort, the President should direct all federal agencies with ocean-related functions to immediately improve their regional coordination, moving over time to adopt a common regional structure (Figure ES.3).

Figure ES.3 Alignment of Federal Regions Is Essential for Communication



Shown above are the existing regional management areas for three federal agencies. Because these areas do not coincide, it is difficult for the agencies to coordinate and communicate about issues of common concern at the regional level. Furthermore, this lack of coordination impedes their ability to effectively interact with regional, state, territorial, tribal, and local entities on a regional basis.

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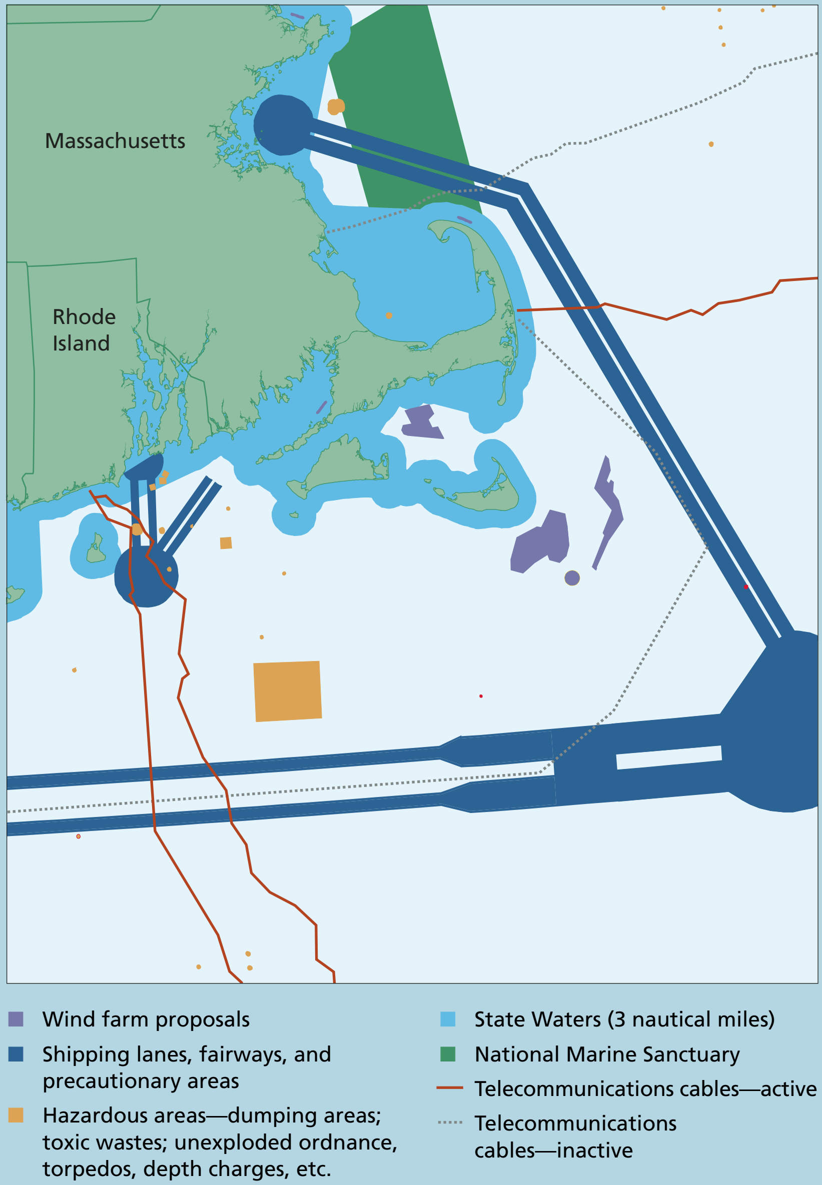
One pervasive problem for state and local managers is lack of sufficient, reliable information on which to base decisions. The Commission recommends that governors within a region identify an appropriate organization to create a regional ocean information program. Such programs will identify user-driven regional priorities for research, data, and science-based information products and help meet those needs by enhancing existing resources and promoting education, training, and outreach in support of improved ocean and coastal management.

Coordinated Governance of Offshore Waters

The nation's vast offshore ocean areas are becoming an increasingly appealing place to pursue economic activities (Figure ES.4). Well-established institutional frameworks exist for longstanding ocean uses, such as fishing and energy extraction; however, authorities governing new activities, such as the placement of wind farms or aquaculture facilities, need to be clarified. A comprehensive offshore management regime is needed that enables us to realize the ocean's potential while safeguarding human and ecosystem health, minimizing conflicts among users, and fulfilling the government's obligation to manage the sea in a way that maximizes long-term benefits for all the nation's citizens.

The National Ocean Council, supported by congressional action where necessary, should ensure that each current or foreseeable activity in federal waters is administered by a lead federal agency. Well-developed laws or authorities that cover existing programs would not be supplanted, but the lead agency would be expected to continue and enhance coordination among all other involved federal partners. For emerging ocean activities whose management is ill defined, dispersed, or essentially non-existent, the National Ocean Council and Congress, working with affected stakeholders, should ensure that the lead agency provides strong coordination, while working toward a more comprehensive governance structure.

Figure ES.4 Coordination Is Essential in Busy Offshore Waters



Like many offshore areas of the nation, the waters off a small portion of the New England coast are home to a number of existing and proposed activities. In addition to the uses shown above, many offshore areas also contain dredging projects, marine protected areas, fishery closures, recreational activities, artificial reefs, and in certain coastal regions, oil and gas development. User conflicts can and do arise when incompatible activities take place in the same area. A comprehensive offshore management regime is needed for the balanced coordination of all offshore uses.

Source: Minerals Management Service, Washington, DC.

Based on an improved understanding of offshore areas and their resources, the federal government should work with appropriate state and local authorities to ensure that the many different activities within a given area are compatible, in keeping with an ecosystem-based management approach. As the pressure for offshore uses grows, and before serious conflicts arise, it is critical that the National Ocean Council review the complete array of single-purpose offshore programs with the goal of achieving coordination among them.

Ultimately, a streamlined program for each activity should be combined with a comprehensive offshore management regime that considers all uses, addresses the cumulative impacts of multiple activities, and coordinates the many authorities with interests in offshore waters. The National Ocean Council, President's Council of Advisors on Ocean Policy, federal agencies, regional ocean councils, and states will all have roles to play in realizing more coordinated, participatory management of offshore ocean activities.

In considering the coordination of ocean activities, marine protected areas provide one valuable tool for achieving more ecosystem-based management of both nearshore and offshore areas. Such areas can be created for many different reasons including: enhancement of living marine resources; protection of habitats, endangered species, and marine biological diversity; or preservation of historically or culturally important submerged archeological resources. Marine protected areas may also provide scientific, recreational, and educational benefits. The level of protection and types of activities allowed can vary greatly depending on the goals of the protected area.

With its multiple use, ecosystem-based perspective, the National Ocean Council should oversee the development of a flexible process—one that is adaptive and based on the best available science—to design, implement, and assess marine protected areas. Regional ocean councils, or other appropriate entities, can provide a forum for engaging all stakeholders in this process.

A Strengthened Federal Agency Structure

Improved coordination through a National Ocean Council is necessary, but not sufficient to bring about the depth of change needed. Some restructuring of existing federal agencies will be needed to make government less redundant, more flexible, more responsive to the needs of states and stakeholders, and better suited to an ecosystem-based management approach. Because of the significant hurdles involved, a phased approach is suggested.

The National Oceanic and Atmospheric Administration (NOAA) is the nation's primary ocean agency. Although it has made significant progress in many areas, there is widespread agreement that the agency could manage its activities more effectively. In addition, many of the recommendations in this report call for NOAA to handle additional responsibilities. A stronger, more effective, science-based and service-oriented ocean agency is needed—one that works with others to achieve better management of oceans and coasts through an ecosystem-based approach.

As an initial step in a phased approach, Congress should pass an organic act that codifies the existence of NOAA. This will strengthen the agency and help ensure that its structure is consistent with three primary functions: management; assessment, prediction, and operations; and research and education. To support the move toward a more ecosystem-based management approach within and among federal agencies, the Office of Management and Budget (OMB) should review NOAA's budget within its natural resource programs directorate, rather than the general government programs directorate. This change would make it easier to reconcile NOAA's budget with those of the other major resource-oriented departments and agencies, all of which are reviewed as natural resource programs at OMB.

As a second step in the phased approach, all federal agencies with ocean-related responsibilities should be reviewed and strengthened and overlapping programs should be considered for consolidation. Programmatic overlaps can be positive, providing useful checks and balances as agencies bring different perspectives and experiences to the table. However, they can also diffuse responsibility, introduce unnecessary redundancy, raise administrative costs, and interfere with the development of a comprehensive management regime. The Commission recommends that program consolidation be pursued in areas such as area-based ocean and coastal resource management, invasive species, marine mammals, aquaculture, and satellite-based Earth observing. The Assistant to the President, with advice from the National Ocean Council and the President's Council of Advisors on Ocean Policy, should review other federal ocean, coastal, and atmospheric programs, and recommend additional opportunities for consolidation.

Ultimately, our growing understanding of ecosystems and the inextricable links among the sea, land, air, and all living things, points to the need for more fundamental reorganization of the federal government. Consolidation of *all* natural resource functions, including those involving oceans and coasts, would enable federal agencies to move toward true ecosystem-based management.

Sound Science and Information for Wise Decisions

An effective national ocean policy should be based on unbiased, credible, and up-to-date scientific information. Unfortunately, the oceans remain one of the least explored and most poorly understood environments on the planet, despite some tantalizing discoveries over the last century.

Sustained investments will be required to: support research and exploration; provide an adequate infrastructure for data collection, science, and management; and translate new scientific findings into useful and timely information products for managers, educators, and the public. This is especially true as we move toward an ecosystem-based management approach that imposes new responsibilities on managers and requires improved understanding of physical, biological, social, and economic forces.

Investing in Science and Exploration

Over the past two decades, with our oceans, coasts, and Great Lakes under siege, federal investment in ocean research has stagnated while other fields have grown. As a result, ocean science funding has fallen from 7 percent of the total federal research budget twenty-five years ago to just 3.5 percent today. This lagging support in the United States, combined with growing foreign capability, has lessened the nation's pre-eminence in ocean research, exploration, and technology development. Chronic under-investment has also left much of our ocean-related infrastructure in woefully poor condition.

The current annual federal investment in marine science is well below the level necessary to adequately meet the nation's needs for coastal and ocean information. The Commission urges Congress to double the federal ocean and coastal research budget over the next five years, including a national program of social science and economic research to examine the human dimensions and economic value of the nation's marine resources. In addition, a dedicated ocean exploration program should be launched to unlock the mysteries of the deep by discovering new ecosystems, natural resources, and archaeological treasures.

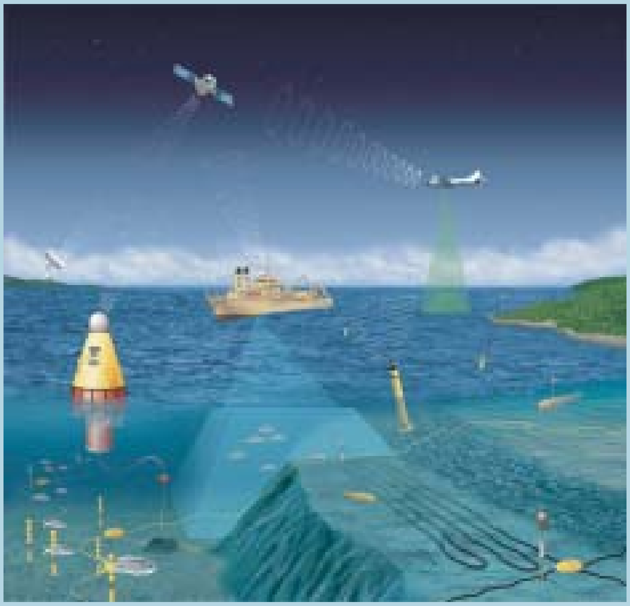
A renewed U.S. commitment to ocean science and technology will require not only substantially increased funding, but also improved strategic planning, closer interagency coordination, robust technology and infrastructure, and 21st century data management systems. The Commission recommends: creation of a national strategy for ocean research that will guide individual agencies' ten-year science plans; enhancement and maintenance of the nation's ocean and coastal infrastructure; and development of new technologies, with more rapid transition of experimental technologies into operational applications.

Launching a New Era of Data Collection

The Integrated Ocean Observing System

About 150 years ago, this nation set out to create a comprehensive weather forecasting and warning network. Today it is hard to imagine living without constantly updated and increasingly accurate weather reports. Now it is time to fully incorporate the oceans in this observational and forecasting capability. A sustained, national Integrated Ocean Observing System (IOOS) will provide invaluable economic, societal, and environmental benefits, including improved warnings of coastal and health hazards, more efficient use of living and nonliving resources, safer marine operations, and a better understanding of climate change. Our information needs are growing and the challenges we face along our coasts and in our oceans are escalating. The nation needs to substantially advance its ability to observe, monitor, and forecast ocean and coastal conditions, and contribute to global Earth observing capabilities (Figure ES.5).

Figure ES.5 Many Different Platforms Collect Data as Part of the IOOS



This picture is an artist's rendering of the various water-, air-, and space-components of ocean observing systems. The data collected by each of these different sensors are transmitted via seafloor fiber optic cables and satellites to a central location on land.

Source: HARRIS Corporation Maritime Communications, Melbourne, FL.

The Commission recommends that the Federal government, through the National Ocean Council, make the development and implementation of the IOOS a high priority, to be organized through a formalized Ocean.US office. The United States simply cannot achieve the levels of understanding and predictive capability needed, or generate the information required by a wide range of users, without the IOOS. While implementation of the IOOS will require significant, sustained funding, estimates suggest that an operational IOOS will save the United States billions of dollars annually through enhanced weather forecasts, improved resource management, and safer, more efficient marine operations.

The IOOS must meet the needs of a broad suite of users, from scientists to the general public. To maximize its benefits, resource managers at federal, regional, state, and local levels will need to explain their information needs and provide guidance on the most useful outputs and products. The regional observing systems, overseen by Regional Associations, will provide a visible avenue for all users to provide input to the national IOOS.

The National Monitoring Network

Despite the growing threats to ocean, coastal, and Great Lakes waters, there is no national monitoring network in place to assess their status, track changes over time, help identify causes and impacts, or determine the success of management efforts. Increased monitoring is needed not only along the nation's coasts, but also inland where pollutants often originate, traveling downstream and ultimately affecting coastal waters. A national monitoring network is essential to support the move toward an ecosystem-based management approach that considers the impacts of human activities within the context of the broader biological and physical environment. NOAA, EPA, and USGS should lead an effort to develop a national monitoring network that coordinates and expands existing efforts by federal, state, local, and private entities.

Because of the inherent overlap between inland, coastal, and open-ocean waters, NOAA should ensure that the national monitoring network includes adequate coverage in both coastal areas and the upland reaches that affect them, and that it is closely linked with the IOOS. User communities should participate fully in developing the network, and the data collected should be made available in useful formats to managers and stakeholders so they can make continual progress toward ecosystem-based management goals. The design and implementation of the national monitoring network will require not only federal coordination, but also significant input from states and regional entities.

Turning Data into Useful Information

The data generated from increased research, enhanced monitoring networks, and new observing systems will be essential in improving our management of ocean and coastal resources. However, two major challenges face today's data managers: the sheer volume of incoming data, which strains storage and assimilation capabilities, and the demand for timely access to the data in a variety of formats by user communities. Meeting these challenges will require a concerted effort to modernize the current data management system and will require greatly improved interagency planning and coordination. The Commission recommends the creation of several new programs and partnerships to achieve these goals.

First, Congress should amend the National Oceanographic Partnership Act to establish Ocean.IT, a new federal interagency mechanism to oversee ocean and coastal data management. This interagency group will enhance coordination, harmonize future software and hardware acquisitions and upgrades, and oversee strategic planning and funding. Building partnerships with the private sector and academia should also be a major goal of Ocean.IT.

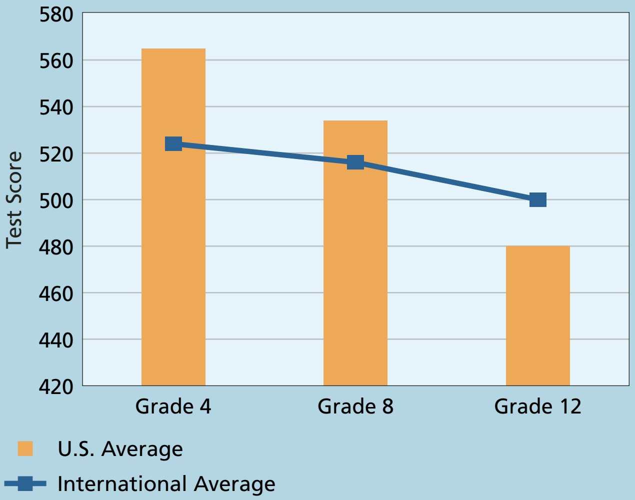
Second, NOAA and the U.S. Navy should establish an ocean and coastal information management and communications partnership to generate information products relevant to national, regional, state, and local operational needs. Building upon the Navy's model for operational oceanography, this partnership would rapidly advance U.S. coastal and ocean analyses and forecasting capabilities by drawing on the distinct, yet complementary capabilities of each organization and using all available physical, biological, chemical, and socioeconomic data.

The Commission recommends the creation of two additional programs that will aid in the creation and dissemination of information: multi-stakeholder regional ocean information programs to develop and disseminate useful information products on a regional basis; and accelerated coastal and ocean mapping and charting, coordinated through the Federal Geographic Data Committee.

Education: A Foundation for the Future

Testing results suggest that, after getting off to a good start in elementary school, by the time U.S. students graduate from high school their achievement in math and science falls well below the international average (Figure ES.6). More specifically, a 1999 study revealed that just 32 percent of the nation's adults grasp simple environmental concepts and even fewer understand more complex issues, such as ecosystem decline, loss of biodiversity, or watershed degradation. It is not widely understood that nonpoint source pollution threatens the health of coastal waters, or that mercury in fish comes from human activities via the atmosphere. From excess application of fertilizers, pesticides, and herbicides on lawns, to the trash washed off city streets into rivers and coastal waters, ordinary activities contribute significantly to the degradation of the marine environment, but without an informed and educated citizenry, it will be difficult to achieve a collective commitment to stewardship, sustained investment, and more effective policies.

Figure ES.6 U.S. Students Fall Behind in Science



U.S. students in fourth grade score above the international average in science achievement, according to the Trends in International Mathematics and Science Study. However, as students approach their final year in secondary school, the performance in U.S. schools drops well below the international average.

Source: Calsyn, C., P. Gonzales, and M. Frase. *Highlights from TIMSS [Trends in International Mathematics and Science Study].* Washington, DC: National Center for Education Statistics, 1999.

A new national ocean policy should include a strong commitment to education to reverse scientific and environmental illiteracy, create a strong, diverse workforce, produce informed decision makers, and develop a national stewardship ethic for the oceans, coasts, and Great Lakes. The Commission recommends that all ocean-related agencies take responsibility for promoting education and outreach as an integral part of their missions. Ocean education at all levels, both formal and informal, should be enhanced with targeted projects and continual assessments and improvement.

A national ocean education office, Ocean.ED, should be created under the National Ocean Council to promote nationwide improvements in ocean education. As an interagency office, Ocean.ED should develop a coordinated national strategy and work in partnership with state and local governments and with K–12, university level, and informal educators. The National Science Foundation Centers for Ocean Science Education Excellence provide one outstanding model that should be expanded. Other recommendations include increased funding for training and fellowships, targeted efforts to increase participation by under-represented groups, and closer interaction between scientists and educators. All ocean-related agencies must explore innovative ways to engage people of all ages in learning and stewardship, using the excitement of ocean science and exploration as a catalyst.

Specific Management Challenges

Building on the foundation of improved governance, new scientific information, and enhanced education, the Commission's report covers the full breadth of topics included in its charge from Congress. As a result, it includes over 200 recommendations that span the gamut of ocean and coastal issues, ranging from upstream areas to the depths of the sea, from practical problem solving to broad guidance for ocean policy.

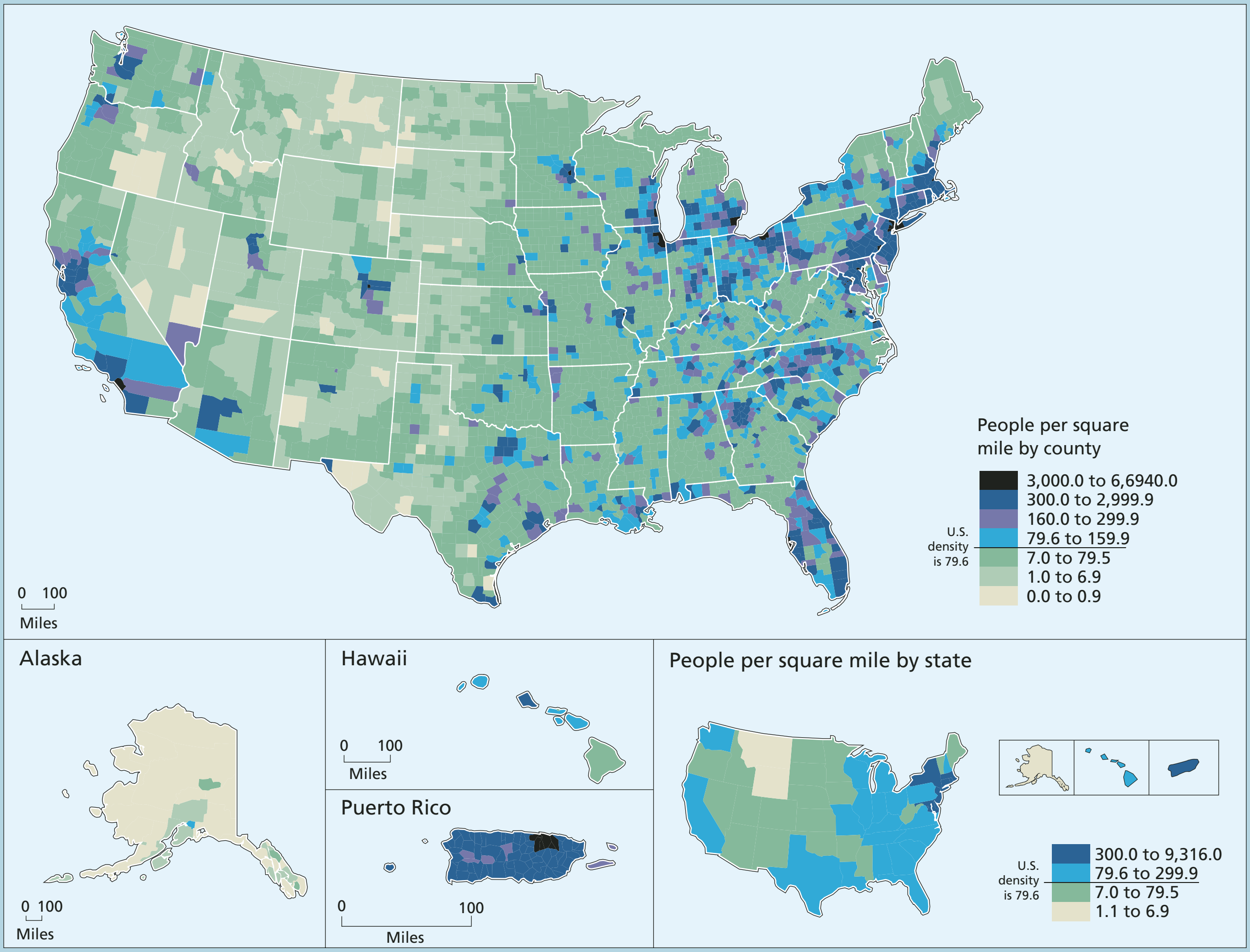
Several important issues pose particular challenges and are highlighted in the following sections. The full report addresses these topics and a number of others in much greater depth.

Managing Coasts and Their Watersheds

While coastal watershed counties comprise less than 25 percent of the land area in the United States, they are home to more than 52 percent of the total U.S. population. On average, some 3,600 people a day are moving to coastal counties, suggesting that by 2015 coastal populations will reach a total of 165 million. With another 180 million people visiting the coast each year, the pressure on our oceans, coasts, and Great Lakes will become ever more intense and the need for effective management greater (Figure ES.7).

Population growth and tourism bring many benefits to coastal communities and the nation, including new jobs, businesses, and enhanced educational opportunities. The great popularity of these areas, however, also puts more people and property at risk from

Figure ES.7 Population Density Peaks Near the Shore



As shown by 2000 U.S. Census figures, population density is generally highest in coastal areas, including counties surrounding the Great Lakes. Population growth and increasing population density in coastal counties reflect the attraction of the coast but also result in increased environmental impacts on coastal ecosystems.

Source: U.S. Census Bureau. "Census 2000." <www.census.gov> (Accessed March 2004).

coastal hazards, reduces and fragments fish and wildlife habitat, alters sediment and water flows, and contributes to coastal water pollution. Fortunately, we are gaining a much-improved understanding of human influences on coastal ecosystems, whether they originate locally, regionally, or in watersheds hundreds of miles upstream.

Without question, management of the nation's coastal zone has made great strides, but further improvements are urgently needed, with an emphasis on ecosystem-based, watershed approaches that consider environmental, economic, and social concerns. The Commission recommends that federal area-based coastal programs be consolidated and federal laws be modified to improve coastal resource protection and sustainable use. Congress should reauthorize and boost support for the Coastal Zone Management Act, strengthening the management capabilities of coastal states and enabling them to incorporate a watershed focus. The Coastal Zone Management Act, Clean Water Act, and other federal laws should be amended to provide financial, technical, and institutional support for watershed initiatives.

At the highest level, the National Ocean Council should develop national goals and direct changes to better link coastal and watershed management and minimize impacts associated with coastal population and housing growth. The President's Council of Advisors on Ocean Policy can serve as a forum through which nonfederal entities have an opportunity to provide critically needed input to help guide this change. Regional ocean councils can also provide a mechanism for coordinating coastal and watershed management.

Guarding People and Property against Natural Hazards

Conservative estimates of damages from natural hazards, looking only at direct costs such as those for structural replacement and repair, put nationwide losses at more than $50 billion a year. Some experts believe this figure represents only half or less of the true costs. More accurate figures are unavailable because the United States does not consistently collect and compile such data, let alone focus specifically on losses in coastal areas or costs associated with damage to natural environments.

Many federal agencies have explicit operational responsibilities related to hazards management, while others provide technical information or deliver disaster assistance. The nation's lead agencies for natural hazards planning, response, recovery, and mitigation are the Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers (USACE). These agencies implement programs that specifically target the reduction and management of risks from natural hazards.

Opportunities for improving Federal natural hazards management include: modifying federal infrastructure policies that encourage inappropriate development in hazard-prone areas; augmenting hazards information collection, analysis, and dissemination; refining the National Flood Insurance Program (NFIP); and undertaking effective and universal state and local hazards mitigation planning.

Conserving and Restoring Coastal Habitat

The diverse habitats that comprise the ocean and coastal environment provide tangible benefits such as filtering pollutants from runoff, buffering coastal communities against the effects of storms, and providing a basis for booming recreation and tourism industries. These habitats also supply spawning grounds, nurseries, shelter, and food for marine life, including a disproportionate number of endangered or commercially important species.

As more people come to the coast to live, work, and visit, coastal habitats are increasingly stressed and damaged. Over the past several decades the nation has lost millions of acres of wetlands, seen the destruction of seagrass and kelp beds, and faced a loss of significant mangrove forests. Cost-effective conservation and restoration programs should be expanded according to a national strategy that sets goals and priorities, enhances the effectiveness and coordination of individual efforts, and periodically evaluates progress. Many habitat conservation and restoration projects have been successful, but continued progress will depend on sustained funding, improved government leadership and coordination, enhanced scientific research and monitoring, better education and outreach, and solid stakeholder support.

Managing Sediment and Shorelines

From a human perspective, sediment has a dual nature—desirable in some locations and unwanted in others—making its management particularly challenging. The natural flow of sediment over land and through waterways is important for sustaining coastal habitats and maintaining beaches. Too little sediment can lead to declining habitats, diminishing wetlands and eroding beaches. However, excess or contaminated sediment can block shipping channels, destroy habitats, poison the food chain, and endanger lives. Navigational dredging, infrastructure projects, farming, forestry, urban development, industrial operations, and many other necessary and beneficial human activities can interfere with natural sediment processes, adversely affecting the interests of other stakeholders and the environment.

The nation must overcome several challenges to improve its management of sediment. The natural processes that create, move, and deposit sediment operate on regional scales, while today's management regime generally addresses discrete locations—a single beach, wetland, or port—and rarely addresses broader upstream or coastal activities that affect sediment processes. To complicate matters further, the policies that control sediment dredging, transport, and quality fall under the jurisdiction of an assortment of programs within multiple agencies at all levels of government. Finally, our understanding of natural sediment processes, and how human activities affect sediment movement, is still limited.

A national sediment management strategy is needed that balances ecological and economic needs according to an ecosystem-based management approach. Such a strategy should consider sediment on a multi-project, regional, watershed basis, and should involve all relevant parties. Participation in watershed management efforts by federal, state, and local entities, along with key stakeholders such as coastal planners and port managers, is an important step in diminishing upland sources of excess or contaminated sediment. Scientifically sound methods for characterizing contaminated sediment, combined with innovative technologies for dredging, treatment, and disposal of this material, will also be critical.

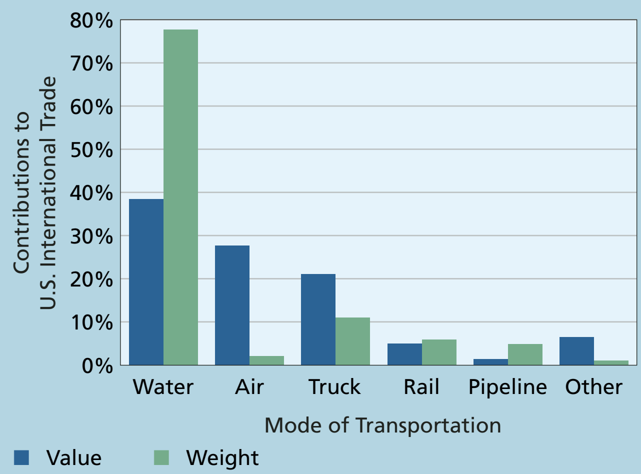
Supporting Marine Commerce and Transportation

Global trade is an essential and growing component of the nation's economy, accounting for nearly 7 percent of the gross domestic product. The vast majority of our import-export goods pass through the nation's extensive marine transportation system (Figure ES.8). To meet current demands and prepare for expected growth in the future, this system will require maintenance, improvement, and significant expansion.

A first step in the process will be better coordination, planning, and allocation of resources at the federal level. As part of a national move toward an ecosystem-based management approach, the efficient, safe, and secure movement of cargo and passengers should be well coordinated with other ocean and coastal uses and activities, and with efforts to protect the marine environment.

Specific recommendations include giving the Department of Transportation (DOT) lead responsibility within the federal government for oversight of the marine transportation system, including regular assessments of its status and future needs. DOT should develop an integrated national freight transportation strategy that strengthens the links between ports and other modes of transportation to support continued growth of international and domestic trade. In developing a national freight transportation strategy, DOT should work closely with the U.S. Department of Homeland Security and FEMA to incorporate port security and other emergency preparedness requirements.

Figure ES.8 Ports are the Primary Gateway for International Trade



In 2001, U.S. ports were major gateways for international trade. Waterborne commerce accounted for 78 percent of total U.S. international trade by weight (1,643 million tons) and 38 percent by value ($718 billion).

Source: U.S. Department of Transportation, Bureau of Transportation. "U.S. International Trade and Freight Transportation Trends 2003." <www.bts.gov/publications/us_international_trade_and_freight_transportation_trends/2003/> (Accessed May 2004).

To ensure good coordination, the Interagency Committee for the Marine Transportation System should be strengthened, codified, and placed under the oversight of the National Ocean Council. Because marine transportation is primarily a nonfederal activity, the Marine Transportation System National Advisory Council should also be maintained to provide a venue for outside input to the federal government on relevant issues.

Addressing Coastal Water Pollution

Coastal and ocean water quality is threatened by multiple sources of pollution, including point, nonpoint, and atmospheric sources, vessels, invasive species, and trash being washed onto beaches and into the ocean. Addressing these many sources requires development of an ecosystem-based and watershed management approach that draws on a variety of management tools. Because water contamination problems are complex and pervasive, their solution will require substantial investments of federal resources and greatly enhanced coordination both among federal agencies (primarily EPA, NOAA, USDA, and USACE) and between the federal government and managers at state, territorial, tribal, and local levels, in addition to watershed groups, nongovernmental organizations, private stakeholders, and the academic and research communities.

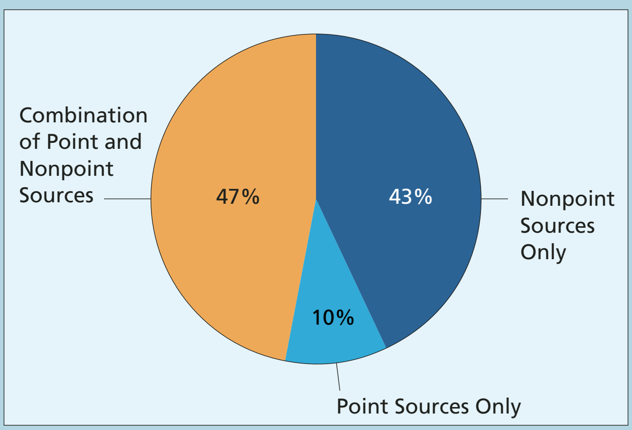
Over the last few decades, great strides have been made in reducing water pollution from point sources, although further improvements can be realized through increased funding, strengthened enforcement, and promotion of innovative approaches, such as market-based incentives. Persistently troublesome point sources of pollution, including wastewater treatment plants, sewer system overflows, septic systems, industrial facilities, and animal feeding operations, must continue to be addressed.

But the widespread and growing problem of nonpoint source pollution (Figure ES.9) has not seen similar success. Significant reduction of such pollution in all impaired coastal watersheds should be established as a national goal with measurable objectives set to meet water quality standards. Federal nonpoint source pollution programs should be better coordinated so they are mutually supportive. Because agricultural runoff contributes substantially to such pollution, USDA should align its conservation programs, technical assistance, and funding with EPA and NOAA programs for reducing nonpoint source pollution. State and local governments can also play central roles through better land-use planning and stormwater management.

Pollution reduction efforts should include the aggressive use of state revolving loan funds, implementation of incentives to reward good practices, and improved monitoring to assess compliance and overall progress. Congress should also amend the Clean Water Act to authorize federal financial disincentives to discourage activities that degrade water quality and to provide federal authority to act if a state chronically fails to make progress in controlling nonpoint sources.

Given the natural functioning of hydrologic systems, watersheds are often the appropriate geographic unit within which to address water-related problems. Collaborative watershed groups have had particular success in addressing nonpoint source pollution. The federal government should strengthen collaborative watershed groups by providing them with adequate technical, institutional, and financial support.

Figure ES.9 Controlling Nonpoint Source Pollution Is Key to Cleaner Waters



Nonpoint source pollution is a factor in 90 percent of all incidents where water quality is determined to be below the standards set for specific activities, such as recreation, water supply, aquatic life, or agriculture.

Source: U.S. Environmental Protection Agency. *Clean Water Act Section 303(d) Lists: Overview of TMDL Program.* Washington, DC, 1998.

Because contaminants can travel long distances through the atmosphere and be deposited far from their origin, EPA and states should also develop and implement regional and national strategies for controlling this source of water pollution, building upon efforts such as the EPA Air-Water Interface Work Plan. In addition, the United States should participate in a vigorous international research program on the sources and impacts of atmospheric deposition and play a leadership role in negotiating international solutions.

Limiting Vessel Pollution and Improving Vessel Safety

Ships carry more than 95 percent of the nation's overseas cargo, but their operations also present safety, security, and environmental risks. To minimize these risks, the Commission recommends that the U.S. Coast Guard work with industry partners and enhance incentive programs to encourage voluntary commitments from vessel owners and operators to build a workplace ethic that values safety, security, and environmental protection as central components of everyday vessel operations. These voluntary measures should be complemented by effective oversight and monitoring, whether conducted by the Coast Guard or third-party audit firms, and backed up by consistent enforcement efforts, including performance-based vessel inspections.

The United States should also work with other nations, through the International Maritime Organization, to enhance flag state oversight and enforcement. Initiatives should include expeditious promulgation of a code outlining flag state responsibilities and development of a mandatory external audit regime to evaluate flag state performance and identify areas where additional technical assistance is needed.

Control over vessels entering U.S. ports should be improved by ensuring that the Coast Guard has sufficient resources to sustain and strengthen its performance-based inspection program for marine safety and environmental protection, while also meeting its enhanced security responsibilities. In addition, the Coast Guard should work at the regional and international levels to increase effective coordination and vessel information sharing among concerned port states.

A number of other important vessel-related priorities are discussed in the report, including the need for a uniform national regime to deal with cruise ship waste streams and reduction of recreational vessel pollution.

Preventing the Spread of Invasive Species

The introduction of non-native organisms into ports, coastal areas, and watersheds is causing harm to marine ecosystems around the world resulting in millions of dollars in costs for monitoring, control, and remediation. The most effective weapon against invasive species is prevention. To control the introduction of invasive species through ships' ballast water, a major pathway, the U.S. Coast Guard's national ballast water management program should: incorporate sound science in the development of biologically meaningful, mandatory, and enforceable ballast water treatment standards; develop new treatment technologies, revising the standards as needed to incorporate these technologies; and allow for full consultation with EPA.

To address introduction pathways other than ballast water, such as ships' hulls, anchors, navigational buoys, drilling platforms, fishing activities, the aquarium trade, aquaculture, and floating marine debris, the Departments of Agriculture, Commerce, the Interior, and Homeland Security should more actively monitor and prevent the importation of potentially invasive aquatic species. Because prevention will never be entirely effective, the Commission also recommends the development of a national plan for early detection of invasive species and a system for prompt notification and rapid response.

The National Ocean Council, working with the Aquatic Nuisance Species Task Force and the National Invasive Species Council, should review and streamline the current proliferation of federal and state programs for managing invasive species and should coordinate education and outreach efforts to increase public awareness about the importance of prevention. In the long run, a rigorous program of research, technology development, and monitoring will be needed to understand and effectively prevent aquatic species invasions.

Reducing Marine Debris

Marine debris refers to the enormous amount of trash, abandoned fishing gear, and other waste that can be found drifting around the global ocean and washing up along its coastlines, posing serious threats to wildlife, habitats, and human health and safety. Approximately 80 percent of this debris originates on land, either washed along in runoff, blown by winds, or intentionally dumped from shore, while 20 percent comes from offshore platforms and vessels, including fishing boats.

The Commission recommends that NOAA, as the nation's primary ocean and coastal management agency, reestablish its defunct marine debris program to build on and complement EPA's modest program. NOAA and EPA should expand their marine debris efforts, taking advantage of each agency's strengths by pursuing: public outreach and education; partnerships with local governments, community groups, and industry; and strengthened research and monitoring efforts.

An interagency committee under the National Ocean Council should coordinate federal marine debris programs and take maximum advantage of the significant efforts conducted by private citizens, state and local governments, and nongovernmental organizations.

The United States should also remain active on the international level. An immediate priority is the development of an international plan of action to address derelict fishing gear on the high seas.

Achieving Sustainable Fisheries

Over the last thirty years, the fishing industry has evolved from being largely unmanaged, with seemingly boundless opportunities, to one that is highly regulated and struggling to remain viable in some places. While the current regime has many positive features, such as an emphasis on local participation, the pairing of science and management, and regional flexibility, it has also allowed overexploitation of many fish stocks, degradation of habitats, and negative impacts on many ecosystems and fishing communities.

The Commission's recommendations to improve fishery management can be grouped into six areas: re-emphasizing the role of science in the management process; strengthening the Regional Fishery Management Council (RFMC) system and clarifying jurisdictions; expanding the use of dedicated access privileges; improving enforcement; adopting an ecosystem-based management approach; and strengthening international management.

To strengthen the link between strong science and sustainable fishery management, RFMCs should be required to rely on the peer-reviewed advice of their Scientific and Statistical Committees (SSCs), particularly in setting harvest levels. In particular, an RFMC should not be allowed to approve any measure that exceeds the allowable biological catch recommended by its SSC. Because of their importance in the process, SSC members should be nominated by the RFMCs but appointed by the Administrator of NOAA, and their credentials and potential conflicts of interest should be vetted by an external organization. An expanded research program is needed that involves fishermen where possible and is responsive to managers' requirements.

Several recommendations are made concerning the composition, responsibilities, and jurisdiction of the various federal and interstate fishery management entities. In particular, membership on the RFMCs needs to be diversified and new members should receive consistent training in the often arcane vocabulary and policies involved in U.S. fishery management.

To reverse existing incentives that create an unsustainable "race for the fish," fishery managers should explore the adoption of dedicated access privileges to promote conservation and help reduce overcapitalization. Congress should amend the Magnuson–Stevens Fishery Conservation and Management Act to affirm that RFMCs are authorized to institute dedicated access privileges, subject to meeting national guidelines, and every federal, interstate, and state fishery management body should consider the potential benefits of adopting such programs. In addition, Congress should address overcapitalization directly by revising federal programs that subsidize this practice, as well as working with NOAA to develop programs that permanently reduce overcapitalization in fisheries.

Fishery enforcement should be continually strengthened through the adoption of better technologies, such as Vessel Monitoring Systems, better cooperation among federal and state agencies, and enhanced support for the infrastructure, personnel, and programs that make enforcement possible.

Consistent with one of the major themes of this report, fishery management needs to move toward a more ecosystem-based approach to improve its effectiveness and reduce conflicts between socioeconomic forces and biological sustainability. An ecosystem-based management approach will be particularly helpful in protecting essential fish habitat and reducing the impacts of bycatch.

Finally, the U.S. should work with other countries on worldwide adoption and enforcement of international agreements that promote sustainable fishery practices, in particular the United Nations Fish Stocks Agreement and the U.N. Food and Agriculture Organization's Compliance Agreement and Code of Conduct for Responsible Fisheries. The United States should also continue to press for the inclusion of environmental objectives—particularly those specified in international environmental agreements—as legitimate elements of trade policy.

Protecting Marine Mammals and Endangered Marine Species

The Marine Mammal Protection Act and the Endangered Species Act are landmark laws that have protected marine mammals, sea turtles, seabirds, and other populations at risk since their passage. However, both Acts need to be updated to support the move toward a more ecosystem-based approach.

As in so many other areas of ocean policy, immediate clarification and coordination of federal agency policies is needed. The Commission recommends that Congress consolidate the jurisdiction for marine mammals within NOAA, and that the National Ocean Council improve coordination between NOAA and the U.S. Fish and Wildlife Service in implementation of the Endangered Species Act, particularly for anadromous species or where land-based activities have significant impacts on marine species. Congress should also amend the Marine Mammal Protection Act to require NOAA to specify categories of activities that are allowed without a permit, those that require a permit, and those that are strictly prohibited. The permitting process itself should be streamlined by using programmatic permitting where possible. The definition of *harassment* in the Marine Mammal Protection Act should also be revised to cover only activities that meaningfully disrupt behaviors that are significant to the survival and reproduction of marine mammals.

The Commission recommends an expanded research, technology, and engineering program, coordinated through the National Ocean Council, to examine and mitigate the effects of human activities—including fishing, pollution, and climate change—on marine mammals, seabirds, sea turtles and all other marine endangered species. In addition, Congress should expand federal funding for research into ocean acoustics and the potential impacts of noise on marine mammals and other species.

Preserving Coral Reefs and Other Coral Communities

Coral communities are among the oldest and most diverse ecosystems on the planet, rivaling tropical rainforests in biodiversity and potential economic value. Unfortunately, like the rainforests, the world's coral reefs are increasingly showing signs of serious decline, with pristine reefs becoming rare and up to one-third of the world's reefs severely damaged according to some estimates.

A strengthened Coral Reef Task Force, under the oversight of the National Ocean Council, should promote immediate actions to reverse the impacts on tropical coral communities from pollution (with EPA and USDA in the lead) and from fishing (with NOAA in the lead). NOAA should be assigned as the lead agency for assessing and protecting the nation's relatively unexplored cold water coral communities, including dedicated research on their distribution and abundance and strategies to reduce major threats to their survival.

Congress should enact a Coral Protection and Management Act that provides direct authorities to protect and manage corals, and creates a framework for research and for cooperation with international efforts. This legislation should include: mapping, monitoring, and research programs to fill critical information gaps; liability provisions for damages to coral reefs, similar to those in the National Marine Sanctuaries Act; outreach activities to educate the public about coral conservation and reduce human impacts; and mechanisms for U.S. involvement in bilateral, regional, and international coral reef programs, particularly through the sharing of scientific, technical, and management expertise.

In many places, harvesting methods continue to damage reefs and overexploit ornamental species. As the world's largest importer of ornamental coral reef resources, the United States has a particular responsibility to help eliminate destructive harvesting practices and ensure the sustainable use of reef resources. The nation should develop standards for the importation of coral species to balance legitimate trade with protection of the world's coral reefs and to ensure that U.S. citizens do not unknowingly promote unsustainable practices.

Setting a Course for Sustainable Marine Aquaculture

Marine aquaculture has the potential to supply a significant part of the ever increasing domestic and global demand for seafood. However, two major concerns must be addressed: environmental problems associated with some aquaculture operations, particularly net-pen facilities, and a confusing, inconsistent array of state and federal regulations that hinder private sector investment.

The Commission recommends that Congress amend the National Aquaculture Act to designate NOAA as the lead federal agency for implementing a national policy on environmentally and economically sustainable marine aquaculture. Through a new Office of Sustainable Marine Aquaculture, NOAA should develop a single, multi-agency federal permitting process for the industry that ensures that aquaculture facilities meet all applicable environmental standards and protects the sustainability and diversity of wild stocks.

Additional investments in research, demonstration projects, and technical assistance can help the industry address environmental issues, conduct risk assessments, develop improved technology, select appropriate species, and create best management practices.

Connecting the Oceans and Human Health

Over the last several decades, scientific studies have demonstrated that the health of humans and the oceans are inextricably linked. Human inputs such as point and nonpoint source pollution adversely affect the health of coastal ecosystems, resulting in conditions which in turn affect human health.

Sewage effluent and stormwater discharges can contaminate water and marine organisms, leading to outbreaks of viral and bacterial diseases with serious medical consequences, and curtailing beach and ocean recreation. Chemicals like polychlorinated biphenyls (PCBs) and toxic metals like mercury enter the oceans from rivers and from atmospheric deposition. Once there, they accumulate in finfish and shellfish, posing potentially serious long-term health threats to consumers. Excessive nutrient inputs from nonpoint source pollution can lead to harmful algal blooms that are toxic to fish and humans and can result in oxygen-depleted "dead zones" that kill marine organisms and decimate recreational and commercial fishing. Global climate change may also result in the spread of human diseases such as cholera and malaria via the marine environment.

On a brighter note, a growing number of important medical treatments and biotechnologies are now based on chemicals that originate from marine organisms. Marine bioproducts with anti-inflammatory and cancer fighting properties are just a few examples of the promising medical advances found in the oceans. A more focused program of exploration and bioprospecting holds great promise for similar discoveries in the future.

Despite these threats and opportunities, our knowledge of the links between the oceans and human health is in its infancy and remains inadequate to make the science-based decisions that are needed. To expand this knowledge base, Congress should establish a major initiative on the oceans and human health. Existing programs at NOAA, NSF, and the National Institute of Environmental Health Sciences should be coordinated under this initiative, with additional input from EPA and FDA.

Managing Offshore Energy and Other Mineral Resources

Oil and gas development on the outer Continental Shelf (OCS) supplies over a quarter of the nation's domestic oil and gas reserves, and contributes thousands of jobs and billions of dollars to the economy. Although controversial in many locations, the process for oil and gas leasing and production is well developed, reasonably comprehensive, and could serve as a model for implementing offshore renewable energy projects within the context of a coordinated offshore management regime.

To maintain a strong link between ocean uses and ocean management, the Commission recommends dedicating federal revenues from OCS energy leasing and production to ensuring the sustainability of ocean and coastal resources. A portion of these funds should be given to coastal states, with larger shares going to OCS producing states to help address the environmental and economic consequences of energy production.

In addition to oil and gas, other offshore energy sources are being explored. The National Ocean Council (NOC), working with the U.S. Department of Energy and others, should determine whether methane hydrates can contribute significantly to meeting the nation's long-term energy needs and, if so, what level of investment in research and development is warranted. Renewable energy sources should also be considered as part of a coordinated offshore management regime. Congress, with input from the NOC, should enact legislation to streamline the licensing of renewable energy facilities in U.S. waters, relying on an open, transparent process that accounts for state, local, and public concerns. The legislation should include the principle that the ocean is a public resource and that the U.S. Treasury should receive a fair return from its use.

Advancing International Ocean Science and Policy

The United States has historically been a world leader in international ocean policy, participating actively in the development of international agreements that govern the planet's ocean areas and resources. That leadership must now be reaffirmed and reinvigorated by acceding to the United Nations Convention on the Law of the Sea, enhancing the participation of all ocean-related federal agencies in international discussions and negotiations, and taking a leading role in building international capacity in ocean science and management, particularly in developing countries.

The United States can advance its own interests and contribute to the health of the world's oceans by first ensuring that U.S. domestic policies and actions embody exemplary standards of wise, sustainable ocean management. The new National Ocean Policy Framework will be instrumental in setting this positive tone for the international community. Many additional recommendations for action at the international level are presented throughout the report in the context of specific ocean and coastal management issues, such as international fisheries, global transportation of air pollutants, trade in corals and other living marine resources, the worldwide spread of marine debris, and many others.

Implementing a New National Ocean Policy

There are over 200 recommendations in the Commission's report, each one calling on specific responsible parties to spearhead its implementation and be accountable for its progress. A large number of recommendations are directed at Congress, the leadership of the executive branch, and federal agencies, as shown in Chapter 31.

Although the Commission has generally targeted few recommendations specifically at state or local governments, it recognizes that a significant enhancement of the ocean and coastal partnership between the federal government and nonfederal governmental and nongovernmental stakeholders is one of the foundations of the new national ocean policy. These entities will have critically important roles to play in the establishment of regional ocean councils, and in areas such as coastal development, water quality, education, natural hazards planning, fishery management, habitat conservation, and much more. Strong state participation is also needed in the design and implementation of regional ocean observing systems and their integration into the national IOOS, as well as in other research and monitoring activities.

A Worthwhile Investment

Implementation of the recommendations in this report will lead to tangible, measurable improvements in U.S. ocean policy and in the health of our oceans, coasts, and Great Lakes. However, significant change cannot be achieved without adequate investments—of time, money, and political will. A summary of costs is presented in Chapter 30, and a detailed breakdown of the cost of each recommendation is provided in Appendix G. The Commission estimates the total additional cost for initiatives outlined in this report at approximately $1.5 billion in the first year and $3.9 billion per year after full implementation. The payoff from these investments will be substantial for the United States and its citizens, benefiting our economy, health, environment, quality of life, and security.

Long Term Support: The Ocean Policy Trust Fund

As noted previously, almost $5 trillion dollars, or one half of the nation's annual gross domestic product, is generated each year within coastal watershed counties. That enormous economic contribution is now being threatened by the degradation of our oceans, coasts, and Great Lakes. Modest levels of additional funding will reap significant dividends by supporting management strategies that restore and sustain our ocean and coastal resources and maximize their long-term value.

Despite pressing needs, the Commission is mindful of the intense budgetary constraints that exist at both federal and state levels—and is sensitive to the hardships associated with unfunded mandates, whether imposed on state governments or federal agencies. To cover

Critical Actions Recommended by the U.S. Commission on Ocean Policy

The following key recommendations provide the foundation for a comprehensive national ocean policy that will lead to significant improvements in ocean and coastal management.

Improved Governance

- Establish a National Ocean Council in the Executive Office of the President, chaired by an Assistant to the President.
- Create a non-federal President's Council of Advisors on Ocean Policy.
- Improve the federal agency structure by strengthening NOAA and consolidating federal agency programs according to a phased approach.
- Develop a flexible, voluntary process for creating regional ocean councils, facilitated and supported by the National Ocean Council.
- Create a coordinated management regime for activities in federal offshore waters.

Sound Science for Wise Decisions

- Double the nation's investment in ocean research, launch a new area of ocean exploration, and create the advanced technologies and modern infrastructure needed to support them.
- Implement the national Integrated Ocean Observing System and a national monitoring network.

Education—A Foundation for the Future

- Improve ocean-related education through coordinated and effective formal and informal efforts.

Specific Management Challenges

- Strengthen coastal and watershed management and the links between them.
- Set measurable goals for reducing water pollution, particularly from nonpoint sources, and strengthen incentives, technical assistance, enforcement, and other management tools to achieve those goals.
- Reform fisheries management by separating assessment and allocation, improving the Regional Fishery Management Council system, and exploring the use of dedicated access privileges.
- Accede to the United Nations Convention on the Law of the Sea to remain fully engaged on the international level.

Implementation

- Establish an Ocean Policy Trust Fund, based on unallocated revenues from offshore oil and gas development and new offshore activities, that is dedicated to supporting improved ocean and coastal management at federal and state levels.

the cost of its recommendations, the Commission believes it is important to identify appropriate, dedicated sources of revenue. In this regard, the nexus between federal offshore activities and the management responsibilities they engender is obvious. Thus, the Commission proposes the creation of an Ocean Policy Trust Fund in the U.S. Treasury, composed of revenues generated from permitted activities in federal waters.

The Trust Fund would start out with OCS oil and gas revenues that are not already committed to the Land and Water Conservation Fund, the National Historic Preservation Fund, or to certain coastal states based on oil and gas production in the three nautical mile area seaward of their submerged lands. After those existing programs are funded in accordance with law, the remaining OCS monies would be deposited into the Trust Fund. New offshore activities, such as renewable energy, aquaculture, or bioprospecting, may also produce revenues in time, and these should be added to the Fund. Establishment of, and distributions from, the Ocean Policy Trust Fund should be kept separate from any decisions about whether a particular offshore activity should be authorized and permitted.

Approximately $5 billion is generated annually from OCS oil and gas revenues. Protecting the three programs noted above would remove about $1 billion from that total. Thus, some $4 billion would remain available for the Ocean Policy Trust Fund each year under current projections. It is not possible to estimate the level of revenue that might accompany emerging activities in federal waters, nor to predict when this income could begin to flow, but the amounts may be significant in years to come.

Trust Fund monies should be used to support the additional research, education, and management responsibilities recommended for federal and state agencies and other appropriate coastal authorities, consistent with a coordinated and comprehensive national ocean policy. Such funds would be used to supplement—not replace—existing appropriations for ocean and coastal programs, and to fund new or expanded duties.

Call to Action

This report reflects the input of hundreds of Americans from across the nation, testimony from many of the world's leading experts, and months of deliberation. The recommendations contained within can set the course toward a future in which our oceans, coasts, and Great Lakes are healthy, enjoyed, and treasured by all people, and America's marine resources are restored and sustained for generations to come.

The opportunity is here and the time to act is now. A new national ocean policy can be implemented that balances ocean use with sustainability, is based on sound science and supported by excellent education, and is overseen by a coordinated system of governance with strong leadership at national and regional levels. It will take great political will, significant fiscal investment, and strong public support, but in the long run all of America will benefit from these changes.

PART I

Our Oceans: A National Asset

CHAPTER 1

Recognizing Ocean Assets and Challenges

America's oceans and coasts are priceless assets. Indispensable to life itself, they also contribute significantly to our prosperity and overall quality of life. Too often, however, we take these gifts for granted, underestimating their value and ignoring our impact on them. Then our use of the oceans becomes abuse, and the productive capacity of our marine resources is diminished.

The nation needs a comprehensive national ocean policy, implemented through an integrated and coordinated management structure that results in greater participation and collaboration in decision making. By rising to the challenge and addressing the many activities that are degrading the oceans and coasts, America can protect the marine environment while creating jobs, increasing revenues, enhancing security, protecting cultural heritage, expanding trade, and ensuring ample supplies of energy, minerals, healthy food, and life-saving drugs.

Evaluating the Vast Wealth of U.S. Oceans and Coasts

America is a nation surrounded by and reliant on the oceans. From the fisherman in Maine, to the homemaker in Oregon, to the businessperson in Miami, and even the farmer in Iowa, every American influences and is influenced by the sea. Our grocery stores are stocked with fish, our docks bustle with waterborne cargo, and millions of tourists visit our coastal communities each year, creating jobs and pumping dollars into our economy. Born of the ocean are clouds that bring life-sustaining rain to our fields and reservoirs, microscopic plankton that generate the oxygen we breathe, energy resources that fuel industry and sustain our standard of living, and a diversity of biological species that is unmatched on land. Careful stewardship of our ocean and coastal resources is imperative to conserve and enhance the financial, ecological, and aesthetic benefits we have come to rely upon and enjoy.

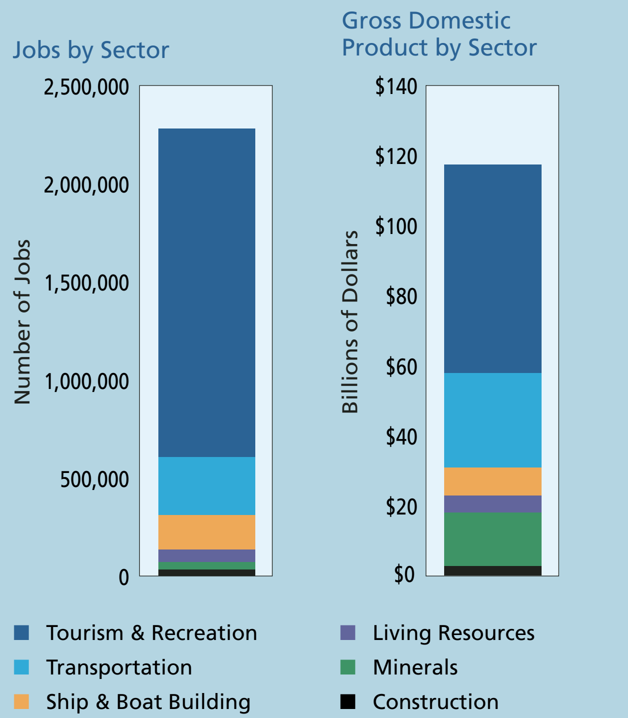
Economic and Employment Value

America's oceans and coasts are big business. The United States has jurisdiction over 3.4 million square nautical miles of ocean territory in its exclusive economic zone—larger than the combined land area of all fifty states. Millions of families depend on paychecks earned directly or indirectly from the value of the sea, including the magnetic pull of the nation's coasts and beaches. However, our understanding of the full economic value of these resources is far from complete. In contrast to sectors like agriculture on which the federal government spends more than $100 million a year for economic research, we do not make a serious effort to analyze and quantify the material contributions of our oceans and coasts. Standard government data are not designed to measure the complex ocean economy. They also ignore the intangible values associated with healthy ecosystems, including clean water, safe seafood, healthy habitats, and desirable living and recreational environments. This lack of basic information has prevented Americans from fully understanding and appreciating the economic importance of our oceans and coasts.

To better inform the public and policy makers, the U.S. Commission on Ocean Policy partnered with the National Ocean Economics Project to produce an economic study, "Living Near... And Making A Living From... The Nation's Coasts And Oceans" (Appendix C). This study pulls together information from a wide range of sources and clearly shows that our oceans and coasts are among our nation's most vital economic assets. In so doing, it distinguishes between the *ocean economy,* the portion of the economy that relies directly on ocean attributes, and the *coastal economy,* which includes all economic activity that takes place on or near the coast, whether or not that activity has a direct link to the sea.

In 2000, the ocean economy contributed more than $117 billion to American prosperity and supported well over two million jobs. Roughly three-quarters of the jobs and half the economic value were produced by ocean-related tourism and recreation (Figure 1.1). For comparison, ocean-related employment was almost 1½ times larger than agricultural employment in 2000, and total economic output was 2½ times larger than that of the farm sector.

Figure 1.1 The Value of the Oceans



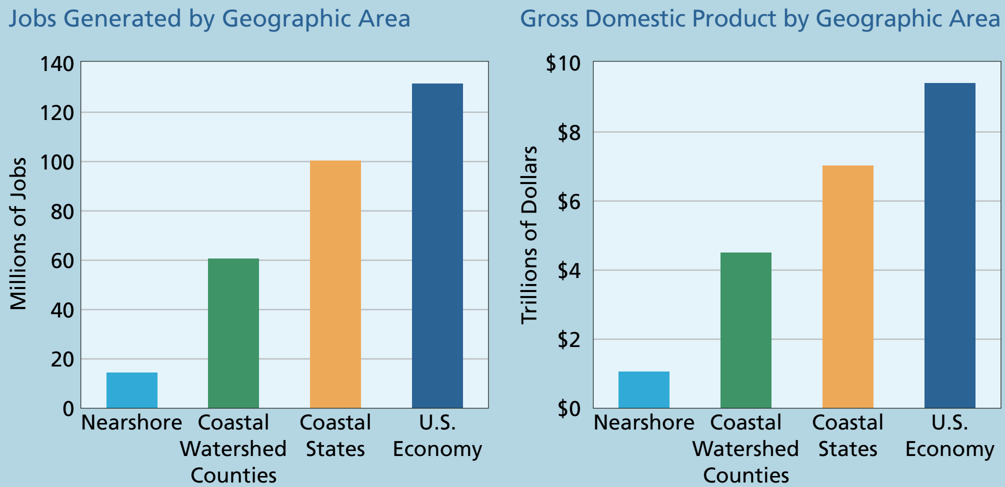
The ocean economy includes activities that rely directly on ocean attributes or that take place on or under the ocean. In 2000, Tourism and Recreation was the largest sector in the ocean economy, providing approximately 1.6 million jobs.

Source: Living Near… and Making a Living From… the Nation's Coasts and Oceans, Appendix C.

The level of overall economic activity within coastal areas is even higher (Figure 1.2). More than $1 trillion, or one-tenth, of the nation's annual gross domestic product (GDP) is generated within *nearshore* areas, the relatively narrow strip of land immediately adjacent to the coast. Looking at all coastal watershed counties, the contribution swells to over $4.5 trillion, half of the nation's GDP. (For definitions of the different coastal zones, see Box 1.1.) The contribution to employment is equally impressive, with sixteen million jobs in nearshore areas and sixty million in *coastal watershed counties*. (See Appendix C for additional details.)

Even these remarkable numbers do not fully capture the economic contributions of oceans and coastal industries. More than thirteen million jobs are related to trade transported by the network of inland waterways and ports that support U.S. waterborne commerce.[1,2] The oceans provide tremendous value to our national economy. Annually, the nation's ports handle more than $700 billion in goods,[3] and the cruise industry and its passengers account for $12 billion in spending.[4] The commercial fishing industry's total value exceeds $28 billion annually,[5] with the recreational saltwater fishing industry valued at around $20 billion,[6] and the annual U.S. retail trade in ornamental fish worth another

Figure 1.2 The Value of the Coasts



Coastal watershed counties, which account for less than a quarter of U.S. land area, are significant contributors to the U.S. economy. In 2000, they were home to nearly half of the nation's jobs and generated a similar proportion of the nation's gross domestic product.

Source: Living Near… and Making a Living from… the Nation's Coasts and Oceans, Appendix C.

$3 billion.[7] Nationwide retail expenditures on recreational boating exceeded $30 billion in 2002.[8] Governments at all levels, universities, and corporations provide many other jobs in ocean-related fields ranging from management and law enforcement to pollution prevention and research.

Our oceans and coasts are among the chief pillars of our nation's wealth and economic well-being. Yet our lack of full understanding of the complexity of marine ecosystems, and our failure to properly manage the human activities that affect them, are compromising the health of these systems and diminishing our ability to fully realize their potential.

Marine Transportation and Ports

The quality of life in America, among the best in the world, is made possible partly through access to goods and markets from around the globe. Our ports are endowed with modern maritime facilities and deep-water channels. Over the next two decades, overseas trade via U.S. ports, including the Great Lakes, is expected to double in volume; for some ports and types of trade, this increase will be even greater.[9] The expanding ferry and cruise line industries continue to provide economically valuable means of transportation for work and leisure. Marine transportation and ports also play a central role in national security as U.S. harbors and ports are major points of entry to our country.

Marine Fisheries

Sustainable sources of fish and shellfish are critical to the United States as a source of healthy food, financial revenue, and jobs. Americans consume more than 4 billion pounds of seafood at home or in restaurants and cafeterias every year. This represents about $54 billion in consumer expenditures.[10] As the population grows and problems such as heart disease and obesity continue to plague our nation, the desire and need for a relatively low-fat source of protein will rise. If every person in America followed the American Heart Association's recommendation to eat at least two servings of fish per week, the United States would need an additional 1½ billion pounds of seafood each year.

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Worldwide, fish are even more important as a source of protein. More than three billion people derive at least one-fifth of their needed protein from freshwater and saltwater fish, and in some parts of the world, fish provide the sole source of animal protein. The aquaculture industry, which has become the fastest growing sector of the world food economy, now supplies more than 25 percent of the globe's seafood consumption.[11,12]

In addition to their dietary value, fish are fundamental to the economy, culture, and heritage of many coastal communities in the United States. Fishing has deep cultural, even spiritual, roots in many seafaring cities and villages where it has provided both a vocation and recreation for hundreds of years.

Offshore Energy, Minerals, and Emerging Uses

Valuable oil and mineral resources are found off our shores and in the seabed; they fuel our cars and our economy, provide materials for construction and shoreline protection, and offer exciting opportunities for the future. Currently, about 30 percent of the nation's oil supplies and 25 percent of its natural gas supplies are produced from offshore areas.[13] These energy supplies also provide a major source of revenue and tens of thousands of jobs. Since the start of the offshore oil and gas program, the U.S. Department of the Interior has distributed an estimated $145 billion to various conservation funds and the U.S. Treasury from bonus bid and royalty payments related to ocean energy.[14]

While advances in technology are enabling the offshore industry to drill deeper, cleaner, and more efficiently, increasing energy demands coupled with environmental concerns have spurred efforts to find alternative sources of power. Modern technology is creating the opportunity to use wind, waves, currents, and ocean temperature gradients to produce renewable, clean energy in favorable settings. Extensive gas hydrates in the seabed also hold promise as a potential—though not yet economically and environmentally feasible—source of energy.

In addition to energy, our offshore waters and the underlying seabed are also rich sources of non-petroleum minerals. As easily accessible sand resources are depleted, offshore areas along the Atlantic and Gulf coasts will be used increasingly to provide such resources to restore and protect coastal communities, beaches, and habitat. Minerals, such as phosphates, polymetallic sulfides, and deposits that form around high-temperature vents, may also have commercial value some day if technical and economic barriers to their extraction can be overcome.

Interest in the ocean goes beyond the traditional resource industries. The telecommunications industry's investment in submerged cables will continue as international communication needs expand. There is also growing interest in other offshore uses including aquaculture, carbon dioxide sequestration, artificial reefs, conservation areas, research and observation facilities, and natural gas offloading stations.

Human Health and Biodiversity

The ocean provides the largest living space on Earth and is home to millions of known species, with millions more yet to be discovered. An expedition to previously unexplored waters typically leads to the discovery of dozens of new species. Within this vast biological storehouse, there exists a treasure trove of potentially useful organisms and chemicals that provide the foundation for a budding multibillion-dollar marine biotechnology industry.

Over the past two decades, thousands of marine biochemicals have been identified. Many have potential commercial uses, especially in the fields of health care and nutrition. For example, a chemical originally derived from a sea sponge is now the basis of an antiviral medicine and two anti-cancer drugs. Blood drawn from the horseshoe crab is used to detect potentially harmful toxins in drugs, medical devices, and water. A synthetic drug

Box 1.1 Defining Coastal Areas

The *coast* is a widely used term encompassing numerous geographic subregions within the broad area where the land meets the sea. Areas of the coast identified in this and other chapters include coastal states, the coastal zone, coastal watershed counties, and the nearshore (Figure 1.3). Some of these terms are defined in law, some agreed to by conventional usage, and others delineated specifically for use in this report.

Coastal States

This report uses the definition of a coastal state established by the Coastal Zone Management Act (CZMA). Under the CZMA, *coastal state* includes any state or territory of the United States in, or bordering on, the Atlantic, Pacific, or Arctic Ocean, the Gulf of Mexico, Long Island Sound, or one or more of the Great Lakes, as well as Puerto Rico, the U.S. Virgin Islands, Guam, the Commonwealth of the Northern Mariana Islands and the Trust Territories of the Pacific Islands, and American Samoa. A total of thirty-five coastal states and territories fall under this definition.

Coastal Zone Counties

The term *coastal zone counties* refers to all counties that fall at least partly within a state's coastal zone, as defined under the CZMA. Under the CZMA, the coastal zone of most states with a federally-approved coastal management program extends on its seaward side to 3 nautical miles offshore (the coastal zones of Texas and the west coast of Florida extend to 9 nautical miles, while those of Great Lakes states bordering Canada extend to the international boundary). The inland extent is determined by each participating state to include the upland region needed to manage activities with a direct and significant impact on coastal waters. Based on this definition, some states have designated their entire land area as the coastal zone, while others have specified certain political jurisdictions, distinct natural features, or geographic boundaries. (Note: Although Illinois does not participate in the CZMA program, Cook and Lake Counties on Lake Michigan are considered coastal counties for the purposes of this report.)

Coastal Watershed Counties

Since approximately 1990, the National Oceanic and Atmospheric Administration has used a specific methodology, also adopted by the U.S. Bureau of the Census after 1992, to define *coastal watershed counties.* The methodology combines the Census Bureau's delineation of counties and the U.S. Geological Survey's mapping of watersheds, identifying those counties with at least 15 percent of their land area in a coastal watershed. Based on this methodology, the United States has 673 coastal watershed counties: 285 along the Atlantic Ocean; 142 in the Gulf of Mexico region; 87 bordering the Pacific Ocean; and 159 fronting the Great Lakes.[i]

The Nearshore

To allow for more detailed analyses of economic conditions in the region closest to the coastline, this report defines the *nearshore* as postal zip code areas that touch the shoreline of the oceans, Great Lakes, and major bays and estuaries.

[i] National Oceanic and Atmospheric Administration. *Spatial Patterns of Socioeconomic Data from 1970 to 2000: A National Research Dataset Aggregated by Watershed and Political Boundaries.* Silver Spring, MD, 2001.

that copies the molecular structure of a salmon gland extract is one of the new treatments available to fight osteoporosis. And coral, mollusk, and echinoderm skeletons are being tested as orthopedic and cosmetic surgical implants.

Scientists are also growing marine organisms in the laboratory and using them as models for physiological research. For example, they are using the damselfish to study cancer tumors, the sea hare and squid to investigate the nervous system, and the toadfish to investigate the effects of liver failure on the brain. In addition, bacteria and other organisms living in extreme deep-sea environments hold promise for the bioremediation of oil spills and other wastes.

Remarkably, in this first decade of the 21st century, about 95 percent of the world's ocean area remains unexplored. We have barely begun to comprehend the full richness and value of the diverse resources residing beneath the surface of the sea.

Tourism and Recreation

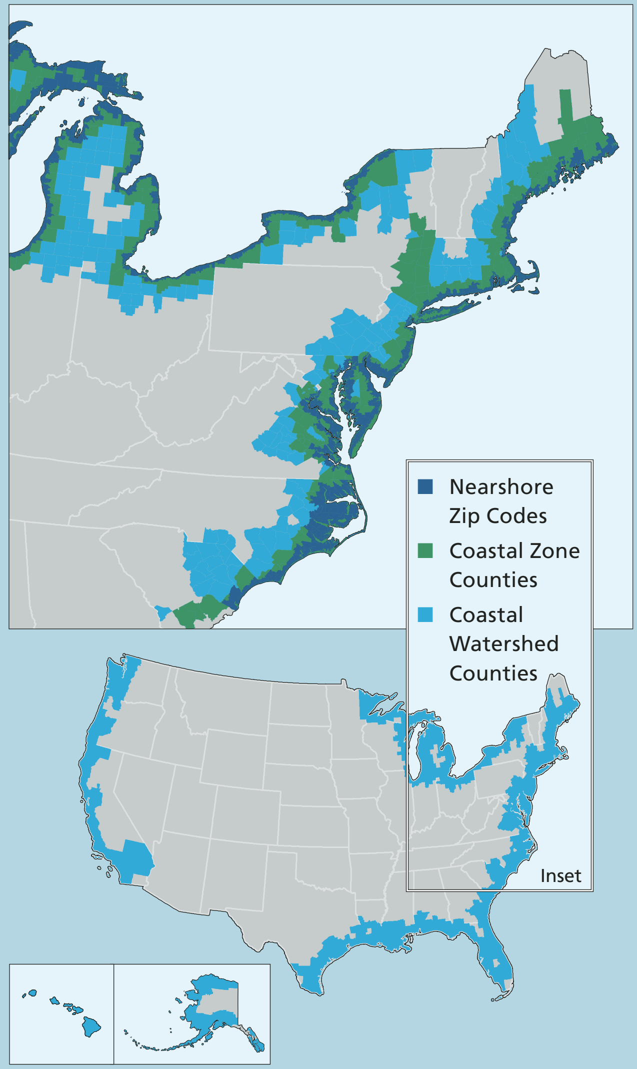
Every year, hundreds of millions of American and international visitors flock to the nation's coasts to enjoy the many pleasures the ocean affords, while spending billions of dollars and directly supporting more than a million and a half jobs. Millions of other tourists take to the sea aboard cruise ships, and still more visit the nation's aquariums, nautical museums, and seaside communities to learn about the oceans and their history.

Tourism and recreation constitute by far the fastest growing sector of the ocean economy (Figure 1.4), extending virtually everywhere along the coasts of the continental United States, southeast Alaska, Hawaii, and our island territories and commonwealths. This rapid growth will surely continue as incomes rise, more Americans retire, and leisure time expands.

While there is no national program to calculate the economic value of the oceans and coasts, several recent studies highlight the contributions of beach-related activities to the economy. In southern California, visitors spent in excess of $1 billion at the beaches of Orange and Los Angeles Counties during the summer of 2000.[15] The annual value of Great Lakes beach visits may be as high as $1.65 billion.[16] And in Hawaii, coral reefs are a major source of recreational benefits, generating an estimated $360 million per year.[17]

The real value of ocean recreation, however, goes beyond the number of jobs created or amount of income produced—there are also immeasurable benefits to individuals and society in being able to enjoy a day at the beach or in the water.

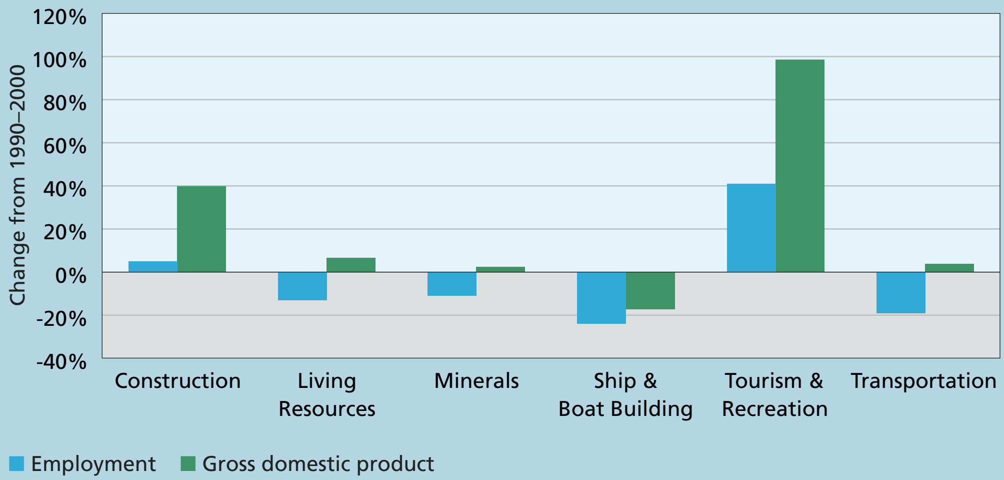
Figure 1.3 The Coasts: From the Nearshore to Coastal Watersheds



Varying interpretations of the geographic area encompassed by "the coast" have hampered our ability to quantify the economic and ecologic importance of this dynamic region. Defining distinct regions, including the nearshore, the coastal zone, and coastal watersheds, provides scientists and decision makers with clear boundaries as they develop policies and investigate coastal processes.

Source: Living Near… and Making a Living From… the Nation's Coasts and Oceans, Appendix C.

Figure 1.4 The Shift from Goods to Services in the Ocean Economy



Between 1990 and 2000, the ocean economy experienced a significant increase in the importance of service-oriented activities. This trend is clearly illustrated by the dramatic increase in both employment and output associated with tourism and recreation. Shifts in employment and revenue in the traditional goods-producing sectors—minerals, living resources, transportation, ship and boat building—were affected by changes in technology, national priorities, and the status of living and nonliving resources.

Source: Living Near… and Making a Living From… the Nation's Coasts and Oceans, Appendix C.

Coastal Real Estate

It is no secret that people are attracted to our coasts. They want to buy property and raise their families near the ocean, and visit it during vacations and on the weekends. They want to fish, sail, swim, listen to the waves crashing, and gaze upon the watery horizon at sunset. Coastal cities are major economic assets, supporting working ports and harbors and generating tourism. This has made areas close to the coast some of the most sought-after property in our nation. Coastal watershed counties comprise less than 25 percent of America's land area, yet they are home to more than 50 percent of our population (Appendix C). Nine of our country's ten largest cities are located in coastal watershed counties.[18] Waterfront properties often sell or rent for several times the value of similar properties just a short distance inland. Even a decade ago, eighteen of the twenty wealthiest U.S. counties (ranked by per capita income) were coastal counties.[19]

Nonmarket Values

Many of the most valuable contributions of our oceans and coasts are not readily measured by traditional market-based accounting. Most dramatically, of course, we need the oceans to live and breathe. Other ocean assets, such as functioning coastal habitats, contribute to the health of our environment and the sustainability of commercial and recreational resources. Still others assist in what our nation's founders referred to as the "pursuit of happiness." In addition, the cultural importance of the ocean and its resources to indigenous populations living along the coasts and in island states and territories should not be underemphasized. It may not be possible to assign a dollar value to all the functions of the sea, but it is necessary to bear each in mind when determining priorities for marine management and protection.

Life Support and Climate Control

The oceans provided the cradle from which all life evolved. They sustain life through evaporation which fills the atmosphere with vapor, producing clouds and rain to grow crops, fill reservoirs, and recharge underground aquifers.

The oceans can absorb over a thousand times more heat than the atmosphere, storing and transporting it around the globe. They also hold sixty-five times more carbon than the atmosphere and twenty times more than terrestrial biomass,[20] a critical factor in counteracting the excess carbon dioxide emitted by human activities. Ocean carbon is used by the sea's immense population of phytoplankton to produce oxygen for our atmosphere. The oceans' dominant role in the cycling of water, heat, and carbon on the planet has profound, and poorly understood, impacts on global climate.

Marine Habitat

Wetlands, estuaries, barrier islands, seagrass and kelp beds, coral reefs, and other coastal habitats, are vital to the health of marine and estuarine ecosystems. They protect the shoreline, maintain and improve water quality, and supply habitat and food for migratory and resident animals. An estimated 95 percent of commercial fish and 85 percent of sport fish spend a portion of their lives in coastal wetlands and estuarine habitats.[21]

Tropical coral reefs cover only about one-fifth of 1 percent of ocean area and yet provide a home to one-third of all marine fish species and tens of thousands of other species. Coral reef fisheries yield 6 million metric tons of seafood annually, including one-quarter of fish production in developing countries.[22] In addition to their immense ecological and direct economic benefits, healthy marine habitats offer highly valuable recreation and tourism opportunities and enhance the worth of coastal real estate.

Exploration, Inspiration, and Education

Throughout history, the oceans' mysteries and our reliance on its resources have inspired great works of literature and art, spurred the human instinct to explore, and provided diverse forms of entertainment. Shipwrecks, prehistoric settlements, and other submerged sites document and preserve important historical and cultural events, while offering unique opportunities for both professional archeologists and recreational divers and for educating the public.

With only about 5 percent of the ocean having been explored, the sea also offers something rare on Earth today: the unknown. Only thirty years ago, no one contemplated the existence of vast biological communities living in the deep sea at hydrothermal vents or the associated mineral-rich flows that form towers more than 50 feet high. Today, we are just beginning to learn about the immense scope of microbial life within and below the seabed.

The ocean provides an exciting way to engage people of all ages in learning and inspire academic achievement in the nation's schools. Using the oceans as a unifying theme, students can participate in research at sea, and teachers can connect mathematic and scientific principles with real-world problems, environmental issues, and the use of modern technology. Exposure to underwater historical resources provides teachers with a bridge to past cultures, offering unique opportunities to study history, sociology, and anthropology. From young to old, in formal and informal education, the ocean offers an unparalleled tool to improve the literacy and knowledge of our citizens. If we are sufficiently creative, we can produce an entire new generation of experts and cultivate a fresh appreciation and understanding that will deepen the stewardship ethic within our society.

International Leadership

Many nations border on, or have direct access to, the sea. All are affected by it. People everywhere have a stake in how well the oceans are managed, how wisely they are used, and how extensively they are explored and understood. For the United States, this means

Box 1.2 The "Fourth Seacoast"—The Great Lakes

The Great Lakes system enjoys global prominence, containing some 6.5 quadrillion gallons of fresh surface water, a full 20 percent of the world's supply and 95 percent of the United States' supply. Its component parts—the five Great Lakes—are all among the fifteen largest freshwater lakes in the world. Collectively, the lakes and their connecting channels comprise the world's largest body of fresh surface water. They lend not only geographic definition to the region, but help define the region's distinctive socioeconomic, cultural, and quality of life attributes, as well.

An international resource shared by the United States and Canada, the system encompasses some 95,000 square miles of surface water and a drainage area of almost 200,000 square miles. Extending some 2,400 miles from its western-most shores to the Atlantic, the system is comparable in length to a trans-Atlantic crossing from the East Coast of the United States to Europe. Recognized in U.S. federal law as the nation's "fourth seacoast," the Great Lakes system includes well over 10,000 miles of coastline. The coastal reaches of all basin jurisdictions are population centers and the locus of intensive and diverse water-dependent economic activity. Almost 20 percent of the U.S. population and 40 percent of the Canadian population reside within the basin.

the oceans provide an ideal vehicle for global leadership. From international security to ocean resource management, education, scientific research, and the development of ocean-related technology, the United States can gain respect by demonstrating exemplary policies and achievements at home and seeking to spread positive results through collaborative efforts around the world.

Undermining America's Ocean and Coastal Assets

Human ingenuity and ever-improving technology have enabled us to harvest—and significantly alter—the ocean's bounty. Our engineering skills have allowed us to redirect the course of rivers, deflect the impacts of waves, scoop up huge quantities of fish, and transform empty shorelines into crowded resort communities. Yet the cumulative effects of these actions threaten the long-term sustainability of our ocean and coastal resources. Through inattention, lack of information, and irresponsibility, we have depleted fisheries, despoiled recreational areas, degraded water quality, drained wetlands, endangered our own health, and deprived many of our citizens of jobs. If we are to adopt and implement an effective national ocean policy, we must first understand and acknowledge the full consequences of failing to take action.

Degraded Waters

Despite some progress, America's ocean and coastal ecosystems continue to show signs of degradation, thereby compromising human health, damaging the economy, and harming marine life. Coastal and ocean water quality is threatened by multiple sources of pollution, including point, nonpoint, and atmospheric sources, vessel pollution, and trash washed onto beaches and into the ocean. In 2001, 23 percent of the nation's estuarine areas were impaired for swimming, fishing, and supporting marine species.[23] Meanwhile, pollution could jeopardize the safety of drinking water for millions of people living near or around the Great Lakes.

Excess Nutrients

The oversupply of nitrogen, phosphorus, and other nutrients in coastal ecosystems is one of our nation's most widespread pollution problems. Runoff from agricultural land, animal feeding operations, and urban areas, along with discharges from wastewater treatment plants, storm sewers, and leaky septic systems, adds nutrients to waters that eventually enter the sea.

All told, more than eighty of our bays and estuaries show signs of nutrient overenrichment, including oxygen depletion, loss of seagrass beds, and toxic algal blooms.[24] And not all of these excess nutrients come from local sources. The Gulf of Mexico's "dead zone" is the result of cumulative drainage from the Mississippi–Atchafalaya River Basin, which includes all or parts of thirty states.[25] In addition, atmospheric deposition from agriculture, power plants, industrial facilities, motor vehicles, and other often distant sources accounts for up to 40 percent of the nitrogen entering estuaries.[26,27]

Other Contaminants

A 2003 National Research Council report estimated that every year, more than 28 million gallons of oil from human activities enter North American waters. Land-based runoff accounts for well over half of this. Much smaller amounts of oil enter our waterways from tanker and barge spills and from recreational boats and personal watercraft.[28]

Pollution from sewage treatment plants has been reduced as the result of tighter regulation during the past thirty years, but concerns remain about the release of untreated human pathogens, pharmaceuticals, toxic substances, and chlorinated hydrocarbons. In 2003, more than 18,000 days of beach closings and swimming advisories were issued across the nation, often directly related to bacteria associated with fecal contamination from stormwater and sewer overflows. This represents a 50 percent increase in closures and advisories from 2002, continuing a rising trend that can be attributed to improved monitoring and more thorough reporting, and revealing the true extent of beachwater pollution.[29] The consequences of such contamination cost many millions of dollars a year in decreased revenues from tourism and recreation and higher costs for health care.

Harmful Algal Blooms

For reasons not yet clearly understood, harmful algal blooms are occurring more frequently both within America's waters and worldwide. The consequences are particularly destructive when the algae contain toxins.

Marine toxins afflict more than 90,000 people annually across the globe and are responsible for an estimated 62 percent of all seafood-related illnesses. In the United States, contaminated fish, shellfish, and other marine organisms are responsible for at least one in six food poisoning outbreaks with a known cause, and for 15 percent of the deaths associated with these incidents.[30] In the last two decades, reports of gastrointestinal and neurological diseases associated with algal blooms and waterborne bacteria and viruses have increased.[31] Though seafood poisonings are probably underreported, they also seem to be rising in incidence and geographic scope.[32]

Harmful algal blooms cost our nation an average of $49 million a year[33] due to fisheries closures, loss of tourism and recreation, and increased health care and monitoring expenses.

Sediment Contamination

A study conducted at more than 2,000 sites representing over 70 percent of the nation's total estuarine area (excluding Alaska) found that 99 percent of the sediments tested contained 5 or more toxic contaminants at detectable levels. More than 600 sites had contamination levels high enough to harm fish and other aquatic organisms.[34] Because some chemicals tend to bind to particles and thus accumulate in sediments, bottom-dwelling and bottom-feeding organisms are particularly at risk. As sediment-bound pollutants enter these organisms and move up through the food web, larger animals and humans are also affected. Excess sediments can also cause harm by smothering stationary, bottom-dwelling marine communities.

Compromised Resources

Fishery declines, degraded coastal habitats, and invasive species are compromising our ability to meet current and future demands for healthy and productive marine resources.

Fishery Declines

Experts estimate that 25 to 30 percent of the world's major fish stocks are overexploited,[35] and a recent report indicates that U.S. fisheries are experiencing similar difficulties. Of the nation's 267 major fish stocks—representing 99 percent of all landings—roughly 20 percent are either already overfished, experiencing overfishing, or approaching an overfished condition.[36] The same report indicates that there is inadequate information to make these status determinations for over 30 percent of the major fish stocks and virtually all of the over 640 minor fish stocks—most of which are not subject to commercial fishing pressure—limiting both our understanding of the overall state of the nation's fisheries and of their role in the marine ecosystem.

Declining fish populations are the result of overfishing, the unintentional removal of non-targeted species (known as bycatch), habitat loss, pollution, climate changes, and uneven management. The cumulative impact of these factors is serious. As fishing boats turn to smaller, less valuable, and once discarded species, they are progressively "fishing down the food web,"[37] thereby causing changes in the size, age structure, genetic makeup, and reproductive status of fish populations. This compromises the integrity of marine ecosystems, the ecological services they provide, and the resources upon which Americans rely.

Although U.S. fishery management has been successful in some regions, failures elsewhere have resulted in substantial social and economic costs. For example, the collapse of the North Atlantic cod fishery in the early 1990s resulted in the loss of an estimated 20,000 jobs and $349 million.[38,39] In the Northwest, decreasing salmon populations have cost 72,000 jobs and more than $500 million.[40] This tally does not begin to assess the social and psychological impacts these events have had on individuals, families, and communities for whom fishing has been a tradition for generations.

Questions also exist about how best to manage our growing marine aquaculture industry. This industry is vital to increase seafood supplies, but its potential impact on the ocean environment and wild populations of fish and shellfish present serious concerns. These include the discharge of wastes and chemicals, the spread of disease or genetic changes resulting from the escape of farmed species, the demand for wild-caught fish as aquaculture feed, and the appropriation of sensitive habitats to create aquaculture facilities.

Coastal Habitat Loss

Since the Pilgrims first arrived at Plymouth Rock, the lands that now comprise the United States have lost over half of their fresh and saltwater wetlands—more than 110 million acres.[41] California has lost 91 percent of its wetlands since the 1780s.[42] And Louisiana, which currently is home to 40 percent of the coastal wetlands in the lower 48 states, is losing 25–35 square miles of wetlands each year.[43]

Pollution, subsidence, sea level rise, development, and the building of structures that alter sediment flow all contribute to the problem. With the loss of the nation's wetlands, shorelines are becoming more vulnerable to erosion, saltwater is intruding into freshwater environments, flooding is on the rise, water quality is being degraded, and wildlife habitat is being fragmented or lost.

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The nation is also losing thousands of acres of seagrass and miles of mangrove and kelp forests. More than 50 percent of the historical seagrass cover has been lost in Tampa Bay, 76 percent in the Mississippi Sound, and 90 percent in Galveston Bay.[44] Extensive seagrass losses have also occurred in Puget Sound, San Francisco Bay, and along Florida's coasts.

Coral reef habitats are also increasingly under siege. Recent research suggests that direct human disturbances and environmental change are two major causes of harm to coral reefs, although a host of other factors also contribute. Many reefs, particularly those within range of growing human populations, are under threat of destruction as evidenced by dramatic declines in Florida, the Caribbean, and parts of Hawaii.[45] Coral reef declines are exacerbated by cumulative impacts, such as when overfishing, coral bleaching, and disease decrease a reef's resilience. As the reefs disappear, so do the fish they harbor and the millions of dollars in jobs and economic revenue they provide.

Living and coastal resources are threatened by pollution and human activities. We've seen collapses of fisheries and overfishing of many stocks. We are losing 20,000 acres of coastal wetlands each year. We are losing millions of acres of coral reefs each year worldwide. Increasing coastal development presents new stresses and greater vulnerability to extremes of weather and changes in sea level.

—The Honorable James Connaughton, *Chairman, White House Council on Environmental Quality, testimony to the Commission, September 2001*

Invasive Species

Across the nation and throughout the world, invasive species of plants and animals are being intentionally and unintentionally introduced into new ecosystems, often resulting in significant ecological and economic impacts. We know that over 500 non-native species have become established in coastal habitats of North America and that hundreds can be found in a single estuary.[46] Asian and European shore crabs inhabit the coasts of New England and California, damaging valuable fisheries. A massive horde of zebra mussels has assaulted the Great Lakes, clogging power plant intakes and fouling hulls, pilings, and navigational buoys. And in the Chesapeake Bay, an alien pathogen has contributed to the decline of the native oyster population.[47]

Many non-native marine animals and plants are introduced through the discharge of ships' ballast water and holding tanks. At least 7,000 different species of marine life are transported around the world every day, and every hour some 2 million gallons of ballast water arrive in U.S. waters carrying at least a portion of this immense fleet of foreign organisms.[48,49] Further contributors to the spread of invasive species include the aquarium trade, fishery-related activities, floating marine debris, boating, navigational buoys, and drilling platforms. Strains on coastal environments caused by other factors may make them even more vulnerable to the spread of non-native species.

The economic impact of invasive species can be substantial. From 1989 to 2000, zebra mussels alone caused between $750 million and $1 billion in losses to natural resources and damage to infrastructure in the Great Lakes. More than $2 million has been spent in California to control and monitor the spread of the Mediterranean green seaweed *Caulerpa taxifolia*, and more than $3 million has been spent investigating the impacts of Atlantic cordgrass on the Pacific Coast.[50] Invasive species can also cause significant ecological damage by outcompeting native species, altering local food webs, and reducing the resources available for other organisms.

Conflicts Between Man and Nature

As population density has risen in coastal watersheds, so has environmental stress. Coastal planning and management policies implemented over the past thirty years have limited, but not prevented, harmful impacts—both incremental and cumulative—on the marine ecosystem.

Coastal Population Growth and Land Use

Contrary to popular perception, the coasts have experienced a relatively stable rate of population growth since 1970; coastal watershed counties representing 25 percent of the nation's land area have continued to support approximately 52 percent of the U.S. population over the past three decades (Appendix C). Between 1970 and 2000, the population of coastal watershed counties grew by 37 million people (Appendix C) and is projected to increase by another 21 million by 2015.[51] At that point, the U.S. coasts will have absorbed more than 58 million additional residents since 1970—more than 1.1 million a year. This steady influx of people into a relatively small area has already created coastal population densities that are on average two to three times higher than that of the nation as a whole (Figure 1.5).

The environmental impacts of rising population density in the coastal zone have been magnified by a relative shift in population and housing development away from expensive shoreline property and toward the upland reaches of coastal watersheds. This has had the effect of expanding environmental consequences over larger geographic areas and has eroded the health of ecosystems and resources throughout coastal watersheds.

Most development profoundly changes the landscape. Impervious materials such as concrete or asphalt typically cover 25–60 percent of the land surface in medium-density, single-family-home residential areas, and more than 90 percent in strip malls, urban areas, and other commercial sites.[52] Research indicates that nearby water bodies can become seriously degraded when more than 10 percent of a watershed is covered by roads, parking lots, rooftops, and similar surfaces.[53] A one-acre parking lot produces sixteen times the volume of runoff that comes from a one-acre meadow.[54] Expanding coastal sprawl can also destroy natural habitats, thus compromising the environment's ability to provide food and refuge for wildlife or supply ecosystem services, such as maintaining water quality.

These concerns are exacerbated by the fact that land is being developed for housing at more than twice the rate of population growth.[55] This is partly the result of a decline in the size of the average American household from 3.14 people in 1970 to 2.59 people in 2000.[56] Nearshore areas also experience spurts of temporary population growth—from commuters, vacationers, day-tourists and others—creating a robust demand for seasonal housing. The result is pressure for development in nearshore areas accelerating at a rate far greater than might be expected based simply on population trends.

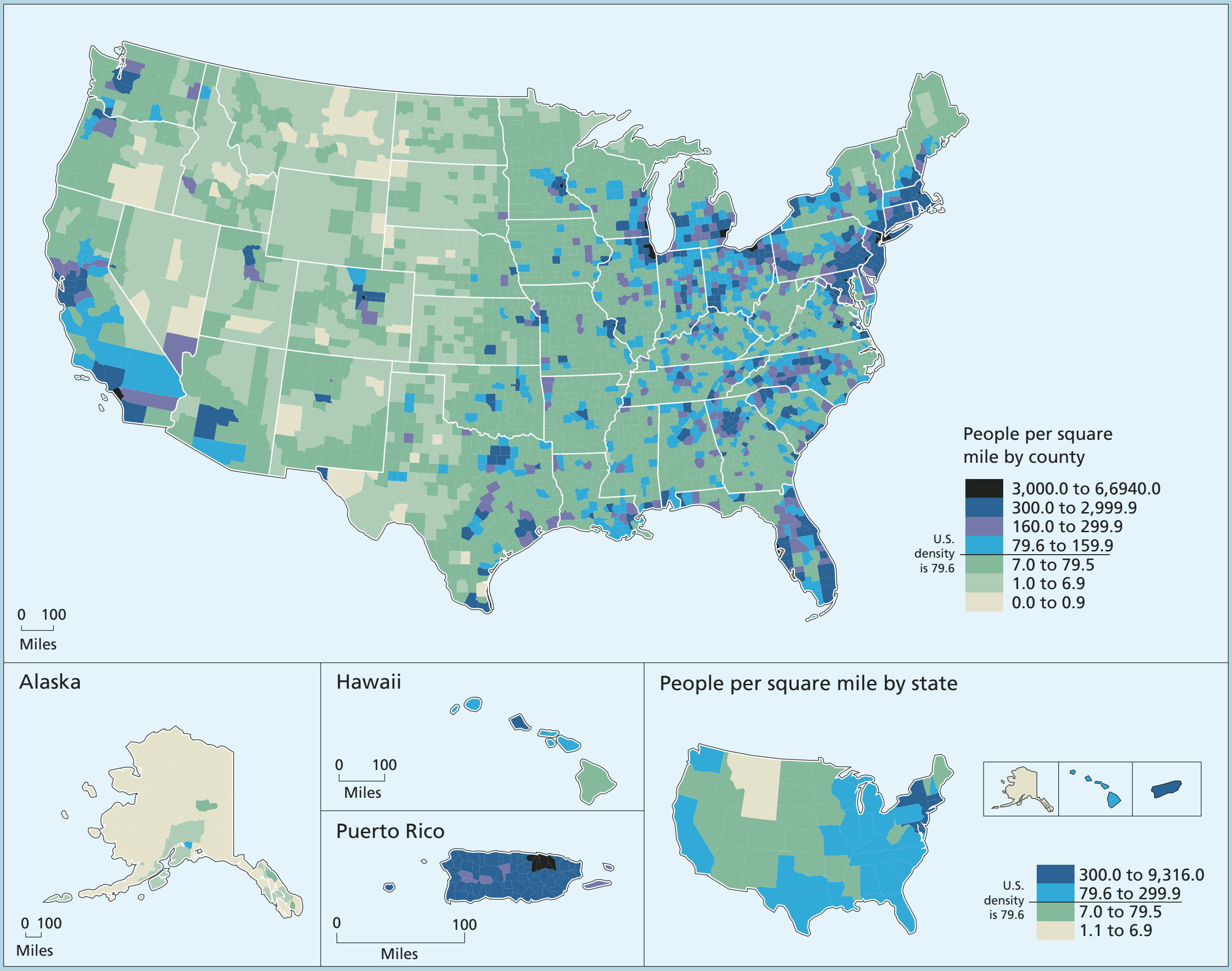
A less apparent, but still important contributor to developmental pressures is the increasing rate of overall economic growth that is occurring in nearshore areas. Although population and housing are moving upstream within coastal watersheds, economic growth has been occurring more rapidly—and more intensely—along the nearshore. This growth has tended to focus on the trade and service industries, which use more land per unit of output than other types of activity. Thus, it is important to understand the significance of the growing recreation and tourism industry and the relative impact its related businesses are having on the coast, in addition to managing coastal population growth.

Natural Hazards

As the nation's shores become more densely populated, people and property are increasingly vulnerable to costly natural hazards. Before 1989, no single coastal storm had caused insured losses greater than $1 billion.[57] Since then, at least ten storms have resulted in such losses, including Hurricane Andrew, with insured losses of $15.5 billion and total economic losses estimated at $30 billion (in 1992 dollars).[58,59]

Coastal erosion, storm surges, tsunamis, and sea level rise are serious threats to people living and working along the shore, particularly in low-lying areas. Roughly 1,500 homes and the land on which they are built are lost to erosion each year, with annual costs to coastal property owners expected to average $530 million over the next several decades.[60] In some instances, American engineering capability has improved protection against natural hazards along the coast; in others, however, it has made us more vulnerable. The loss of wetlands and other shoreline vegetation increases susceptibility to erosion and flooding. The installation of seawalls, groins, and other coastal armoring structures can alter patterns of sediment and current flow, eventually accelerating erosion, rather than preventing it.

Figure 1.5 Population Density Peaks Near the Shore



As shown by 2000 U.S. Census figures, population density is generally highest in coastal areas, including counties surrounding the Great Lakes. Population growth and increasing population density in coastal counties reflect the attraction of the coast but also result in increased environmental impacts on coastal ecosystems.

Source: U.S. Census Bureau. "Census 2000." <www.census.gov> (Accessed March 2004).

Climate Change

Average global temperatures have been rising over the last several decades. Scientists believe these changes are probably due primarily to the accumulation of greenhouse gases in Earth's atmosphere from human activities, although natural variability may also be a contributing factor.[61] The Intergovernmental Panel on Climate Change reports that the average near-surface temperature of the Earth increased by about 1˚F between 1861 and 1990, but is expected to increase by another 2.5—10.4˚F by the end of this century.[62] As oceans warm, the global spread and incidence of human diseases, such as cholera and malaria, may also increase.[63,64] Marine organisms that are sensitive to temperature must either alter their geographic distribution or face extinction. Already, changing ocean conditions in the North Pacific have altered ecosystem productivity and have been associated with poor ocean survival of young salmon and modifications in the composition of nearshore fish populations.[65]

One of the most immediate phenomena associated with increasing global temperatures has been a change in average sea level, which is estimated to have risen by 4–8 inches during the 20th century. By 2100, sea level is projected to rise by another 4–35 inches.[66] Although the exact amount and rate of the increase are uncertain, the fact that the ocean will continue to expand is widely accepted. As this occurs, low-lying coastal regions and island territories will be particularly vulnerable to flooding and storms. In the Pacific, for example, entire archipelagos have maximum elevations of only a few meters above sea level, leaving both human communities and natural ecosystems in danger. This vulnerability is compounded by the concentration of human activities along the water's edge, the point of greatest risk. Many island jurisdictions are already facing problems associated with long-term sea-level rise, including saltwater contamination of fresh-water sources, coastal erosion, damage to natural barriers such as corals and mangroves, and loss of agricultural sites and infrastructure. For example, saltwater intrusion has rendered aquifers on the Marshall Islands unusable, and ocean waters regularly flood the airport. A steady increase in sea-level rise could cause whole islands to disappear.

Polar regions are also exhibiting dramatic signs of change due to rising temperatures, with thinning ice caps and melting glaciers. The average thickness of sea ice in the Arctic has decreased by approximately 4.25 feet from the late 1950s to the late 1990s.[67] Alarming changes are occurring in Arctic permafrost, with potentially significant economic and ecological impacts.[68] In the tropics, coral reef diseases and bleaching are occurring more frequently, and coral growth may be inhibited by increasing concentrations of dissolved carbon dioxide in the sea.[69]

The transport and transformation of heat, carbon, and many other gases and chemicals in the ocean play a central role in controlling, moderating, and altering global climate. In fact, research into ancient climate cycles suggests that change can actually occur much more rapidly than once expected.[70] Rather than the scenario of gradual surface temperature increases often envisioned for the next century, sudden shifts in polar ice and ocean circulation could result in drastic temperature changes occurring within a decade or less.[71]

The specter of abrupt change, and a growing awareness of the impacts even gradual climate change can have on coastal development, ecosystems, and human health, call for a significant improvement in climate research, monitoring, assessment, and prediction capabilities. Understanding the role of the oceans in climate is an area in need of particular attention.

Acting Today for Tomorrow's Generations

For centuries, Americans have been drawn to the sea. We have battled the tides, enjoyed the beaches, and harvested the bounty of our coasts. The oceans are among nature's greatest gifts to us. The responsibility of our generation is to reclaim and renew that gift for ourselves, for our children, and—if we do the job right—for those whose footprints will mark the beaches from Maine to Hawaii long after ours have washed away.

The nation's ocean and coastal assets are worth hundreds of billions of dollars to society and untold more to the Earth's complex ecosystems and the many cultures whose heritage is directly tied to the sea. Although losses in some areas have been significant and continue, in other areas sound policy and sustained investments have slowed or reversed harmful trends. There is every reason to believe that wise actions taken today, based on the best available science, can restore what has been lost and create even greater benefits. But to achieve this, our nation's leaders must take immediate steps to formulate a coherent, comprehensive, and effective national ocean policy. Implementation of the far-reaching recommendations offered throughout this report can halt the losses and help restore, protect, and enhance America's ocean assets.

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CHAPTER 2

Understanding the Past to Shape a New National Ocean Policy

The phrase national ocean policy encompasses a vast array of issues, each of which requires policy makers to answer some key questions. What is the current situation? What goals does the nation wish to achieve? What rules, if any, should apply? And who will formulate and enforce those rules? Those in charge must also be prepared to justify their decisions to a wide variety of interested people and find a way to place decisions about particular uses of the oceans into a larger framework so the results will be coherent and enduring.

In considering how to craft an ocean framework for the future, the U.S. Commission on Ocean Policy reviewed the lessons of the past and listened closely to affected individuals around the country.

Ocean Policy from World War II to the Oceans Act of 2000

Volumes have been written about the intricacies of ocean policy and its development in the United States. The following sections offer a brief glimpse of this history, setting the stage for the work of the U.S. Commission on Ocean Policy.

Formative Years

U.S. ocean policy developed slowly and fairly consistently from the founding of the United States until the immediate aftermath of World War II. Since then, it has zigged and zagged in response to shifting public attitudes based on major events related to national security, the environment, and political philosophy. American policy—or more accurately the amalgamation of many policies—has been shaped by the nation's unique status as both the world's leading maritime power and the possessor of a long and rich shoreline, giving us a stake both in protecting freedom of navigation and in expanding the resource jurisdiction of coastal countries. Over time, our management of ocean issues has been roiled by conflicting interests of the federal and state governments, torn by tensions between short- and long-term needs, blurred by ideological disagreements, and complicated by the wide variety of uses we make of our vast and versatile—but also vulnerable—seas.

One ongoing challenge for policy makers has been to find the right balance between the exploitation of marine resources, whether living or nonliving, and the conservation of those resources and protection of the marine environment. Petroleum exploration, commercial fishing, and marine mammal protection are just three of the arenas where this

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drama has played out. The United States has also shown a tendency to swing back and forth between internationalism and unilateralism—at times working with other countries to shape global rules, and at other times asserting the right to establish our own rules outside of, or in advance of, the global consensus.

The nation's primary maritime concerns have been to preserve the right to free navigation while asserting jurisdiction over fishing and law enforcement in U.S. waters. In a letter from Secretary of State Thomas Jefferson to the governments of Britain and France in 1793, the United States officially claimed authority over a 3 nautical mile territorial sea. Over the next century and a half, the federal government's role in the oceans was limited primarily to the activities of the U.S. Navy, the U.S. Coast Guard, and the Coast and Geodetic Survey, the promotion of the U.S. Merchant Marine, and diplomatic negotiations over access to the rich fishing grounds off the North Atlantic coast and the taking of fur seals in the North Pacific and Bering Sea.

Interestingly, the problem of depleted fish stocks, often assumed to be a recent development, is not new. In 1871, the federal government established the Office of the Commissioner of Fish and Fisheries to study the dilemma. Warnings have been issued and various remedies proposed periodically ever since. In 1882, the first U.S. research vessel built exclusively for fisheries and oceanographic research entered service, and for the next thirty-nine years the 234-foot USS *Albatross* plied waters around the globe.

It was not until after World War II that a process referred to as *enclosure of the oceans* began in earnest. In contrast to the traditional view of the oceans as belonging to everyone (and therefore to no one), a movement to extend the rights of coastal states gathered momentum. Among the factors driving this trend was competition for oil and gas. On September 28, 1945, President Truman issued a proclamation asserting control over the natural resources of the continental shelf beneath the high seas adjacent to the territorial waters of the United States. In 1947, the Supreme Court decision in Uni*ted States v. California* awarded the federal government jurisdiction over all U.S. ocean resources from the tidemark seaward. This judgment, highly unpopular in coastal regions, led to the passage of the Submerged Lands Act of 1953, which returned resource jurisdiction within the 3 nautical mile territorial sea to coastal states. A companion bill enacted in the same year, the Outer Continental Shelf Lands Act, authorized the Secretary of the Interior to lease federal areas of the continental shelf for oil and gas exploration and development.

From Sputnik to Stratton

On October 4, 1957, the Soviet Union launched Sputnik, the world's first space satellite. This was one of several major events that would sharply alter the direction of U.S. ocean policy during the last half of the 20th century. The show of Soviet prowess shocked America, spurring national resolve. It seemed suddenly as if every arena of activity, from the construction of intercontinental ballistic missiles to the training of athletes for the Olympic high jump, had become a test of dueling national wills. The foremost areas of competition were technology and science.

In 1959, the National Research Council released a report that recommended doubling the federal government's commitment to oceanography, building a new research fleet, and forging stronger partnerships with academic institutions.[1] The recommendations served as the basis for ocean policy under President Kennedy and attracted strong support from such influential senators as Warren Magnuson of Washington who warned, in the spirit of the times, "Soviet Russia aspires to command the oceans and has mapped a shrewdly conceived plan, using science as a weapon to win her that supremacy."[2]

This era of scientific enthusiasm and advancement saw the Navy and the National Science Foundation (NSF) take on critical roles in developing U.S. ocean capabilities. The post-World War II period brought significant Navy investment in basic research into ocean processes, resulting in the development of most of today's oceanographic instruments. The Navy's ocean data holdings have been called the crown jewels of global oceanography, and its investment in operational ocean infrastructure has contributed greatly to U.S. ocean capability and influence in international ocean affairs. NSF came into existence at the end of World War II, largely due to the recognition that support for basic research was essential to national well-being. Since that time, NSF has increasingly become the leader in support for ocean research and related infrastructure. Through their investments in basic and applied research, operations, education, and infrastructure, NSF and the Navy helped create a robust and influential ocean research community in the United States.

In the 1960s, faith in the power of science was at its apogee. Said *Time* magazine:

> U.S. scientists and their colleagues in other free lands are indeed the true 20th century adventurers, the explorers of the unknown, the real intellectuals of the day, the leaders of mankind's greatest inquiry into the mysteries of matter, of the earth, the universe and of life itself. Their work shapes the life of every human presently inhabiting the planet, and will influence the destiny of generations to come.[3]

In this context, the appetite for exploring the unknown was seemingly insatiable, applying not only to outer space but also to inner space—the mysterious depths of the sea. In addition to ongoing investments in ocean research by the Navy and NSF, in 1966 Congress created the National Sea Grant College Program (Sea Grant) within NSF, based on the long-established model of Land Grant colleges. After a modest beginning, Sea Grant evolved into a popular initiative within the marine science community and the public and became a prime source of support for research in marine-related subjects outside oceanography, including fisheries and law.

Support grew for the creation of an independent national ocean agency, a watery counterpart to the National Aeronautics and Space Administration. To prepare the way, Congress approved the Marine Resources and Engineering Development Act, signed by President Johnson on June 17, 1966. The Act included a declaration of U.S. policy, the formation of a national council chaired by the Vice President, and the establishment of a presidential Commission on Marine Science, Engineering and Resources. Julius Stratton, president emeritus of the Massachusetts Institute of Technology and chairman of the Ford Foundation, was named as chair of that Commission.

During the next two years, the Stratton Commission's fifteen members and four congressional advisers conducted hearings and held meetings in every coastal region of the country. In January 1969, the Commission issued its report, *Our Nation and the Sea*, containing 126 recommendations.[4] The report had a catalytic impact for several reasons. It was the first truly comprehensive study of American ocean policy. It went beyond oceanography to examine a wide range of marine issues, including: the organization of the federal government; the role of the ocean in national security; the potential economic contributions of oil, gas, and other marine resources; the importance of protecting coastal and marine environments; and the need to promote American fisheries. Some recommendations were never realized (such as building offshore nuclear power plants), but others comprised the foundation for a new era in U.S. ocean policy, leading most directly to creation of the National Oceanic and Atmospheric Administration (NOAA) in 1970 and the enactment of the Coastal Zone Management Act (CZMA) in 1972.

The Stratton Commission called for the centralization of federal civilian ocean management efforts within a single new agency—envisioning a NOAA that would be independent and in charge of virtually every nonmilitary aspect of marine policy. This did not happen. The White House budget office opposed the establishment of an independent agency, the Secretary of Transportation was unwilling to give up the Coast Guard, and the

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Maritime Administration remained separate. So when NOAA was born on July 9, 1970 (via Reorganization Plan #4), its prospects for thriving within the bureaucracy were slim. Lodged within the U.S. Department of Commerce, it lacked cabinet status, independence, a congressional charter, and control over many federal marine activities. NOAA did, however, become a center of federal ocean and atmospheric expertise, bringing together nine programs from five departments, including the Environmental Sciences Services Administration, the Bureau of Commercial Fisheries, and the Sea Grant program.

The impact of the Stratton Commission report was magnified by its timeliness. Once again, events were occurring that would guide the direction of ocean policy, this time toward greater environmental awareness. In 1966, seismic tests in the Georges Bank fishing grounds caused an explosion that halted fishing for three weeks and prompted calls for a ban on oil and gas activity in the area. In January 1969, Union Oil's Platform A in the Santa Barbara Channel blew out, spilling some 3 million gallons of oil, killing marine life, and affecting more than 150 miles of shoreline. The images of soiled beaches, oil-soaked birds, and belly-up fish generated widespread public concern and contributed to the enactment of a law that would profoundly affect the approach of the federal government to natural resources of every description—the 1969 National Environmental Policy Act (NEPA).

Thirty years ago when the Stratton Commission looked at the problems of our oceans, the main focus was the threat to our ocean resources from others. One of the things that helped the Stratton Commission is the fact that when you have an enemy you can identify, you can get policy done pretty fast. But when your enemy is your own behavior, that's tough to do. I think that's what we confront now.

—The Honorable Leon Panetta, *Chairman of the Pew Oceans Commission, testimony to the Commission, October 2002*

Years of Activism

To an extent not seen before or since, the political climate between 1969 and 1980 was ripe for initiatives to expand the federal role in ocean and environmental management. The Stratton report had sounded the trumpet, calling upon "Congress and the President to develop a national ocean program worthy of a great sea nation." Segments of the American public, aroused by the Santa Barbara oil spill and the inaugural Earth Day on April 22, 1970, lent support to a new generation of activist environmental organizations demanding federal action. Members of Congress, empowered by internal reforms that enlarged staffs and somewhat weakened the seniority system for selection of committee chairs, were eager to play a policy-making role. Internationally, the United Nations Conference on the Human Environment met in Stockholm in 1972, a milestone for the environmental movement. Both at home and overseas, the oceans were caught up in the larger pro-environment trend.

As a result, the stewardship ethic embodied by NEPA—the idea that the government should study, plan, and offer the opportunity for public comment before acting—was applied to the oceans. This principle was at the heart of the new law dealing with America's increasingly populous coastal zone. The CZMA constituted a marriage of federal activism and states' rights. Entirely voluntary, the program offered grants to states to help develop and implement coastal management plans tailored to local needs but reflecting broad national interests. To encourage states to enforce their plans, the federal government agreed to honor them as well. This pledge to make federal actions affecting the coastal zone consistent with state plans (referred to as the federal consistency provisions) was novel and would, at times, prove controversial.

Other major ocean-related legislation enacted during this period included measures to improve the nation's water quality, regulate ocean dumping, designate marine sanctuaries, prohibit the taking of marine mammals, protect endangered species, license deep-water ports, promote aquaculture, and encourage the development of ocean thermal energy conversion as a renewable source of power. The most dramatic expansion of federal ocean activity, however, resulted from enactment of the Fishery Conservation and Management Act, later renamed the Magnuson–Stevens Fishery Conservation and Management Act. According to its terms, on March 1, 1977, American fisheries jurisdiction was extended from 12 to 200 nautical miles, an expansion in area roughly equal to the size of the continental United States. This action reflected a triumph of America's interest in championing the rights of coastal nations to control resources over its interest in defending the maximum degree of freedom on the high seas.

The legislation was prompted by the anger of U.S. fishermen, especially in the North Atlantic and off Alaska, regarding the presence on their traditional fishing grounds of massive foreign factory trawlers scooping tons of fish from the sea. The trawlers, many from the Soviet Union, were able to operate at all hours, even in harsh weather, catching fish and freezing them on the spot. By the end of the 1960s, America had dropped from second to sixth in its share of world fishery catch and a substantial segment of the U.S. commercial fishing industry was in deep trouble. Compared to the large, modern, efficient Soviet trawlers, most U.S. vessels were small and inefficient. Although the U.S. Department of State urged Congress to delay action pending the outcome of global negotiations on the U.N. Convention on the Law of the Sea (LOS Convention), those discussions were going slowly, and the pressure to act became overwhelming.

The management scheme created by the Magnuson–Stevens Act was imaginative, yet complicated: Regional Fishery Management Councils were appointed and required to develop and submit plans for managing particular species to the Secretary of Commerce for approval. The intention was to harness regional expertise in the national interest, make full use of scientific data, and give the industry a voice in designing the means of its own regulation. The Coast Guard was tasked with achieving the law's main selling point—foreigner fishing fleets out, Americans in—and various measures were developed to encourage new investment in the U.S. fishing fleet. The explicit intent of the statute was to prevent overfishing, rebuild overfished stocks, and realize the full potential of the nation's fishery resources. Despite the challenge of persuading fiercely independent fishermen to accept restrictions on their activities, there was much optimism in the early years that the Magnuson–Stevens Act's ambitious goals would be met.

Meanwhile, policy makers were coping with another pressing concern: the Arab oil embargo triggered by the 1973 Middle East war had a direct impact on the lives of millions of Americans. Heating costs soared, and the simple act of filling up at the local gas station turned into a nightmare. The country's vulnerability to disruptions caused by dependence on uncertain supplies of foreign oil became a major economic and national security issue. In response, the Nixon administration proposed a massive expansion of outer Continental Shelf (OCS) oil and gas leasing to include frontier areas off the Atlantic, Gulf, and Pacific coasts. This proposal ran counter to the pro-environmental currents then circulating, and posed a challenge to lawmakers searching for a way to address ecological and energy supply concerns simultaneously. The result was the OCS Lands Act Amendments of 1978, the product of three years of bipartisan legislative effort, designed to encourage leasing subject to new planning requirements, more rigorous environmental standards, and measures to ensure that the views of state and local governments were taken into account.

The many ocean-related laws spawned during the 1970s addressed urgent needs, introduced creative management concepts, and multiplied the scope of federal responsibility. But they lacked an overarching vision critical to a coherent national ocean policy. NOAA was neither equipped nor authorized to set priorities across more than a small portion of the spectrum of marine activities, and most of the laws enacted were aimed at a single purpose or ocean use, and implemented with little reference to others.

The inherent difficulty of managing diverse activities over a vast geographic area, and the incremental manner in which the federal ocean regime was assembled, inevitably resulted in fragmentation. The three presidents who served between 1969 and 1981 did not provide strong policy direction on ocean issues. In the absence of such direction, neither the executive branch nor Congress was structured in a way that fostered a comprehensive approach to the oceans. No federal department could claim the lead, and crosscutting legislative initiatives were referred to multiple congressional committees where differing perspectives tended to cancel each other out. Notwithstanding the Stratton Commission's call for centralization, by 1980 federal responsibility for ocean-related programs was distributed among ten departments and eight independent agencies.

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Contention and Stalemate

The 1981 inauguration of President Reagan altered the direction of America's approach to ocean and coastal issues. For the first time since the days of Presidents Kennedy and Johnson, the White House was the source of clear policy direction for the oceans. While the consensus in the 1970s had favored a larger federal role, the new administration wanted to reduce the size of government. While legislation approved in the 1970s called for a steady increase in investments to achieve marine-related goals, the Reagan philosophy called for cutbacks. While the mood of the 1970s leaned heavily in the direction of environmental protection, the new administration favored a minimum of restrictions on the private sector.

U.S. Department of the Interior (DOI) Secretary James Watt departed from the earlier practice of offering limited offshore areas for energy leases and, in 1982, introduced the concept of area-wide leasing, opening dramatically larger areas of the OCS simultaneously. As a result of Watt's new policy, 275 million acres of the OCS were offered for lease in 1983-84, compared to a two-year average of less than 8.5 million acres in the immediately preceding ten year period. At the same time, the administration proposed to eliminate funding for the Sea Grant and Coastal Zone Management programs, reduce investments in oceanographic research, and privatize a number of functions carried out by NOAA. Congress responded to Secretary Watt's proposals by including a provision in the 1982 DOI appropriations bill that prohibited it from leasing certain offshore areas. This practice of legislating moratoria soon took hold, leading eventually to 50 nautical mile no-leasing buffer zones along much of the Atlantic and Pacific coasts. President Reagan's successors later removed almost all new areas from leasing consideration through 2012. As the OCS program gyrated from one extreme to the other, the balanced approach Congress sought when amending the OCS Lands Act in 1978 was never fully tested, despite the still-compelling need for secure energy supplies.

The Reagan administration also changed the tenor of American ocean policy internationally. Since 1958, efforts had been underway to negotiate an international agreement on the law of the sea, spelling out a global consensus on such matters as freedom of navigation, fisheries jurisdiction, continental shelf resources, and the width of the territorial sea. At the request of less developed nations, the third round of negotiations, begun in 1973, included consideration of an elaborate international regime to govern the mining of minerals from the deep seabed in areas outside the jurisdiction of any country. Advocates argued that minerals found beneath international waters should be considered part of the "common heritage of mankind," thus subject to a system of controls on production, mandatory technology transfer provisions, and other regulatory requirements implemented by an international seabed institution. The Reagan administration, with support from many in both parties in Congress, argued that the deep seabed was a frontier area to which access for exploration and exploitation should be assured without the restrictions of what it deemed to be the anti-free market components of the pending regime. When the Law of the Sea negotiations concluded in 1982, the United States was one of four countries to vote against the resulting convention.

Despite this, the administration soon took a number of steps that recognized provisions in the convention. In 1983, President Reagan declared a 200 nautical mile exclusive economic zone (EEZ), changing what had been a continental shelf and fishery resource jurisdictional system into an exclusive regime governing access to all ocean and continental shelf resources, including the water column itself (though not impeding the right to free navigation). The Reagan EEZ Proclamation included an accompanying presidential statement that the United States would accept and act in accordance with the balance of interests reflected in the convention, except for the provisions on deep seabed mining. Finally, five years later, the United States officially extended its territorial sea from 3 to 12 nautical miles. The administration, however, did not offer any significant plans for exploring or exercising a new management role in these areas.

The architects of ocean-related programs in the 1970s built on the foundation of the Stratton Commission, creating a multidimensional framework for the management of America's stake in the oceans. The Reagan administration saw much of that framework as unrelated to—or even interfering with—the core government functions of national defense and fostering free enterprise. The result was an ongoing clash that ratified the vision of neither side, producing a stalemate. The administration did not succeed in eliminating programs such as Sea Grant and Coastal Zone Management, but it was able to hold the line or reduce financial support for most of them. Funding for NOAA's ocean research, for example, declined from $117.9 million in 1982 to $40.7 million in 1988. Many managers, earlier preoccupied with implementing their programs, spent much of the 1980s trying to save them.

Search for Coherence

Recent years have been characterized neither by the rapid growth in federal ocean activity characteristic of the 1970s, nor by the change in course that took place in the 1980s. The *EXXON Valdez* oil spill in Prince William Sound, occurring a few months after President George H.W. Bush took office in 1989, helped revive support for environmentally protective legislation. The spill led directly to enactment of the 1990 Oil Pollution Act, mandating double hulls for tankers entering U.S. ports by 2015 and setting liability standards for oil spills. That same year, amendments to the CZMA clarified that OCS lease sales are subject to the federal consistency provisions of the statute. Frustrated by the persistence of marine pollution, Congress continued to search for effective ways to reduce pollution from nonpoint sources, such as urban runoff and agriculture. Mounting alarm about the depletion of major groundfish stocks, despite two decades of management under the Magnuson–Stevens Act, led to the 1996 Sustainable Fisheries Act, designed to prevent overfishing.

On the world stage, the United Nations Conference on Environment and Development—the Earth Summit—held in Rio de Janeiro in 1992, made recommendations in seven program areas dealing with the conservation of marine and coastal resources. It also produced the United Nations Framework Agreement on Climate Change (ratified by the United States in 1992) and the Convention on Biological Diversity (which the United States has not ratified). In 1994, an agreement was reached addressing U.S. concerns on implementing the deep seabed mining provisions of the LOS Convention, and the Clinton administration sent the treaty to the Senate for advice and consent, where it still lingers, though it is in force internationally. (For a summary of many ocean-related international agreements, see Table 29.1.)

The dominant trend in U.S. ocean policy in the 1990s was a growing sense of dissatisfaction with the ad hoc approach. Much had changed since the Stratton Commission report was issued in 1969. New opportunities, such as offshore aquaculture and marine biotechnology, were being held back by the lack of appropriate management structures to guide development. Pressures on ocean and coastal areas continued to intensify and new threats loomed, such as sea-level rise and increased storm frequency attributed to global climate change, as well as puzzling and sometimes deadly algal blooms. The link between science and policy that had seemed so essential and exciting to the nation in the 1960s now suffered from insufficient investment and high-level neglect. On many key ocean issues, debate was leading not to consensus, but rather to heightened disagreements that could not be resolved under existing laws and arrangements, and often to litigation.

The sense of partial paralysis was strengthened by the existence through most of the decade of divided government, with different parties in control of the White House and Congress. None of the many centers of power was able to lead with sustained success. In search of coherence, panels assembled by the National Research Council, as well as expert groups brought together under other auspices, recommended a detailed study of the nation's ocean-related laws, programs, activities, and needs.

Consensus for Change

Since the publication of the Stratton Commission's report, seventeen Congresses and seven presidents have created, expanded, and remodeled the current framework of laws governing ocean and coastal management. At last count, more than 55 congressional committees and subcommittees (Appendix F) oversee some 20 federal agencies and permanent commissions in implementing at least 140 federal ocean-related statutes.

Recognition of the growing economic importance and ecological sensitivity of the oceans and coasts, our responsibility to future generations, and the inadequacies of the current management regime set the stage for enactment of the Oceans Act of 2000 (Appendix A), establishing the U.S. Commission on Ocean Policy. Although publicly financed, the Commission is fully independent and is charged with carrying out the first comprehensive review of marine-related issues and laws in more than thirty years to assist the nation in creating a truly effective and farsighted ocean policy. The timing of the Commission's work overlapped with that of the privately funded and more narrowly focused Pew Oceans Commission, whose recommendations contributed to the growing dialogue on the need for such policy.[5]

In enacting the Oceans Act, Congress cited the pressing need for a coherent national system of ocean governance. Factors contributing to this need include rising coastal populations, increased competition for ocean space, demand for port facilities, the emergence of potential new ocean uses, the decline of vital commercial fishery stocks, unresolved debates over offshore energy and mineral development, the persistence of marine pollution, the contamination of seafood, the loss of coastal wetlands, and the prospect that enhanced knowledge of the oceans will improve our ability to comprehend the causes of climate variability and other not yet fully grasped environmental threats.

The Commission was established because the nation is not now sufficiently organized legally or administratively to make decisions, set priorities, resolve conflicts, and articulate clear and consistent policies that respond to the wealth of problems and opportunities ocean users face. In the words of the Senate Committee on Commerce, Science, and Transportation: "Today, people who work and live on the water, from fishermen to corporations, face a patchwork of confusing and sometimes contradictory federal and state authorities and regulations. No mechanism exists for establishing a common vision or set of objectives."[6]

In September 2001, a major event again altered the lens through which America views ocean policy. Terrorist attacks on U.S. soil resulted in the placement of a higher priority on maritime security issues. That very month, the Commission's initial organizational meeting was held. The Coast Guard was soon transferred to the new U.S. Department of Homeland Security. Meanwhile, partly as a result of the war on terror, constraints on the domestic discretionary part of the U.S. government's budget raised new questions not only about what U.S. ocean policy should be, but also about what policy choices the nation can afford.

The world has changed politically, technologically, scientifically, and socially in the past thirty years. The convening of this Commission is timely as it examines the present status of ocean policy in the United States, and changes that are needed.

—Dr. Robert White, *President Emeritus of the National Academy of Engineering, Member of the Stratton Commission ('67–'68), and First NOAA Administrator ('70–'77), testimony to the Commission, October 2002*

Launching the U.S. Commission on Ocean Policy

A Broad Mandate

The Commission was directed to address numerous challenging issues, ranging from the stewardship of fisheries and marine life to the status of knowledge about the marine environment, as well as the relationships among federal, state, and local governments and the private sector in carrying out ocean and coastal activities. The Oceans Act requires that the Commission suggest ways to reduce duplication, improve efficiency, enhance cooperation, and modify the structure of federal agencies involved in managing the oceans and coasts.

With input from the states, a science advisory panel, and the public, the Commission was instructed to prepare a report presenting recommendations to the President and

Congress on ocean and coastal issues for the purpose of developing a coordinated and comprehensive national ocean policy. The Oceans Act states that this national ocean policy should promote protection of life and property, responsible stewardship of ocean and coastal resources, protection of the marine environment and prevention of marine pollution, enhancement of marine commerce, expansion of human knowledge of the marine environment, investment in technologies to promote energy and food security, close cooperation among government agencies, and preservation of U.S. leadership in ocean and coastal activities. In developing its recommendations, the Commission was required to give equal consideration to environmental, technical feasibility, economic, and scientific factors.

Specifically, the Commission's report was required to include the following elements:

- An assessment of ocean facilities including vessels, people, laboratories, computers, and satellites (Appendix 5);
- A review of federal laws and regulations on U.S. ocean and coastal activities (Appendix 6);
- A review of the supply and demand for ocean and coastal resources;
- A review of the relationships among federal, state, and local governments and the private sector;
- A review of the opportunities for investment in new products and technologies;
- Recommendations for modifications to federal laws and the structure of federal agencies; and
- A review of the effectiveness of existing federal interagency policy coordination.

The Commission Members

In accordance with guidelines set forth in the Oceans Act, in July 2001 President George W. Bush appointed sixteen citizens knowledgeable in ocean and coastal activities to serve on the U.S. Commission on Ocean Policy. The President selected twelve members from lists submitted by the Senate Majority Leader, the Senate Minority Leader, the Speaker of the House of Representatives, and the Minority Leader of the House. The remaining four members were chosen directly by the President. The Commission members (listed at the front of this report) come from positions and diverse professional backgrounds in: federal, state, and local governments; private industry; and academic and research institutions involved in marine-related issues. Admiral James D. Watkins, USN (Retired), was elected chair by his fellow commissioners at the first Commission meeting.

How the Commission Did Its Work

This report was developed after careful consideration of materials gathered during public meetings, through public comment, from existing literature, and through input of science advisors and other noteworthy experts. The input received from all of these sources served to guide the development of this report.

Regional Meetings

Because of the vast scope of topics the Commission was required to address, it sought input from a wide range of experts across the country. After two initial organizing meetings in Washington, D.C., the Commission heard testimony on ocean and coastal issues in nine different areas around the United States during a series of regional meetings and related site visits (Box 2.1). The Commission was required to hold at least one public meeting in Alaska, the Northeast (including the Great Lakes), the Southeast (including the Caribbean), the Southwest (including Hawaii and the Pacific Territories), the Northwest, and the Gulf of Mexico. To obtain information from an even greater segment of U.S. marine-related interests, the commissioners held three additional regional meetings. The commissioners also learned about important regional issues through site visits.

Box 2.1 Public Meetings of the U.S. Commission on Ocean Policy

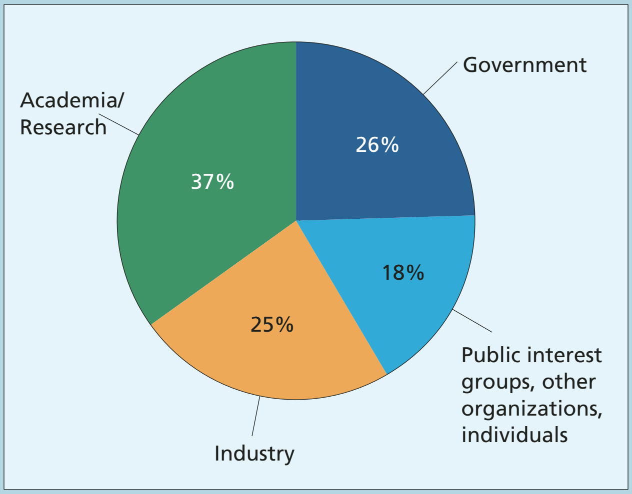
The Commissioners held sixteen public meetings and conducted eighteen regional site visits to examine a wide range of important issues and gain input from local, state, and regional ocean communities throughout the United States.

- **Washington, D.C.**
  September 17–18, 2001: Public meeting
- **Washington, D.C.**
  November 13–14, 2001: Public meeting
- **Southeast—Delaware to Georgia**
  January 14, 2002: Regional site visits (Annapolis/Chesapeake Bay, MD; Charleston, SC)
  January 15–16, 2002: Public meetings in Charleston, SC
- **Florida and the Caribbean**
  February 21, 2002: Regional site visits (Puerto Rico; South Florida east coast; Tampa–Sarasota, FL)
  February 22, 2002: Public meeting in St. Petersburg, FL
- **Gulf of Mexico—Alabama to Texas**
  February 19, 2002: Regional site visit (Texas A&M University, TX)
  March 6, 2002: Regional site visits (offshore New Orleans, LA; Stennis Space Center, MS)
  March 7–8, 2002: Public meetings in New Orleans, LA
- **Southwest—California**
  April 17, 2002: Regional site visits (San Diego and Monterey, CA)
  April 18–19, 2002: Public meetings in San Pedro, CA
- **Hawaii and Pacific Islands**
  May 13–14, 2002: Public meetings in Honolulu, HI
- **Northwest—Washington and Oregon**
  March 20, 2002: Regional site visit (Portland, OR)
  June 12, 2002: Regional site visits (Olympia and Seattle, WA)
  June 13–14, 2002: Public meetings in Seattle, WA
- **Northeast—New Jersey to Maine**
  July 22, 2002: Regional site visits (southern New England; New York–New Jersey; northern New England)
  July 23–24, 2002: Public meetings in Boston, MA
- **Alaska**
  August 21–22, 2002: Public meetings in Anchorage, AK
  August 23, 2002: Regional site visits (Dutch Harbor and Juneau, AK)
- **Great Lakes**
  September 24–25, 2002: Public meetings in Chicago, IL
- **Washington, D.C.**
  October 30, 2002: Public meeting
- **Washington, D.C.**
  November 22, 2002: Public meeting
- **Washington, D.C.**
  January 24, 2003: Public meeting
- **Washington, D.C.**
  April 2–3, 2003: Public meetings
- **Washington, D.C.**
  April 20, 2004: Release of the Preliminary Report
- **Washington, D.C.**
  July 22, 2004: Public meeting and approval of the draft Final Report

The public meetings provided government agencies, nongovernmental organizations, industry, academia, and the public the opportunity to directly discuss ocean and coastal concerns with the Commission. Commissioners held dialogues with invited speakers and sought comments from members of the public to gain insight into issues and opportunities facing each region, and to solicit recommendations for Commission consideration. The regional meetings highlighted relevant case studies and regional models with potential national applicability.

Invited panelists were selected based on their expertise on the topics highlighted at each meeting, with a strong effort to maintain a balance of interests and gain perspectives from all sectors (Figure 2.1). Six additional public meetings were held in Washington,

Figure 2.1 Invited Panelists Represented All Sectors of the Ocean Community



A breakdown of the 275 panelists invited to present testimony before the U.S. Commission on Ocean Policy illustrates the breadth of input received.

D.C., after completion of the regional meetings. At the four immediately following the regional meetings, the commissioners presented and discussed the many policy options that served as the foundation for the Commission's recommendations. Overall during its public meetings, the Commission heard from some 447 witnesses, including over 275 invited presentations and an additional 172 comments from the public, resulting in nearly 1,900 pages of testimony (Appendices 1 and 2).

Working Groups

During the first Commission meeting in September 2001, the commissioners agreed to establish four working groups in the areas of: Governance; Stewardship; Research, Education, and Marine Operations; and Investment and Implementation. These working groups were charged with reviewing and analyzing issues within their area and reporting their findings to the full Commission.

Based on extensive reviews of the testimony, public comments, background papers prepared by expert consultants, existing literature, and discussions with a broad cross-section of the marine-related community, the working groups identified key issues and outlined possible options for addressing them. The working groups shared their work with each other throughout the deliberative process to ensure thorough integration and coordination in developing the final Commission report and recommendations.

The Governance Working Group examined the roles of federal, state, and local governments as they relate to the oceans. It also assessed the management of the coastal zone and nonliving marine resources and provided options for improvement.

The Stewardship Working Group addressed living marine resources, pollution, and water quality issues and assessed the current status of ocean stewardship—the behavior of people with respect to the oceans—and incentives for responsible actions. The group concentrated on actions to achieve responsible and sustainable use of the ocean and its resources.

The Research, Education, and Marine Operations Working Group examined ocean and coastal research, exploration, air-ocean interaction research, education, marine operations, and related technology and facilities. This group analyzed the current status in these areas to assess their adequacy in achieving the national goals set forth in the Oceans Act.

Finally, the Investment and Implementation Working Group discussed the new investment and implementation strategies needed to carry out the Commission's proposed ocean policy. This working group concentrated on identifying the federal structures, processes, and investments necessary to integrate, implement, and sustain the recommendations proposed by the other working groups.

Science Advisory Panel

The Oceans Act directed the Commission, with assistance from the National Academy of Sciences, to establish a multidisciplinary science advisory panel consisting of experts in living and nonliving marine resource issues from outside the federal government. The panel (listed at the front of this report) included many of the finest ocean science and marine policy practitioners and researchers in the nation and reflected the breadth of issues before the Commission. Panel members provided expert advice on a range of issues and reviewed draft materials to ensure the Commission's report was based on the best scientific information available.

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Other Sources of Information
Throughout its work, the Commission continuously sought advice from experts on specific issues of concern through formal seminars and conferences, informal meetings and discussions, and preparation of background reports. Striving to maintain communication with all interested parties and to gain knowledge from a range of sources, the Commission also encouraged members of the public to submit information for the official record throughout the Commission's fact-finding and deliberative phases. An active Web site was maintained to facilitate public input.

As a result of the Commission's outreach efforts, some 3,200 pages of information have been filed in the official Commission record. This vast wealth of accumulated information provided examples of successful approaches and formed the basis for the Commission's recommendations.

The Preliminary Report and Governors' Comments

Following extensive consideration, and deliberations on a broad array of potential solutions, the Commission released a preliminary report in April 2004. Although the Oceans Act only required the draft report be sent to coastal state governors, the Commission went further, soliciting feedback from all state and territorial governors, tribal leaders, and the public. The response was overwhelming. Thoughtful, constructive feedback was received from thirty-seven governors (including 33 of the 34 from coastal states), five tribal leaders, and a multitude of other organizations and individuals—over one thousand pages in all. Commenters were nearly unanimous in praising the report, agreeing that our oceans are in trouble, and supporting the call for action to rectify the situation. Where governors and others offered corrections or suggestions for improvement, the Commission paid close attention and made changes as needed.

The Result

This final report of the U.S. Commission on Ocean Policy, along with its extensive appendices, is the culmination of more than two and a half years of information gathering, discussion, deliberation, review, and refinement. It represents a consensus of the sixteen Commission members on the best course of action for this nation to realize a coordinated and comprehensive national ocean and coastal policy. Meaningful change will require a reorientation of political, economic, and social attitudes and behaviors. Such change is likely to take time, but it must begin now if we are to reverse a continuing decline in the health and economic vitality of ocean and coastal waters.

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CHAPTER 3

Setting the Nation's Sights

The first step in any call for change should be to paint a picture of the desirable end result and specify the principles that will guide the changes. For U.S. ocean policy to improve, it must be based on a positive vision for the future, broad guiding principles, and translation of those principles into an effective governance system with working policies and programs.

In keeping with the latest scientific understanding about the world, management based on ecosystems rather than political boundaries should be at the heart of any new ocean policy framework. Success also depends on greatly improved public awareness of the relationship between the oceans and human existence, the connections among the land, air, and sea, the balance of benefits and costs inherent in using ocean and coastal resources, and the role of governments and citizens as ocean stewards.

Imagining a Brighter Future

The potential benefits associated with oceans and coasts are vast; however, the problems we face in protecting them and realizing their full potential are numerous and complex. There is a growing awareness of the connectivity within and between ecosystems and the impacts of human activities on the marine environment. The need for change emerged as a compelling theme at each of the U.S. Commission on Ocean Policy's public meetings—change not only in management and policies, but also in public awareness and education, and in the use of science and technology. However, before attempting to reform any system, it is important to identify the desired result. What would an improved ocean management system achieve? What would be its most important attributes? How would the oceans and coasts benefit from this improved system? What would the world look like after such reforms were realized?

In the desirable future, the oceans and coasts would be clean, safe, and sustainably managed. The oceans would contain a high level of biodiversity and contribute significantly to the economy, supporting multiple beneficial uses, including food production, development of energy and mineral resources, recreation, transportation of goods and people, and the discovery of novel life-saving drugs and other useful products. The coasts would be attractive places to live, work, and play, with clean water and beaches, easy

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public access, vibrant economies, safe bustling harbors and ports, adequate roads and services, and special protection for sensitive habitats. Beach closings, toxic algal blooms, proliferation of invasive species, and vanishing native species would be rare. Better land use planning and improved predictions of severe weather and other natural hazards would save lives and money.

In the desirable future, management of the oceans and coasts would follow ecosystem boundaries, looking at interactions among all elements of the system, rather than addressing isolated areas or problems. In the face of scientific uncertainty, managers would balance competing considerations and proceed with caution. Ocean governance would be effective, participatory, and well coordinated among government agencies, the private sector, and the public.

An improved ocean governance framework would recognize the critical importance of good information and provide strong support for physical, biological, social, and economic research. Investments would be made in the tools and technologies needed to conduct this research: ample, well-equipped surface and underwater research vessels; reliable, sustained satellites; state-of-the-art computing facilities; and innovative sensors that withstand harsh ocean conditions. A widespread network of observing and monitoring stations would provide data for research, planning, marine operations, timely forecasts, and periodic assessments. Scientific findings and observations would be translated into practical information, maps, and products used by decision makers and the public.

Better education would be a key element of the desirable future, with the United States once again joining the top ranks in math, science, and technology achievement. An ample, well-trained, and motivated workforce would be available to study the oceans, set wise policies, apply technological advances, engineer new solutions, and teach the public about the value and beauty of the oceans and coasts throughout their lives. As a result of this lifelong education, people would understand the links among the sea, land, air, and human activities, and would be better stewards of the nation's resources.

Finally, the United States would be a leader and full partner globally, sharing its science, engineering, technology, and policy expertise, particularly with developing countries, to facilitate the achievement of sustainable ocean management on a global level.

The Commission believes this vision is practical and achievable.

Building Ocean Policy on Sound Guiding Principles

To achieve the vision, national ocean policy should be guided by a set of overarching principles. Although existing ocean policies address specific issues or resources with varying degrees of success, there are no broad principles in place to guide the development and implementation of new policies, provide consistency among the universe of different policies, and assess the effectiveness of any particular policy. The fundamental principles that should guide ocean policy include the following:

- **Sustainability:** Ocean policy should be designed to meet the needs of the present generation without compromising the ability of future generations to meet their needs.
- **Stewardship:** The principle of stewardship applies both to the government and to every citizen. The U.S. government holds ocean and coastal resources in the public trust—a special responsibility that necessitates balancing different uses of those resources for the continued benefit of all Americans. Just as important, every member of the public should recognize the value of the oceans and coasts, supporting appropriate policies and acting responsibly while minimizing negative environmental impacts.
- **Ocean–Land–Atmosphere Connections:** Ocean policies should be based on the recognition that the oceans, land, and atmosphere are inextricably intertwined and that actions that affect one Earth system component are likely to affect another.

USCOP File Photo

The Commission's guiding principles and other recommendations were based on input received at meetings throughout the nation, such as this one held in July 2002 at historic Faneuil Hall in Boston, Massachusetts.

- **Ecosystem-based Management:** U.S. ocean and coastal resources should be managed to reflect the relationships among all ecosystem components, including humans and nonhuman species and the environments in which they live. Applying this principle will require defining relevant geographic management areas based on ecosystem, rather than political, boundaries.
- **Multiple Use Management**: The many potentially beneficial uses of ocean and coastal resources should be acknowledged and managed in a way that balances competing uses while preserving and protecting the overall integrity of the ocean and coastal environments.
- **Preservation of Marine Biodiversity**: Downward trends in marine biodiversity should be reversed where they exist, with a desired end of maintaining or recovering natural levels of biological diversity and ecosystem services.
- **Best Available Science and Information**: Ocean policy decisions should be based on the best available understanding of the natural, social, and economic processes that affect ocean and coastal environments. Decision makers should be able to obtain and understand quality science and information in a way that facilitates successful management of ocean and coastal resources.
- **Adaptive Management:** Ocean management programs should be designed to meet clear goals and provide new information to continually improve the scientific basis for future management. Periodic reevaluation of the goals and effectiveness of management measures, and incorporation of new information in implementing future management, are essential.
- **Understandable Laws and Clear Decisions**: Laws governing uses of ocean and coastal resources should be clear, coordinated, and accessible to the nation's citizens to facilitate compliance. Policy decisions and the reasoning behind them should also be clear and available to all interested parties.
- **Participatory Governance**: Governance of ocean uses should ensure widespread participation by all citizens on issues that affect them.
- **Timeliness:** Ocean governance systems should operate with as much efficiency and predictability as possible.

- **Accountability:** Decision makers and members of the public should be accountable for the actions they take that affect ocean and coastal resources.
- **International Responsibility:** The United States should act cooperatively with other nations in developing and implementing international ocean policy, reflecting the deep connections between U.S. interests and the global ocean.

Translating Principles into Policy

While articulating a vision for the future and identifying fundamental principles are necessary first steps, these must then be translated into working policies and programs. Four concepts serve as guideposts for developing and implementing new ocean policies: ecosystem-based management; incorporation of scientific information in decision making; improved governance; and broad public education.

Ecosystem-based Management

Sound ocean policy requires managers to simultaneously consider the economic requirements of society, the need to protect the nation's oceans and coasts, and the interplay among social, cultural, economic, and ecological factors. These factors are closely intertwined, just like the land, air, sea, and marine organisms. Activities that affect the oceans and coasts may take place far inland. For example, land-based sources of pollution, such as runoff from farms and city streets, are a significant source of the problems that plague marine ecosystems. Ocean policies cannot manage one activity, or one part of the system, without considering its connections with all the other parts. Thus, policies governing the use of U.S. ocean and coastal resources must become ecosystem-based, science-based, and adaptive.

Ecosystem-based management looks at all the links among living and nonliving resources, rather than considering single issues in isolation. This system of management considers human activities, their benefits, and their potential impacts within the context of the broader biological and physical environment. Instead of developing a management plan for one issue (such as a commercial fishery or an individual source of pollution), ecosystem-based management focuses on the multiple activities occurring within specific areas that are defined by ecosystem, rather than political, boundaries.

Defining New Management Boundaries

Splitting the natural world into clearly defined management units is a somewhat arbitrary process. Existing management boundaries primarily follow political lines. However, new scientific understanding of ecosystems makes it possible to design management areas that conform more closely to ecological units.

Since the 1960s, scientists have developed and refined the concept of "large marine ecosystems," (LMEs).[1] These regions divide the ocean into large functional units based on shared bathymetry, hydrography, productivity, and populations. LMEs encompass areas from river basins and estuaries to the outer edges of continental shelves and seaward margins of coastal current systems (Figure 3.1). Large marine ecosystems are not currently employed as management areas, although they were used in part to define the fishery management regions in the Magnuson–Stevens Fishery Conservation and Management Act. On land, watersheds have often been identified as appropriate ecosystem-based management units, particularly for issues related to hydrology and water pollution. Because of the connection between land-based activities and ocean conditions, an appropriate geographic boundary for ecosystem-based management of ocean areas might combine all or part of a large marine ecosystem with the watersheds that drain into it.

Figure 3.1 Large Marine Ecosystems Correspond to Natural Features

Ten large marine ecosystems (LMEs) have been identified for the United States. These LMEs are regions of the ocean starting in coastal areas and extending out to the seaward boundaries of continental shelves and major current systems. They take into account the biological and physical components of the marine environment as well as terrestrial features such as river basins and estuaries that drain into these ocean areas.

Source: University of Rhode Island Environmental Data Center, Department of Natural Resources. <mapper.edc.uri.edu/website/lmeims/viewer.htm> (Accessed January 2004).

While determining appropriate new boundaries is necessary to move toward ecosystem-based management, it is also important to maintain sufficient flexibility to manage on both larger and smaller scales when necessary. For example, air pollution problems must be dealt with on national and even international levels, while certain water pollution issues may need to be addressed on a small-scale watershed level. Managers should be able to adapt to the scale of different activities and the ecosystems they affect.

Aligning Decision Making within Ecosystem Boundaries

The current political and issue-specific delineation of jurisdictional boundaries makes it difficult to address complex issues that affect many parts of the ecosystem. Economic development in a coastal area may fall under the jurisdiction of several local governments, and natural resource management under the jurisdiction of one or more states, while pollution control and environmental monitoring of the same area may be overseen by several federal agencies. Yet water, people, fish, marine mammals, and ships flow continually across these invisible institutional borders.

Ecosystem-based management can provide many benefits over the current structure. The coordination of efforts within a specific geographic area allows agencies to reduce duplication and maximize limited resources. It also provides an opportunity for addressing conflicts among management entities with different mandates. Less obvious, but equally important, ecosystem-based management may engender a greater sense of stewardship among government agencies, private interests, and the public by promoting identification and connection with a specific area.

Finally, ecosystem-based management makes it easier to assess and manage the cumulative impacts of many different activities. For example, the U.S. Army Corps of Engineers' wetlands permitting program has been criticized for not evaluating cumulative impacts in its review of individual dredge-and-fill permits. A true ecosystem-based management approach would ameliorate this fragmented approach.

While ecosystem-based management is being attempted in some places on a limited basis, applying it broadly and successfully will take time and effort. In particular, the transition to such management will require explicit recognition of the uncertainty of current information and understanding. This uncertainty creates risks. One widely accepted guideline for managing in the face of uncertainty and risk is to adopt a precautionary and adaptive approach.

Precautionary and Adaptive Management

Scientific uncertainty has always been, and will probably always be, a reality of the management process. Because scientists cannot predict the behavior of humans or the environment with 100 percent accuracy, managers cannot be expected to manage with complete certainty. Nevertheless, scientists *can* provide managers with an estimate of the level of uncertainty associated with the information they are providing. Managers must incorporate this level of uncertainty into the decision-making process, support the research and data collection needed to reduce the uncertainties, and be prepared to adapt their decisions as the information improves.

Rather than a crisis-based approach to managing our oceans, we should adopt a proactive, integrated, and adaptive one.

—Ted Danson, *Founding President, American Oceans Campaign, testimony to the Commission, April 2002*

The *precautionary principle* has been proposed by some parties as a touchstone for managers faced with uncertain scientific information. In its strictest formulation, the precautionary principle states that when the potentially adverse effects of a proposed activity are not fully understood, the activity should not be allowed to proceed. While this may appear sensible at first glance, its application could lead to extreme and often undesirable results. Because scientific information can never fully explain and predict all impacts, strict adoption of the precautionary principle would prevent most, if not all, activities from proceeding.

In contrast to the precautionary principle, the Commission recommends adoption of a more balanced *precautionary approach* that weighs the level of scientific uncertainty and the potential risk of damage as part of every management decision. Such an approach can be explained as follows:

> **Precautionary Approach:** To ensure the sustainability of ecosystems for the benefit of future as well as current generations, decision makers should follow a balanced precautionary approach, applying judicious and responsible management practices based on the best available science and on proactive, rather than reactive, policies. Where threats of serious or irreversible damage exist, lack of full scientific certainty shall not be used as a justification for postponing action to prevent environmental degradation. Management plans and actions based on this precautionary approach should include scientific assessments, monitoring, mitigation measures to reduce environmental risk where needed, and periodic reviews of any restrictions and their scientific bases.

According to this approach, scientific uncertainty—by itself—should neither prevent protective measures from being implemented nor prevent uses of the ocean. Managers should review the best available science and weigh decisions in light of both the level of scientific uncertainty and the potential for damage. When the level of uncertainty is low and the likelihood of damage is also low, the decision to proceed is clearly supported. At the other extreme, when the level of uncertainty is high and the potential for irreversible damage is also high, managers should clearly not allow a proposed action to proceed. In the real world, managers will most likely face decisions between these two extremes, where the correct outcome will require balancing competing interests, using the best available information despite considerable uncertainty, and imposing some limits or mitigation measures to prevent environmental damage. After a decision is made, managers must continue to gather the information needed to reduce uncertainty, periodically assess the situation, and modify activities as appropriate.

Goals and Objectives for Ecosystem-based Management Plans

As with any major, complex undertaking, ecosystem-based management should be guided by clear, measurable goals and objectives. These goals should cover multiple uses and should be based on a combination of policy judgments, community values, and science. Although good science is essential for solving problems and scientists should advise managers about the consequences of various courses of action, science cannot determine the "best" outcome in the absence of clearly identified management goals. The setting of goals and objectives will depend on a blending of values and information.

Where multiple desirable but competing objectives exist, it is not possible to maximize each. For example, both recreational boating and marine aquaculture are potential uses of nearshore marine waters. Both provide benefits and costs to society, and both have impacts on the environment that can be lessened with proper planning. However, these activities can also conflict with each other: a large-scale aquaculture operation would prevent access by recreational boaters to certain waters. Science can inform managers of the potential positive or negative impacts of each activity but cannot ultimately determine whether to favor aquaculture or boating. Instead, a community judgment must be made, weighing the value of each activity against its potential impacts.

Ecosystem-based management will lead to better decisions that protect the environment while balancing multiple uses of ocean areas. Managers will need to work with the scientific community to develop the necessary information and understanding to support such complex decisions. But the critical process of setting goals to guide management will require active participation by many different stakeholders with divergent views. This will be difficult to achieve without changes to the existing governance system.

Biodiversity

One of the central goals for ecosystem-based management should be the explicit consideration of biodiversity on species, genetic, and ecosystem levels. While humans have always depended on particularly valued marine species for food, medicine, and other useful products, there has been a tendency to ignore species that do not have a clear, recognizable impact on society. However, it is now understood that every species makes some contribution to the structure and function of its ecosystem. Thus, an ecosystem's survival may well be linked to the survival of all species that inhabit it.

Species diversity, or the number of species within an ecosystem, is one measure of biodiversity. However, biodiversity is also significant at larger and smaller scales. Within a single-species population, it is important to preserve *genetic diversity*—the bedrock of evolution. Maintaining genetic diversity is important for species to adapt to changing environmental conditions. It is also important to understand and protect *ecosystem diversity*, the number of different ecosystems and different kinds of ecosystems, on Earth.

Because scientists have tended to study specific habitats, such as coral reefs, mangroves, or wetlands, quantitative measures of marine biodiversity at larger scales are rare. Nevertheless, there is broad consensus that the biodiversity of life in the oceans is being affected by human activities. Studies indicate that in many marine and coastal locations, community composition has changed to conditions that are less valuable from ecological, economic, and even cultural perspectives.[2] There have been reductions in food and medicinal species and alterations of aesthetic and recreational values important to humans, including much greater abundance of less desirable species like toxic algae and bacteria.

Despite the importance of biodiversity to ecosystem functions and values, very little is known about how biodiversity arises, is maintained, and is affected by outside forces including climate variability and direct human impacts.

Science for Decision Making

Ecosystem-based management provides many potential benefits, but also imposes new responsibilities on managers. The need to collect good information and to improve understanding is perhaps foremost among these new responsibilities. Despite considerable progress over the last century, the oceans remain one of the least explored and most poorly understood environments on the planet.

Greater knowledge can enable policy makers and managers to make science-based decisions at the national, regional, state, and local levels. Existing research and monitoring programs, which tend to be agency- and issue-centric, should be reoriented to become ecosystem-based. This will help resolve the current mismatch between the size and complexity of marine ecosystems and the many fragmented research and monitoring programs for coastal and ocean ecosystems.

In addition to the need for better understanding, the nation lacks effective mechanisms for incorporating scientific information into decision-making processes in a timely manner. As knowledge improves, it must be actively incorporated into policy through an adaptive process. To make this policy translation effective, local, state, regional, and national managers need an avenue to communicate their information needs and priorities.

Better coordination can facilitate more efficient use of existing funds. However, to significantly improve U.S. management of oceans and coasts and make ecosystem-based management a reality, the nation will need to commit to greater investments in ocean science, engineering, exploration, observations, infrastructure, and data management. Increased investments will help restore the pre-eminence of U.S. ocean capabilities, which has eroded since the end of the Cold War.

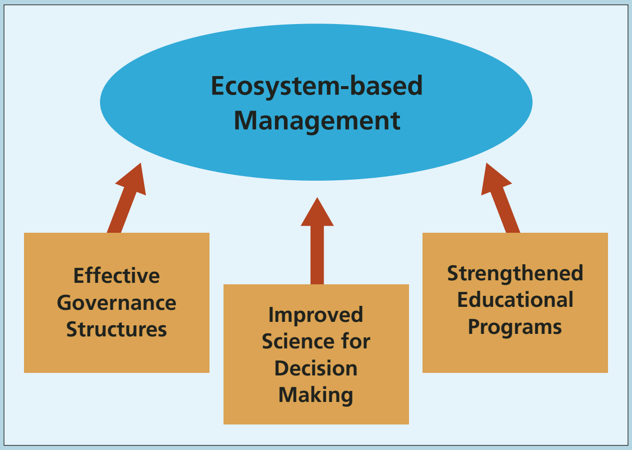
Although multiple use conflicts are common in coastal and ocean environments, efforts to understand the social, cultural, and economic dimensions of ocean issues have received surprisingly little support. Because of this, studies of humans and their behavior—so critical to virtually every ecosystem—deserve special emphasis.

Climate Change

The causes and impacts of climate variability and climate change are among the most pressing scientific questions facing our nation and the planet. Changing atmospheric composition and global temperatures, due to natural variation and human activities, have the potential to significantly affect societies and environments on local, regional, and worldwide scales. Decision makers require reliable information on which to base both short- and long-term strategies for addressing these impacts. In addition, a growing awareness of the possibility of abrupt climate change (characterized by extreme climatic shifts over relatively short time periods) reinforces the need for enhanced prediction and response capabilities.

Although a solid body of knowledge exists on which to base immediate actions, continued improvements in understanding will help refine these strategies over time. Two areas in particular need of elucidation are the role of oceans in the global cycling of water, heat, and carbon, and the effects of changes in atmospheric chemistry and temperatures on marine ecosystems and biological processes themselves. For example, research shows that over the last 200 years the oceans have absorbed 48 percent of the carbon dioxide

Figure 3.2 The Foundations of a New National Ocean Policy



Implementing an ecosystem-based management approach for oceans and coasts will require a strong foundation of effective national, regional, and local governance; improvements in research and monitoring to provide managers with sound information on which to base decisions; and a strengthened stewardship ethic among all citizens, achieved through formal and informal education.

emitted by human activities.[3] This has resulted in elevated concentrations of carbon dioxide in ocean waters, impairing the ability of certain marine organisms to produce protective shells, with potentially profound impacts on marine productivity and biodiversity.[4] Armed with expanded research findings in these areas and others, and with more comprehensive ocean observations, the nation's leaders will be able to modify management strategies to more effectively predict and mitigate the potential impacts of climate change.

Effective Ocean Governance

National ocean policy can only be implemented if an effective governance system is in place. Many of the guiding principles defined in this chapter speak directly to this need. An effective governance system will be predictable, efficient, and accountable. Laws, policies, and programs must be well coordinated and easily understood by regulated parties and the public. A comprehensive framework should be in place that defines the appropriate roles for different levels of government, the private sector, and citizens, promoting effective partnerships for managing ocean and coastal resources. Equally important, decision makers and the public should be accountable for decisions and actions that affect the ocean and its resources.

Participation by a broad sector of the public is essential to a successful ocean governance system. Facing an array of complex problems and competing desires, interested parties must reach agreements on what actions are needed, which are of greatest priority, and how to implement decisions once they are made. Public input is critical to this decision-making process so that all interests are fairly represented and support is built from the ground up. Without a truly participatory form of ocean governance, dispute and litigation are inevitable. At the same time, clear roles, jurisdictions, and authorities must be delineated to avoid gridlock and allow progress.

Today, no federal entity has the mission to evaluate the vast array of federal actions affecting ocean and coastal resources and to advocate for more effective approaches, prioritized investment, improved agency coordination, and program consolidation where needed. Nor is there a coherent national policy for ocean management that guides the missions of various federal agencies. A more unified federal voice is also needed in discussing policy options with the many nonfederal stakeholders.

Not since the Stratton Commission in the 1960s has an opportunity such as this existed. One of the top priorities of this Commission is to instigate changes in ocean governance that will result in tangible improvements, today and for future generations.

Public Education

Education has provided the skilled and knowledgeable workforce that made America a world leader in technology, productivity, prosperity, and security. However, rampant illiteracy about science, mathematics, and the environment now threaten the future of America, its people, and the oceans on which we rely.

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Testing results suggest that, after getting off to a good start in elementary school, by the time U.S. students graduate from high school their achievement in math and science falls well below the international average.[5] Ocean-related topics offer an effective tool to keep students interested in science, increase their awareness of the natural world, and boost their academic achievement in many areas. In addition, the links between the marine environment and human experience make the oceans a powerful vehicle for teaching history, culture, economics, and other social sciences. Yet, teachers receive little guidance on how they might use exciting ocean subjects to engage students, while adhering to the national and state science and other education standards that prescribe their curricula.

A 1999 study indicated that just 32 percent of the nation's adults grasp simple environmental concepts, and even fewer understand more complex issues, such as ecosystem decline, loss of biodiversity, or watershed degradation.[6] It is not generally understood that nonpoint source pollution threatens the health of our coastal waters or that mercury in fish comes from human activities via the atmosphere. Few people understand the tangible value of the ocean to the nation or that their own actions can have an impact on that resource. From excess applications of fertilizers, pesticides, and herbicides on lawns, to the trash washed off city streets into rivers and coastal waters, ordinary activities can and do contribute significantly to the degradation of the marine environment. Instilling a stewardship ethic in the American public is an important element of a national ocean policy. Without an acknowledgement of the impacts associated with ordinary behavior and a willingness to take the necessary action—which may incur additional costs—achieving a collective commitment to more responsible lifestyles and new policies will be difficult.

Excellent lifelong education in marine affairs and sciences is essential to raising public awareness of the close connection between the oceans and humans, including our history and culture. This awareness will result in better public understanding of the connections among the ocean, land, and atmosphere, the potential benefits and costs inherent in resource use, and the roles of government and citizens as ocean stewards.

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PRIMER ON OCEAN JURISDICTIONS:

Drawing Lines in the Water

Although invisible to the naked eye, governments have carved the world's oceans into many zones, based on both international and domestic laws. These zones are often complex, with overlapping legal authorities and agency responsibilities. Internationally, the closer one gets to the shore, the more authority a coastal nation has. Similarly, for domestic purposes, the closer one gets to the shore, the more control an individual U.S. state has.

This primer explains the ocean jurisdiction of the United States under international law, as well as the domestic distinction between federal and state waters (Figure P.1).

The Baseline (0 Miles)

For purposes of both international and domestic law, the boundary line dividing the land from the ocean is called the baseline. The baseline is determined according to principles described in the 1958 United Nations Convention on the Territorial Sea and the Contiguous Zone and the 1982 United Nations Convention on the Law of the Sea (LOS Convention), and is normally the low water line along the coast, as marked on charts officially recognized by the coastal nation. In the United States, the definition has been further refined based on federal court decisions; the U.S. baseline is the mean lower low water line along the coast, as shown on official U.S. nautical charts. The baseline is drawn across river mouths, the opening of bays, and along the outer points of complex coastlines. Water bodies inland of the baseline—such as bays, estuaries, rivers, and lakes—are considered "internal waters" subject to national sovereignty.

State Seaward Boundaries in the United States

(0 to 3 Nautical Miles; 0 to 9 Nautical Miles for Texas, Florida's Gulf Coast, and Puerto Rico)

In the 1940s, several states claimed jurisdiction over mineral and other resources off their coasts. This was overturned in 1947, when the Supreme Court determined that states had no title to, or property interest in, these resources. In response, the Submerged Lands Act was enacted in 1953 giving coastal states jurisdiction over a region extending 3 nautical miles seaward from the baseline, commonly referred to as *state waters*. For historical reasons, Texas and the Gulf Coast of Florida are an exception, with state waters extending to 9 nautical miles offshore. (Note: A nautical mile is approximately 6,076 feet. All references hereafter in this Primer to miles are to nautical miles.) Subsequent legislation granted the U.S. Virgin Islands, Guam, and American Samoa jurisdiction out to 3 miles, while Puerto Rico has a 9-mile jurisdictional boundary.

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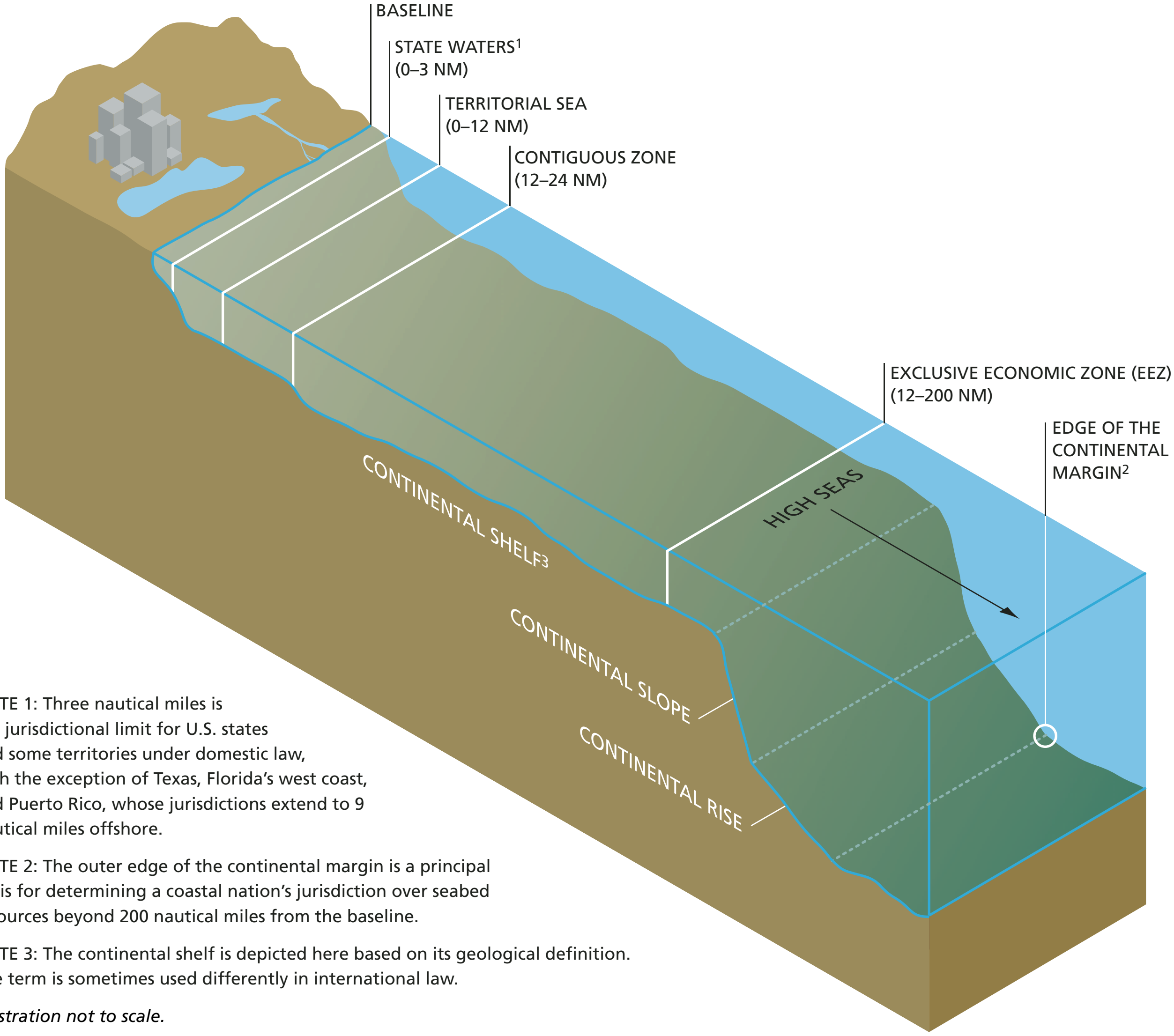
Figure P.1 Lines of U.S. Authority in Offshore Waters



NOTE 1: Three nautical miles is the jurisdictional limit for U.S. states and some territories under domestic law, with the exception of Texas, Florida's west coast, and Puerto Rico, whose jurisdictions extend to 9 nautical miles offshore.

NOTE 2: The outer edge of the continental margin is a principal basis for determining a coastal nation's jurisdiction over seabed resources beyond 200 nautical miles from the baseline.

NOTE 3: The continental shelf is depicted here based on its geological definition. The term is sometimes used differently in international law.

Illustration not to scale.

Several jurisdictional zones exist off the coast of the United States for purposes of international and domestic law. Within these zones, the United States asserts varying degrees of authority over offshore activities, including living and nonliving resource management, shipping and maritime transportation, and national security. A nation's jurisdictional authority is greatest near the coast.

The federal government retains the power to regulate commerce, navigation, power generation, national defense, and international affairs throughout state waters. However, states are given the authority to manage, develop, and lease resources throughout the water column and on and under the seafloor. (States have similar authorities on the land side of the baseline, usually up to the mean high tide line, an area known as state tidelands.)

In general, states must exercise their authority for the benefit of the public, consistent with the public trust doctrine. Under this doctrine, which has evolved from ancient Roman law and English common law, governments have an obligation to protect the interests of the general public (as opposed to the narrow interests of specific users or any particular group) in tidelands and in the water column and submerged lands below navigable waters. Public interests have traditionally included navigation, fishing, and commerce. In recent times, the public has also looked to the government to protect their interests in recreation, environmental protection, research, and preservation of scenic beauty and cultural heritage.

The Territorial Sea (0 to 12 Nautical Miles)

Under international law, every coastal nation has sovereignty over the air space, water column, seabed, and subsoil of its *territorial sea,* subject to certain rights of passage for foreign vessels and, in more limited circumstances, foreign aircraft.

For almost two hundred years, beginning with an assertion by Secretary of State Thomas Jefferson in 1793, the United States claimed a territorial sea out to 3 miles. In 1988, President Reagan proclaimed a 12-mile territorial sea for the United States, consistent with provisions in the LOS Convention. The proclamation extended the territorial sea only for purposes of international law, explicitly stating that there was no intention to alter domestic law.

The Contiguous Zone (12 to 24 Nautical Miles)

International law recognizes a *contiguous zone* outside the territorial sea of each coastal nation. Within its contiguous zone, a nation can assert limited authority related to customs, fiscal, immigration, and sanitary laws. In 1999, President Clinton proclaimed a U.S. contiguous zone from 12 to 24 miles offshore enhancing the U.S. Coast Guard's authority to take enforcement actions against foreign flag vessels throughout this larger area.

The Exclusive Economic Zone (12 to 200 Nautical Miles)

The LOS Convention allows each coastal nation to establish an *exclusive economic zone* (EEZ) adjacent to its territorial sea, extending a maximum of 200 miles seaward from the baseline. Within its EEZ, the coastal nation has sovereign rights for the purpose of exploring, exploiting, conserving, and managing living and nonliving resources, whether found in ocean waters, the seabed, or subsoil. It also has jurisdiction over artificial islands or other structures with economic purposes.

In 1983, President Reagan proclaimed the U.S. EEZ, which currently occupies the area between 12 miles (the seaward limit of the territorial sea) and 200 miles offshore for international purposes. It also includes areas contiguous to its commonwealths, territories, and possessions. Consistent with international law and traditional high-seas freedoms, the U.S. does not generally assert control over surface or submarine vessel transit, aircraft overflight, or the laying of cables and pipelines on the ocean floor, nor does it assert jurisdiction over marine scientific research in the U.S. EEZ to the same extent that most coastal nations do. The United States requires advance consent for marine research, if and only if, any portion of the research is conducted within the U.S. territorial sea, involves the study of marine mammals, requires taking commercial quantities of marine resources, or involves contact with the U.S. continental shelf.

The Continental Shelf (12 to 200 Nautical Miles or Outer Edge of Continental Margin)

The legal concept of the continental shelf has evolved over the last sixty years. A 1945 proclamation by President Truman first asserted a U.S. claim to resources of its continental shelf. This proclamation set a precedent for other coastal nations to assert similar claims over resources far from their shores. The need to establish greater uniformity was one of the driving forces behind the 1958 United Nations Convention on the Continental Shelf. However, the 1958 Convention showed limited vision, defining the continental

D-1264

Box P.1 Acknowledging Change: The Need to Update Federal Laws

Over the past twenty years, U.S. presidents have issued a series of proclamations changing the extent and nature of U.S. authority over the oceans. The changes, creating a territorial sea to 12 miles, a contiguous zone to 24 miles, and an exclusive economic zone to 200 miles, have not been comprehensively reflected in domestic laws. Many laws also use imprecise or inconsistent terms to refer to ocean areas, such as "navigable waters," "coastal waters," "ocean waters," "territory and waters," "waters of the United States," and "waters subject to the jurisdiction of the United States." These terms can mean different things in different statutes and sometimes are not defined at all.

Legal disputes have already occurred over the seaward extent of jurisdiction of the Endangered Species Act and the National Environmental Policy Act. The Clean Water Act and the Oil Pollution Act both refer to a 3-mile territorial sea. Inconsistencies and ambiguities in geographic definitions have caused problems in civil and criminal cases unrelated to natural resources, such as the regulation of offshore gambling. Congress has amended some laws regulating marine commerce to reflect the 12-mile U.S. territorial sea. However, there has been no systematic effort to review and update all ocean-related U.S. statutes and regulations.

shelf based on a nation's ability to recover resources from the seabed. As technological capabilities improved, uncertainty began anew about the seaward boundary of a nation's exclusive rights to continental shelf resources.

The LOS Convention generally defines the *continental shelf* for purposes of international law as the seafloor and subsoil that extend beyond the territorial sea throughout the natural prolongation of a coastal nation's land mass to the outer edge of the continental margin or to 200 miles from the baseline if the continental margin does not extend that far. The legal definition of the continental shelf thus overlaps geographically with the EEZ.

Where a coastal nation can demonstrate that its continental margin extends beyond 200 miles, the LOS Convention has a complex process for asserting such claims internationally. The U.S. continental margin extends beyond 200 miles in numerous regions, including the Atlantic Coast, the Gulf of Mexico, the Bering Sea, and the Arctic Ocean. However, because the United States is not a party to the LOS Convention, it can not assert its claims through LOS Convention mechanisms. (For more discussion on the LOS Convention, see Chapter 29.)

The High Seas (Areas Beyond National Jurisdictions)

International law has long considered areas of the ocean beyond national jurisdiction to be the *high seas*. On the high seas, all nations have certain traditional freedoms, including the freedom of surface and submerged navigation, the freedom to fly over the water, harvest fish, lay submarine cables and pipelines, conduct scientific research, and construct artificial islands and certain other installations. These freedoms are subject to certain qualifications, such as the duty to conserve living resources and to cooperate with other nations toward this end. In addition, a nation exercising its high seas freedoms must give due regard to the interests of other nations.

Originally defined as the area beyond the territorial seas of coastal nations, today the high seas are defined by the LOS Convention as the area seaward of the EEZs of those nations. Sixty percent of the world's oceans remain in this zone, where the traditional freedom of the seas still prevails. Even on the high seas, the United States and other coastal nations have some limited ability to exercise governmental authority. For example, U.S. citizens on the high seas remain subject to U.S. law, as do individuals on U.S.-flagged vessels and aircraft.

Acc. No. 0571 – *A Case-Control Analysis of Exposure to Traffic and Acute Myocardial Infarction* can be viewed on the docket:
http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0573 is a duplicate of Acc. No. 0568 – *Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers: A Guide for Future Research* can be viewed on the docket: http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0577

Public Submission: NHTSA-2008-0060-0577 **Bookmark:** Learn more Public Subr

Docket	NHTSA-2008-0060
Docket Title	Notice of Intent to Prepare an Environmental Impact Statement for New Corp Economy Standards
Docket Type	Rulemaking
Document	NHTSA-2008-0060-0528
Document Title	Notice of Availability of a Draft Environmental Impact Statement (DEIS) for N Average Fuel Economy Standards; Notice of Public Hearing
Public Submission	NHTSA-2008-0060-0577
Public Submission Title	S. Jaafar A. Rizvi - Comments
Views	
Add Comments	
How To Comment	

Title	S. Jaafar A. Rizvi - Comments
Abstract	
Document Type	PUBLIC SUBMISSIONS
Document Sub-Type	Comment(s)
CFR Citation	
Author / Document Date	08/18/2008
Answer Date	
Media Location	
Media Type	
Page Count	1
Start End Page	
Order Number	
Old Submitter Rep	
Old Submitter	
Effective Date	
OMB / PRA Approval Number	
Received / Filing Date	08/18/2008
Legacy ID	
Federal Reg Citation	
Federal Register Number	
Date Posted	08/19/2008
Comment Start Date	03/28/2008
Comment Due / Reply Date	
Implementation / Service Date	

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D-1268

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Government Agency	

General Comment

Comment Written testimony for docket number NHTSA-2008-0060

Attachments

NHTSA-2008-0060-0577.1	**S. Jaafar A. Rizvi - Comments**
NHTSA-2008-0060-0577.2	**S. Jaafar A. Rizvi - Comments**

Acc. No. 0577.1

Jaafar Rizvi
August 4, 2008

Good afternoon. My name is Jaafar Rizvi, and I am a student. I would first like to thank the National Highway Safety Administration for being receptive to public opinion on the matter of emissions standards. However, I am here because I am concerned that fuel economy standards are not strong enough.

According to the Draft Environmental Impact Statement, fuel economy standards should be set at "the maximum feasible average that the Secretary of Transportation decides the manufacturers can achieve in that model year" while simultaneously considering "technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need for the US to conserve energy."

I agree, in general, with the guidelines put forth for determining fuel economy standards. However, I fear that the NHTSA hasn't fully analyzed several relevant factors, and as a result, I fear that the NHTSA will recommend emissions standards that are not strong enough.

When considering economic practicability, the report does not adequately consider the economic costs of high emissions.

The report considers only the economic burden that would be placed on the automobile manufacturers as a result of stricter emissions standards, while it ignores the economic benefits to the rest of the economy.

First, the scientific community agrees that emissions contribute to global warming and, in so doing, cause or intensify natural disasters. The nearly 90 billion dollars of repairs that are needed to rebuild what Katrina destroyed have to be funded, and thus there are 90 billion dollars that cannot be spent in other ways. This also holds true for the two billion dollars that private American citizens donated.

The "opportunity costs" of not reducing emissions is extremely high and must considered when calculating economic effects of action.

While natural disasters are not entirely preventable by reducing greenhouse gases, it is within our power to curb global warming and thereby reduce the severity of these events. Unfortunately, we can begin to expect more disasters every year. The International Federation of the Red Cross showed in its *World Disasters Report 2007* that there has been an increase in natural disasters of over 115% since 2004, totaling 541 individual disasters. It states that this increase has been due to weather related disasters. As there are more and more natural disasters, the amount of money that the federal government and private donors commit to restoration will increase — again, making this money unavailable for other important uses, such as national defense, business investment, education, or renewable energy, all of which would benefit America in future years.

There is another opportunity cost related to emissions standards. We have the technology to produce more fuel-efficient cars. By allowing manufacturers to keep such vehicles out of consumer hands, Americans are forced to spend thousands of dollars at the pump every year that they could spend in other ways, such as improvements on their homes, small business hiring, and college education.   According to a report by U.S. PIRG, fuel costs are the second highest expense for the average American family, after rent and ahead of healthcare and food. Higher emissions standards would help American's save gas and thereby save money. At a time when fuel prices are skyrocketing and do not look to be going down substantially due to increasing worldwide demand for oil, an increase in fuel economy standards would allow more dollars to flow to non-energy sectors of the economy.

I urge NHTSA to first, take into consideration the opportunity costs incurred as a result of the global warming-related disasters and in household spending in determining the meaning of "economic practicability" and second, increase emissions standards accordingly.

Please give the push that we all need. In doing so, America will become a leader in tackling the environmental crisis, the one of the most formidable challenges of this era.

Acc. No. 0577.2 (Letter from Jaafar Rizvi) is a duplicate of Acc. No. 0577.1

Acc. No. 0578 – *The Particle Pollution Report* (EPA 454-R-04-002) can be viewed on the docket:
http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0579 Does not exist. A numbering error occurred in the docket. The docket can be viewed at the following link:
http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0580

Federal Register

Thursday,

May 15, 2008

Part II

Department of the Interior

Fish and Wildlife Service

50 CFR Part 17

Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Polar Bear (Ursus maritimus) Throughout Its Range; Final Rule

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

50 CFR Part 17

[FWS-R7-ES-2008-0038; 1111 FY07 MO-B2]

RIN 1018-AV19

Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Polar Bear (Ursus maritimus) Throughout Its Range

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Final rule.

SUMMARY: We, the U.S. Fish and Wildlife Service (Service), determine threatened status for the polar bear (*Ursus maritimus*) under the Endangered Species Act of 1973, as amended (Act) (16 U.S.C. 1531 et seq.). Polar bears evolved to utilize the Arctic sea ice niche and are distributed throughout most ice-covered seas of the Northern Hemisphere. We find, based upon the best available scientific and commercial information, that polar bear habitat—principally sea ice—is declining throughout the species' range, that this decline is expected to continue for the foreseeable future, and that this loss threatens the species throughout all of its range. Therefore, we find that the polar bear is likely to become an endangered species within the foreseeable future throughout all of its range. This final rule activates the consultation provisions of section 7 of the Act for the polar bear. The special rule for the polar bear, also published in today's edition of the **Federal Register**, sets out the prohibitions and exceptions that apply to this threatened species.

DATES: This rule is effective May 15, 2008. The U.S. District Court order in *Center for Biological Diversity* v. *Kempthorne,* No. C 08–1339 CW (N.D. Cal., April 28, 2008) ordered that the 30-day notice period otherwise required by the Administrative Procedure Act be waived, pursuant to 5 U.S.C. 553(d)(3).

ADDRESSES: Comments and materials received, as well as supporting scientific documentation used in the preparation of this rule, will be available for public inspection, by appointment, during normal business hours at: U.S. Fish and Wildlife Service, Marine Mammals Management Office, 1011 East Tudor Road, Anchorage, AK 99503. Copies of this final rule are also available on the Service's Marine Mammal website: *http://alaska.fws.gov/fisheries/mmm/polarbear/issues.htm.*

FOR FURTHER INFORMATION CONTACT: Scott Schliebe, Marine Mammals Management Office (see **ADDRESSES** section) (telephone 907–786–3800). Persons who use a telecommunications device for the deaf (TDD) may call the Federal Information Relay Service (FIRS) at 1–800–877–8339, 24 hours a day, 7 days a week.

SUPPLEMENTARY INFORMATION:

Background

Information in this section is summarized from the following sources: (1) The Polar Bear Status Review (Schliebe et al. 2006a); (2) information received from public comments in response to our proposal to list the polar bear as a threatened species published in the **Federal Register** on January 9, 2007 (72 FR 1064); (3) new information published since the proposed rule (72 FR 1064), including additional sea ice and climatological studies contained in the Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report* (AR4) and other published papers; and (4) scientific analyses conducted by the U.S. Geological Survey (USGS) and co-investigators at the request of the Secretary of the Department of the Interior specifically for this determination. For more detailed information on the biology of the polar bear, please consult the Status Review and additional references cited throughout this document.

Species Biology

Taxonomy and Evolution

Throughout the Arctic, polar bears are known by a variety of common names, including nanook, nanuq, ice bear, sea bear, isbjørn, white bears, and eisbär. Phipps (1774, p. 174) first proposed and described the polar bear as a species distinct from other bears and provided the scientific name *Ursus maritimus.* A number of alternative names followed, but Harington (1966, pp. 3–7), Manning (1971, p. 9), and Wilson (1976, p. 453) (all three references cited in Amstrup 2003, p. 587) subsequently promoted the name *Ursus maritimus* that has been used since.

The polar bear is usually considered a marine mammal since its primary habitat is the sea ice (Amstrup 2003, p. 587), and it is evolutionarily adapted to life on sea ice (see further discussion under General Description section). The polar bear is included on the list of species covered under the U.S. Marine Mammal Protection Act of 1972, as amended (16 U.S.C. 1361 et seq.) (MMPA).

Polar bears diverged from grizzly bears (*Ursus arctos*) somewhere between 200,000 and 400,000 years ago (Talbot and Shields 1996a, p. 490; Talbot and Shields 1996b, p. 574). However, fossil evidence of polar bears does not appear until after the Last Interglacial Period (115,000 to 140,000 years ago) (Kurten 1964, p. 25; Ingolfsson and Wiig 2007). Only in portions of northern Canada, Chukotka, Russia, and northern Alaska do the ranges of polar bears and grizzly bears overlap. Cross-breeding of grizzly bears and polar bears in captivity has produced reproductively viable offspring (Gray 1972, p. 56; Stirling 1988, p. 23). The first documented case of cross-breeding in the wild was reported in the spring of 2006, and Wildlife Genetics International confirmed the cross-breeding of a female polar bear and male grizzly bear (Paetkau, pers. comm. May 2006).

General Description

Polar bears are the largest of the living bear species (DeMaster and Stirling 1981, p. 1; Stirling and Derocher 1990, p. 190). They are characterized by large body size, a stocky form, and fur color that varies from white to yellow. They are sexually dimorphic; females weigh 181 to 317 kilograms (kg) (400 to 700 pounds (lbs)), and males up to 654 kg (1,440 lbs). Polar bears have a longer neck and a proportionally smaller head than other members of the bear family (Ursidae) and are missing the distinct shoulder hump common to grizzly bears. The nose, lips, and skin of polar bears are black (Demaster and Stirling 1981, p. 1; Amstrup 2003, p. 588).

Polar bears evolved in sea ice habitats and as a result are evolutionarily adapted to this habitat. Adaptations unique to polar bears in comparison to other Ursidae include: (1) White pelage with water-repellent guard hairs and dense underfur; (2) a short, furred snout; (3) small ears with reduced surface area; (4) teeth specialized for a carnivorous rather than an omnivorous diet; and (5) feet with tiny papillae on the underside, which increase traction on ice (Stirling 1988, p. 24). Additional adaptations include large, paddle-like feet (Stirling 1988, p. 24), and claws that are shorter and more strongly curved than those of grizzly bears, and larger and heavier than those of black bears (*Ursus americanus*) (Amstrup 2003, p. 589).

Distribution and Movements

Polar bears evolved to utilize the Arctic sea ice niche and are distributed throughout most ice-covered seas of the Northern Hemisphere. They occur throughout the East Siberian, Laptev, Kara, and Barents Seas of Russia; Fram Strait (the narrow strait between northern Greenland and Svalbard), Greenland Sea and Barents Sea of northern Europe (Norway and Greenland (Denmark)); Baffin Bay, which separates Canada and Greenland, through most of the Canadian Arctic archipelago and the Canadian Beaufort Sea; and in the Chukchi and Beaufort Seas located west and north of Alaska.

Over most of their range, polar bears remain on the sea ice year-round or spend only short periods on land. However, some polar bear populations occur in seasonally ice-free environs and use land habitats for varying portions of the year. In the Chukchi Sea and Beaufort Sea areas of Alaska and northwestern Canada, for example, less than 10 percent of the polar bear locations obtained via radio telemetry were on land (Amstrup 2000, p. 137; Amstrup, USGS, unpublished data); the majority of land locations were bears occupying maternal dens during the winter. A similar pattern was found in East Greenland (Wiig et al. 2003, p. 511). In the absence of ice during the summer season, some populations of polar bears in eastern Canada and Hudson Bay remain on land for extended periods of time until ice again forms and provides a platform for them to move to sea. Similarly, in the Barents Sea, a portion of the population is spending greater amounts of time on land.

Although polar bears are generally limited to areas where the sea is ice-covered for much of the year, they are not evenly distributed throughout their range on sea ice. They show a preference for certain sea ice characteristics, concentrations, and specific sea ice features (Stirling et al. 1993, pp. 18–22; Arthur et al. 1996, p. 223; Ferguson et al. 2000a, p. 1,125; Ferguson et al. 2000b, pp. 770–771; Mauritzen et al. 2001, p. 1,711; Durner et al. 2004, pp. 18–19; Durner et al. 2006, p. pp. 34–35; Durner et al. 2007, pp. 17 and 19). Sea-ice habitat quality varies temporally as well as geographically (Ferguson et al. 1997, p. 1,592; Ferguson et al. 1998, pp. 1,088–1,089; Ferguson et al.2000a, p. 1,124; Ferguson et al.2000b, pp. 770–771; Amstrup et al. 2000b, p. 962). Polar bears show a preference for sea ice located over and near the continental shelf (Derocher et al. 2004, p. 164; Durner et al. 2004, p. 18–19; Durner et al. 2007, p. 19), likely due to higher biological productivity in these areas (Dunton et al. 2005, pp. 3,467–3,468) and greater accessibility to prey in near-shore shear zones and polynyas (areas of open sea surrounded by ice) compared to deep-water regions in the central polar basin (Stirling 1997, pp. 12–14). Bears are most abundant near the shore in shallow-water areas, and also in other areas where currents and ocean upwelling increase marine productivity and serve to keep the ice cover from becoming too consolidated in winter (Stirling and Smith 1975, p. 132; Stirling et al. 1981, p. 49; Amstrup and DeMaster 1988, p. 44; Stirling 1990, pp. 226–227; Stirling and Øritsland 1995, p. 2,607; Amstrup et al. 2000b, p. 960).

Polar bear distribution in most areas varies seasonally with the seasonal extent of sea ice cover and availability of prey. The seasonal movement patterns of polar bears emphasize the role of sea ice in their life cycle. In Alaska in the winter, sea ice may extend 400 kilometers (km) (248 miles (mi)) south of the Bering Strait, and polar bears will extend their range to the southernmost proximity of the ice (Ray 1971, p. 13). Sea ice disappears from the Bering Sea and is greatly reduced in the Chukchi Sea in the summer, and polar bears occupying these areas move as much as 1,000 km (621 mi) to stay with the pack ice (Garner et al. 1990, p. 222; Garner et al. 1994, pp. 407–408). Throughout the polar basin during the summer, polar bears generally concentrate along the edge of or into the adjacent persistent pack ice. Significant northerly and southerly movements of polar bears appear to depend on seasonal melting and refreezing of ice (Amstrup 2000, p. 142). In other areas, for example, when the sea ice melts in Hudson Bay, James Bay, Davis Strait, Baffin Bay, and some portions of the Barents Sea, polar bears remain on land for up to 4 or 5 months while they wait for winter and new ice to form (Jonkel et al. 1976, pp. 13–22; Schweinsburg 1979, pp. 165, 167; Prevett and Kolenosky 1982, pp. 934–935; Schweinsburg and Lee 1982, p. 510; Ferguson et al. 1997, p. 1,592; Lunn et al. 1997, p. 235; Mauritzen et al. 2001, p. 1,710).

In areas where sea ice cover and character are seasonally dynamic, a large multi-year home range, of which only a portion may be used in any one season or year, is an important part of the polar bear life history strategy. In other regions, where ice is less dynamic, home ranges are smaller and less variable (Ferguson et al. 2001, pp.51–52). Data from telemetry studies of adult female polar bears show that they do not wander aimlessly on the ice, nor are they carried passively with the ocean currents as previously thought (Pedersen 1945 cited in Amstrup 2003, p. 587). Results show strong fidelity to activity areas that are used over multiple years (Ferguson et al. 1997, p. 1,589). All areas within an activity area are not used each year.

The distribution patterns of some polar bear populations during the open water and early fall seasons have changed in recent years. In the Beaufort Sea, for example, greater numbers of polar bears are being found on shore than recorded at any previous time (Schliebe et al. 2006b, p. 559). In Baffin Bay, Davis Strait, western Hudson Bay and other areas of Canada, Inuit hunters are reporting an increase in the numbers of bears present on land during summer and fall (Dowsley and Taylor 2005, p. 2; Dowsley 2005, p. 2). The exact reasons for these changes may involve a number of factors, including changes in sea ice (Stirling and Parkinson 2006, p. 272).

Food Habits

Polar bears are carnivorous, and a top predator of the Arctic marine ecosystem. Polar bears prey heavily throughout their range on ice-dependent seals (frequently referred to as ''ice seals''), principally ringed seals (*Phoca hispida*), and, to a lesser extent, bearded seals (*Erignathus barbatus).* In some locales, other seal species are taken. On average, an adult polar bear needs approximately 2 kg (4.4 lbs) of seal fat per day to survive (Best 1985, p. 1035). Sufficient nutrition is critical and may be obtained and stored as fat when prey is abundant.

Although seals are their primary prey, polar bears occasionally take much larger animals such as walruses (*Odobenus rosmarus*), narwhal (*Monodon monoceros*), and belugas (*Delphinapterus leucas*) (Kiliaan and Stirling 1978, p. 199; Smith 1980, p. 2,206; Smith 1985, pp. 72–73; Lowry et al. 1987, p. 141; Calvert and Stirling 1990, p. 352; Smith and Sjare 1990, p. 99). In some areas and under some conditions, prey other than seals or carrion may be quite important to polar bear sustenance as short-term supplemental forms of nutrition. Stirling and Øritsland (1995, p. 2,609) suggested that in areas where ringed seal populations were reduced, other prey species were being substituted. Like other ursids, polar bears will eat human garbage (Lunn and Stirling 1985, p. 2,295), and when confined to land for long periods, they will consume coastal marine and terrestrial plants and other terrestrial foods (Russell 1975, p. 122; Derocher et al. 1993, p. 252); however the significance of such other terrestrial foods to the long-term welfare of polar bears may be limited (Lunn and Stirling 1985, p. 2,296; Ramsay and Hobson 1991, p. 600; Derocher et al. 2004, p. 169) as further expanded under the section entitled ''Adaptation'' below.

Reproduction

Polar bears are characterized by late sexual maturity, small litter sizes, and extended parental investment in raising young, all factors that contribute to a low reproductive rate (Amstrup 2003, pp. 599–600). Reproduction in the female polar bear is similar to that in other ursids. Females generally mature and breed for the first time at 4 or 5 years and give birth at 5 or 6 years of age. Litters of two cubs are most common, but litters of three cubs are seen sporadically across the Arctic (Amstrup 2003, p. 599). When foraging conditions are difficult, polar bears may ''defer'' reproduction in favor of survival (Derocher et al. 1992, p. 564).

Polar bears enter a prolonged estrus between March and June, when breeding occurs. Ovulation is induced by mating (Wimsatt 1963, p. 72), and implantation is delayed until autumn. The total gestation period is 195 to 265 days (Uspenski 1977, cited in Amstrup 2003, p. 599), although active development of the fetus is suspended during most of this period. The timing of implantation, and therefore the timing of birth, is likely dependent on body condition of the female, which depends on a variety of environmental factors. Pregnant females that spend the late summer on land prior to denning may not feed for 8 months (Watts and Hansen 1987, p. 627). This may be the longest period of food deprivation of any mammal, and it occurs at a time when the female gives birth to and then nourishes new cubs.

Newborn polar bears are helpless and have hair, but are blind and weigh only 0.6 kg (1.3 lb) (Blix and Lentfer 1979, p. 68). Cubs grow rapidly, and may weigh 10 to 12 kg (22 to 26 lbs) by the time they emerge from the den in the spring. Young bears will stay with their mothers until weaning, which occurs most commonly in early spring when the cubs are 2.3 years of age. Female polar bears are available to breed again after their cubs are weaned; thus the reproductive interval for polar bears is 3 years.

Polar bears are long-lived mammals not generally susceptible to disease, parasites, or injury. The oldest known female in the wild was 32 years of age and the oldest known male was 28, though few polar bears in the wild live to be older than 20 years (Stirling 1988, p. 139; Stirling 1990, p. 225). Due to extremely low reproductive rates, polar bears require a high survival rate to maintain population levels (Eberhardt 1985, p. 1,010; Amstrup and Durner 1995, pp. 1,313, 1,319). Survival rates increase up to a certain age, with cubs-of-the-year having the lowest rates and prime age adults (between 5 and 20 years of age) having survival rates that can exceed 90 percent. Amstrup and Durner (1995, p. 1,319) report that high survival rates (exceeding 90 percent for adult females) are essential to sustain populations.

Polar Bear—Sea Ice Habitat Relationships

Polar bears are distributed throughout the ice-covered waters of the circumpolar Arctic (Stirling 1988, p. 61), and rely on sea ice as their primary habitat (Amstrup 2003, p. 587). Polar bears depend on sea ice for a number of purposes, including as a platform from which to hunt and feed upon seals; as habitat on which to seek mates and breed; as a platform to move to terrestrial maternity denning areas, and sometimes for maternity denning; and as a substrate on which to make long-distance movements (Stirling and Derocher 1993, p. 241). Mauritzen et al. (2003b, p. 123) indicated that habitat use by polar bears during certain seasons may involve a trade-off between selecting habitats with abundant prey availability versus the use of safer retreat habitats (i.e., habitats where polar bears have lower probability of becoming separated from the main body of the pack ice) of higher ice concentrations with less prey. Their findings indicate that polar bear distribution may not be solely a reflection of prey availability, but other factors such as energetic costs or risk may be involved.

Stirling et al. (1993, p. 15) defined seven types of sea ice habitat and classified polar bear use of these ice types based on the presence of bears or bear tracks in order to determine habitat preferences. The seven types of sea ice are: (1) stable fast ice with drifts; (2) stable fast ice without drifts; (3) floe edge ice; (4) moving ice; (5) continuous stable pressure ridges; (6) coastal low level pressure ridges; and (7) fiords and bays. Polar bears were not evenly distributed over these sea ice habitats, but concentrated on the floe ice edge, on stable fast ice with drifts, and on areas of moving ice (Stirling 1990 p. 226; Stirling et al. 1993, p. 18). In another assessment, categories of ice types included pack ice, shore-fast ice, transition zone ice, polynyas, and leads (linear openings or cracks in the ice) (USFWS 1995, p. 9). Pack ice, which consists of annual and multi-year older ice in constant motion due to winds and currents, is the primary summer habitat for polar bears in Alaska. Shore-fast ice (also known as ''fast ice'', it is defined by the *Arctic Climate Impact Assessment* (2005, p. 190) as ice that grows seaward from a coast and remains in place throughout the winter; typically it is stabilized by grounded pressure ridges at its outer edge) is used for feeding on seal pups, for movement, and occasionally for maternity denning. Open water at leads and polynyas attracts seals and other marine mammals and provides preferred hunting habitats during winter and spring. Durner et al. (2004, pp. 18–19; Durner et al. 2007, pp. 17–18) found that polar bears in the Arctic basin prefer sea ice concentrations greater than 50 percent located over the continental shelf with water depths less than 300 m (984 feet (ft)).

Polar bears must move throughout the year to adjust to the changing distribution of sea ice and seals (Stirling 1988, p. 63; USFWS 1995, p. 4). In some areas, such as Hudson Bay and James Bay, polar bears remain on land when the sea ice retreats in the spring and they fast for several months (up to 8 months for pregnant females) before fall freeze-up (Stirling 1988, p. 63; Derocher et al. 2004, p. 163; Amstrup et al. 2007, p. 4). Some populations unconstrained by land masses, such as those in the Barents, Chukchi, and Beaufort Seas, spend each summer on the multi-year ice of the polar basin (Derocher et al. 2004, p. 163; Amstrup et al. 2007, p. 4). In intermediate areas such as the Canadian Arctic, Svalbard, and Franz Josef Land archipelagos, bears stay on the sea ice most of the time, but in some years they may spend up to a few months on land (Mauritizen et al. 2001, p. 1,710). Most populations use terrestrial habitat partially or exclusively for maternity denning; therefore, females must adjust their movements in order to access land at the appropriate time (Stirling 1988, p. 64; Derocher et al. 2004, p. 166).

Sea ice changes between years in response to environmental factors may have consequences for the distribution and productivity of polar bears as well as their prey. In the southern Beaufort Sea, anomalous heavy sea ice conditions in the mid-1970s and mid-1980s (thought to be roughly in phase with a similar variation in runoff from the Mackenzie River) caused significant declines in productivity of ringed seals (Stirling 2002, p. 68). Each event lasted approximately 3 years and caused similar declines in the birth rate of polar bears and survival of subadults, after which reproductive success and survival of both species increased again.

Maternal Denning Habitat

Throughout the species' range, most pregnant female polar bears excavate dens in snow located on land in the fall-early winter period (Harington 1968, p. 6; Lentfer and Hensel 1980, p. 102; Ramsay and Stirling 1990, p. 233; Amstrup and Gardner 1994, p. 5). The only known exceptions are in western and southern Hudson Bay, where polar bears first excavate earthen dens and later reposition into adjacent snow drifts (Jonkel et al. 1972, p. 146; Ramsay and Stirling 1990, p. 233), and in the southern Beaufort Sea, where a portion of the population dens in snow caves located on pack and shore-fast ice. Successful denning by polar bears requires accumulation of sufficient snow for den construction and maintenance. Adequate and timely snowfall combined with winds that cause snow accumulation leeward of topographic features create denning habitat (Harington 1968, p. 12).

A great amount of polar bear denning occurs in core areas (Harington 1968, pp. 7–8), which show high use over time (see Figure 8). In some portions of the species' range, polar bears den in a more diffuse pattern, with dens scattered over larger areas at lower density (Lentfer and Hensel 1980, p. 102; Stirling and Andriashek 1992, p. 363; Amstrup 1993, p. 247; Amstrup and Gardner 1994, p. 5; Messier et al. 1994, p. 425; Born 1995, p. 81; Ferguson et al. 2000a, p. 1125; Durner et al. 2001, p. 117; Durner et al. 2003, p. 57).

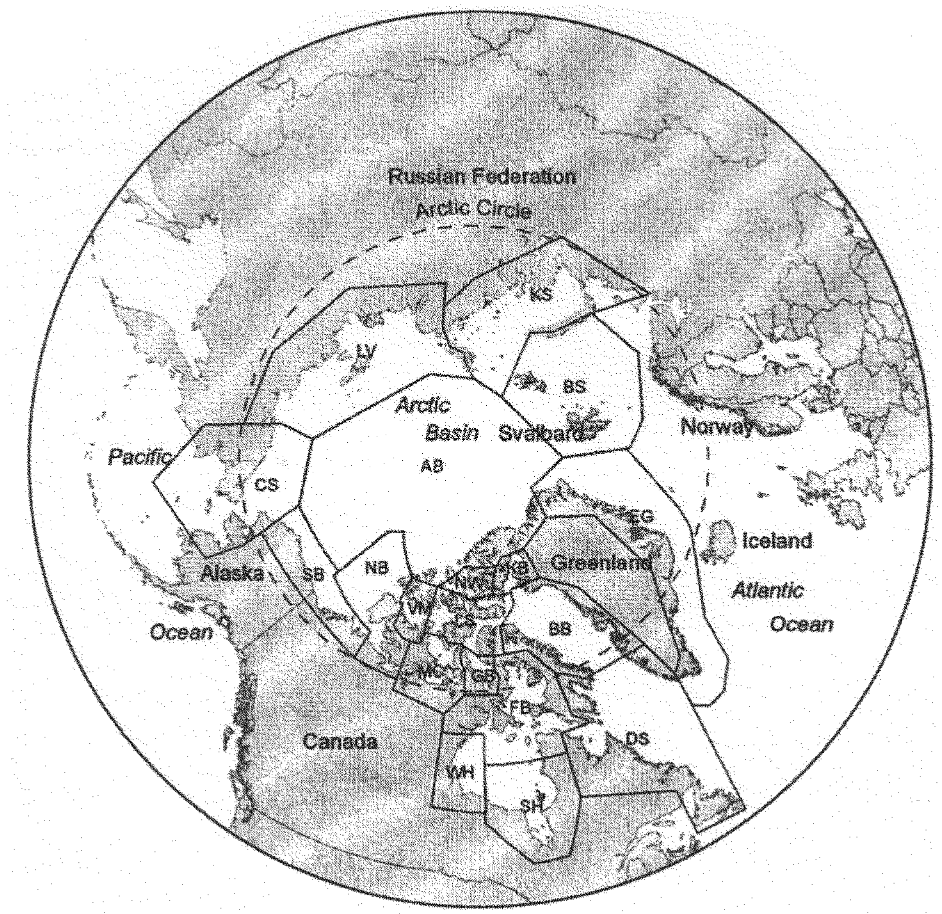
Habitat characteristics of denning areas vary substantially from the rugged mountains and fjordlands of the Svalbard archipelago and the large islands north of the Russian coast (Lønø 1970, p. 77; Uspenski and Kistchinski 1972, p. 182; Larsen 1985, pp. 321–322), to the relatively flat topography of areas such as the west coast of Hudson Bay (Ramsay and Andriashek 1986, p. 9; Ramsay and Stirling 1990, p. 233) and north slope of Alaska (Amstrup 1993, p. 247; Amstrup and Gardner 1994, p. 7; Durner et al. 2001, p. 119; Durner et al. 2003, p. 61), to offshore pack ice-pressure ridge habitat (Amstrup and Gardner 1994, p. 4; Fischbach et al. 2007, p. 1,400). The key characteristic of all denning habitat is topographic features that catch snow in the autumn and early winter (Durner et al. 2003, p. 61). Across the range, most polar bear dens occur relatively near the coast. The main exception to coastal denning occurs in the western Hudson Bay area, where bears den farther inland in traditional denning areas (Kolenosky and Prevett 1983, pp. 243–244; Stirling and Ramsay 1986, p. 349).

Current Population Status and Trend

The total number of polar bears worldwide is estimated to be 20,000–25,000 (Aars et al. 2006, p. 33). Polar bears are not evenly distributed throughout the Arctic, nor do they comprise a single nomadic cosmopolitan population, but rather occur in 19 relatively discrete populations (Aars et al. 2006, p. 33). The use of the term ''relatively discrete population'' in this context is not intended to equate to the Act's term ''distinct population segments'' (Figure 1). Boundaries of the 19 polar bear populations have evolved over time and are based on intensive study of movement patterns, tag returns from harvested animals, and, to a lesser degree, genetic analysis (Aars et al. 2006, pp. 33–47). The scientific studies regarding population bounds began in the early 1970s and continue today. Within this final rule we have adopted the use of the term ''population'' to describe polar bear management units consistent with their designation by the World Conservation Union-International Union for Conservation of Nature and Natural Resources (IUCN), Species Survival Commission (SSC) Polar Bear Specialist Group (PBSG) with information available as of October 2006 (Aars et al. 2006, p. 33), and to describe a combination of two or more of these populations into ''ecoregions,'' as discussed in following sections. Although movements of individual polar bears overlap extensively, telemetry studies demonstrate spatial segregation among groups or stocks of polar bears in different regions of their circumpolar range (Schweinsburg and Lee 1982, p. 509; Amstrup et al. 1986, p. 252; Amstrup et al., 2000b, pp. 957–958.; Garner et al. 1990, p. 224; Garner et al. 1994, pp.112–115; Amstrup and Gardner 1994, p. 7; Ferguson et al. 1999, pp. 313–314; Lunn et al. 2002, p. 41). These patterns, along with information obtained from survey and reconnaissance, marking and tagging studies, and traditional knowledge, have resulted in recognition of 19 relatively discrete polar bear populations (Aars et al. 2006, p. 33). Genetic analysis reinforces the boundaries between some designated populations (Paetkau et al. 1999, p. 1,571; Amstrup 2003, p. 590) while confirming the existence of overlap and mixing among others (Paetkau et al. 1999, p. 1,571; Cronin et al. 2006, p. 655). There is considerable overlap in areas occupied by members of these groups (Amstrup et al. 2004, p. 676; Amstrup et al. 2005, p. 252), and boundaries separating the groups are adjusted as new data are collected. These boundaries, however, are thought to be ecologically meaningful, and the 19 units they describe are managed as populations, with the exception of the Arctic Basin population where few bears are believed to be year-round residents.

Figure 1. Distribution of Polar Bear Populations

Throughout the Arctic Circumpolar Basin



Legend: CS = Chukchi Sea; SB = Southern Beaufort Sea; NB = Northern Beaufort Sea; VM = Viscount Melville Sound, NW = Norwegian Bay; LS = Lancaster Sound; MC = M'Clintock Channel; GB = Gulf of Boothia; FB = Foxe Basin; WH = Western Hudson Bay; SH = Southern Hudson Bay; KB = Kane Basin; BB = Baffin Bay; DS = Davis Strait; EG = East Greenland; BS = Barents Sea; KS = Kara Sea; LV = Laptev Sea; AB = Arctic Basin

Population size estimates and qualitative categories of current trend and status for each of the 19 polar bear populations are discussed below. This discussion was derived from information presented at the IUCN/SSC PBSG meeting held in Seattle, Washington, in June 2005, and updated with results that became available in October 2006 (Aars et al. 2006, p. 33). The following narrative incorporates results from two recent publications (Stirling et al. 2007; Obbard et al. 2007). The remainder of the information on each population is based on the available status reports and revisions given by each nation, as reported in Aars et al. (2006).

Status categories include an assessment of whether a population is believed to be not reduced, reduced, or severely reduced from historic levels of abundance, or if insufficient data are available to estimate status. Trend categories include an assessment of whether the population is currently increasing, stable, or declining, or if insufficient data are available to estimate trend. In general, an assessment of trend requires a monitoring program or data to allow population size to be estimated at more than one point in time. Information on the date of the current population estimate and information on previous population estimates and the basis for those estimates is detailed in Aars et al. (2006, pp. 34–35). In some instances a subjective assessment of trend has been provided in the absence of either a monitoring program or estimates of population size developed for more than one point in time. This status and trend analysis only reflects information about the past and present polar bear populations. Later in this final rule a discussion will be presented about the scientific information on threats that will affect the species within the foreseeable future. The Act establishes a five-factor analysis for using this information in making listing decisions.

Populations are discussed in a counterclockwise order from Figure 1, beginning with East Greenland. There is no population size estimate for the East Greenland polar bear population because no population surveys have been conducted there. Thus, the status and trend of this population have not been determined. The Barents Sea population was estimated to comprise 3,000 animals based on the only population survey conducted in 2004. Because only one abundance estimate is available, the status and trend of this population cannot yet be determined. There is no population size estimate for the Kara Sea population because population surveys have not been conducted; thus status and trend of this population cannot yet be determined. The Laptev Sea population was estimated to comprise 800 to 1,200 animals, on the basis of an extrapolation of historical aerial den survey data (1993). Status and trend cannot yet be determined for this population.

The Chukchi Sea population is estimated to comprise 2,000 animals, based on extrapolation of aerial den surveys (2002). Status and trend cannot yet be determined for this population. The Southern Beaufort Sea population is comprised of 1,500 animals, based on a recent population inventory (2006). The predicted trend is declining (Aars et al. 2006, p.33), and the status is designated as reduced. The Northern Beaufort Sea population was estimated to number 1,200 animals (1986). The trend is designated as stable, and status is believed to be not reduced. Stirling et al. (2007, pp. 12–14) estimated long-term trends in population size for the Northern Beaufort Sea population. The model-averaged estimate of population size from 2004 to 2006 was 980 bears, and did not differ in a statistically significantly way from estimates for the periods of 1972 to 1975 (745 bears) and 1985 to 1987 (867 bears), and thus the trend is stable. Stirling et al. (2007, p. 13) indicated that, based on a number of indications and separate annual abundance estimates for the study period, the population estimate may be slightly biased low (i.e., might be an underestimate) due to sampling issues.

The Viscount Melville Sound population was estimated to number 215 animals (1992). The observed or predicted trend based on management action is listed as increasing (Aars et al. 2006, p. 33), although the status is designated as severely reduced from prior excessive harvest. The Norwegian Bay population estimate was 190 animals (1998); the trend, based on computer simulations, is noted as declining, while the status is listed as not reduced. The Lancaster Sound population estimate was 2,541 animals (1998); the trend is thought to be stable, and status is not reduced. The M'Clintock Channel population is estimated at 284 animals (2000); the observed or predicted trend based on management actions is listed as increasing although the status is severely reduced from excessive harvest. The Gulf of Boothia population estimate is 1,523 animals (2000); the trend is thought to be stable, and status is designated as not reduced. The Foxe Basin population was estimated to number 2,197 animals in 1994; the population trend is thought to be stable, and the status is not reduced. The Western Hudson Bay population estimate is 935 animals (2004); the trend is declining, and the status is reduced. The Southern Hudson Bay population was estimated to be 1,000 animals in 1988 (Aars et al. 2006, p. 35); the trend is thought to be stable, and status is not reduced. In a more recent analysis, Obbard et al. (2007) applied open population capture-recapture models to data collected from 1984–86 and 1999–2005 to estimate population size, trend, and survival for the Southern Hudson Bay population. Their results indicate that the size of the Southern Hudson Bay population appears to be unchanged from the mid-1980s. From 1984–1986, the population was estimated at 641 bears; from 2003–2005, the population was estimated at 681 bears. Thus, the trend for this population is stable. The Kane Basin population was estimated to be comprised of 164 animals (1998); its trend is declining, and status is reduced. The Baffin Bay population was estimated to be 2,074 animals (1998); the trend is declining, and status is reduced. The Davis Strait population was estimated to number 1,650 animals based on traditional ecological knowledge (TEK) (2004); data were unavailable to assess trends or status. Preliminary information from the second of a 3-year population assessment estimates the population number to be 2,375 bears (Peacock et al. 2007, p. 7). The Arctic Basin population estimate, trend, and status are unknown (Aars et al. 2006, p. 35).

On the basis of information presented above, two polar bear populations are designated as increasing (Viscount Melville Sound and M'Clintock Channel-both were severely reduced in the past and are recovering under conservative harvest limits); six populations are stable (Northern Beaufort Sea, Southern Hudson Bay, Davis Strait, Lancaster Sound, Gulf of Bothia, Foxe Basin); five populations are declining (Southern Beaufort Sea, Norwegian Bay, Western Hudson Bay, Kane Basin, Baffin Bay); and six populations are designated as data deficient (Barents Sea, Kara Sea, Laptev Sea, Chukchi Sea, Arctic Basin, East Greenland) with no estimate of trend. The two populations with the most extensive time series of data, Western Hudson Bay and Southern Beaufort Sea, are both considered to be declining.

As previously noted, scientific information assessing this species in the foreseeable future is provided later in this final rule.

Polar Bear Ecoregions

Amstrup et al. (2007, pp. 6–8) grouped the 19 IUCN-recognized polar bear populations (Aars et al. 2006, p. 33) into four physiographically different functional groups or ''ecoregions'' (Figure 2) in order to forecast future polar bear population status on the basis of current knowledge of polar bear populations, their relationships to sea ice habitat, and predicted changes in sea ice and other environmental variables. Amstrup et al. (2007, p. 7) defined the ecoregions ''on the basis of observed temporal and spatial patterns of ice formation and ablation (melting or evaporation), observations of how polar bears respond to those patterns, and how general circulation models (GCMs) forecast future ice patterns.''

The *Seasonal Ice Ecoregion* includes the Western and Southern Hudson Bay populations, as well as the Foxe Basin, Baffin Bay, and Davis Strait populations. These 5 IUCN-recognized populations are thought to include a total of about 7,200 polar bears (Aars et al. 2006, p. 34–35). The 5 populations experience sea ice that melts entirely in summer, and bears spend extended periods of time on shore.

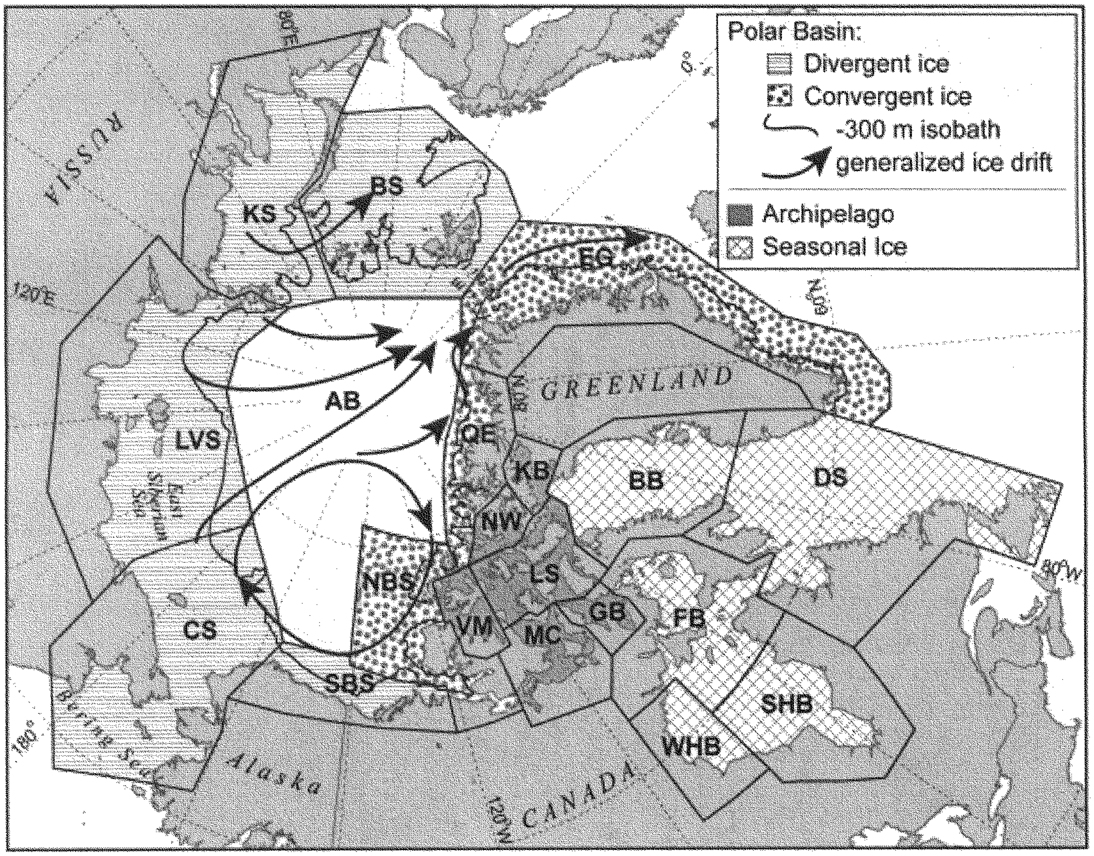


Figure 2. Map of four polar bear ecoregions in Amstrup et al. (2007)(used with permission).

The *Archipelago Ecoregion,* islands and channels of the Canadian Arctic, has approximately 5,000 polar bears representing 6 populations recognized by the IUCN (Aars et al. 2006, p. 34–35). These populations are Kane Basin, Norwegian Bay, Viscount Melville Sound, Lancaster Sound, M'Clintock Channel, and the Gulf of Boothia. Much of this region is characterized by heavy annual and multi-year ice that fills the inter-island channels year round and polar bears remain on the sea ice throughout the year.

The polar basin was split into a *Convergent Ecoregion* and a *Divergent Ecoregion,* based upon the different patterns of sea ice formation, loss (via melt and transport) (Rigor et al. 2002, p. 2,658; Rigor and Wallace 2004, p. 4; Maslanik et al. 2007, pp. 1–3; Meier et al. 2007, pp. 428–434; Ogi and Wallace 2007, pp. 2–3).

The *Divergent Ecoregion* is characterized by extensive formation of annual sea ice that is transported toward the Canadian Arctic islands and Greenland, or out of the polar basin through Fram Strait. The Divergent ecoregion includes the Southern Beaufort, Chukchi, Laptev, Kara, and Barents Seas populations, and is thought to contain up to 9,500 polar bears. In the Divergent Ecoregion, as in the Archipelago Ecoregion, polar bears mainly stay on the sea ice year-round.

The *Convergent Ecoregion,* composed of the Northern Beaufort Sea, Queen Elizabeth Islands (see below), and East Greenland populations, is thought to contain approximately 2,200 polar bears. Amstrup et al. (2007, p. 7) modified the IUCN-recognized population boundaries (Aars et al. 2006, pp. 33,36) of this ecoregion by redefining a Queen Elizabeth Islands population and extending the original boundary of that population to include northwestern Greenland (see Figure 2). The area contained within this boundary is characterized by heavy multi-year ice, except for a recurring lead system that runs along the Queen Elizabeth Islands from the northeastern Beaufort Sea to northern Greenland (Stirling 1980, pp. 307–308). The area may contain over 200 polar bears and some bears from other regions have been recorded moving through the area (Durner and Amstrup 1995, p. 339; Lunn et al. 1995, pp. 12–13). The Northern Beaufort Sea and Queen Elizabeth Islands populations occur in a region of the polar basin that accumulates ice (hence, the Convergent Ecoregion) as it is moved from the polar basin Divergent Ecoregion, while the East Greenland population occurs in area where ice is transported out of the polar basin through the Fram Strait (Comiso 2002, pp. 17–18; Rigor and Wallace 2004, p. 3; Belchansky et al. 2005, pp. 1–2; Holland et al. 2006, pp. 1–5; Durner et al. 2007, p. 3; Ogi and Wallace 2007, p. 2; Serreze et al. 2007, pp. 1,533–1536).

Amstrup et al. (2007) do not incorporate the central Arctic Basin population into an ecoregion. This population was defined by the IUCN in 2001 (Lunn et al. 2002, p.29) to recognize polar bears that may reside outside the territorial jurisdictions of the polar nations. The Arctic Basin region is characterized by very deep water, which is known to be unproductive (Pomeroy 1997, pp. 6–7). Available data indicate that polar bears prefer sea ice over shallow water (less then 300 m (984 ft) deep) (Amstrup et al. 2000b, p. 962; Amstrup et al. 2004, p. 675; Durner et al. 2007, pp. 18–19), and it is thought that this preference reflects increased hunting opportunities over more productive waters. Also, tracking studies indicate that few if any bears are year-round residents of the central Arctic Basin, and therefore this relatively unpopulated portion of the Arctic was not designated as an ecoregion.

Sea Ice Environment

As described in detail in the ''Species Biology'' section of this rule, above, polar bears are evolutionarily adapted to life on sea ice (Stirling 1988, p. 24; Amstrup 2003, p. 587). They need sea ice as a platform for hunting, for seasonal movements, for travel to terrestrial denning areas, for resting, and for mating (Stirling and Derocher 1993, p. 241). Moore and Huntington (in press) classify the polar bear as an ''ice-obligate'' species because of its reliance on sea ice as a platform for resting, breeding, and hunting, while Laidre et al. (in press) similarly describe the polar bear as a species that principally relies on annual sea ice over the continental shelf and areas toward the southern edge of sea ice for foraging. Some polar bears use terrestrial habitats seasonally (e.g., for denning or for resting during open water periods). Open water is not considered to be an essential habitat type for polar bears, because life functions such as feeding, reproduction, or resting do not occur in open water. However, open water is a fundamental part of the marine system that supports seal species, the principal prey of polar bears, and seasonally refreezes to form the ice needed by the bears (see ''Open Water Habitat'' section for more information). Further, the open water interface with sea ice is an important habitat used to a great extent by polar bears. In addition, the extent of open water is important because vast areas of open water may limit a bear's ability to access sea ice or land (see ''Open Water Swimming'' section for more detail). Snow cover, both on land and on sea ice, is an important component of polar bear habitat in that it provides insulation and cover for young polar bears and ringed seals in snow dens or lairs (see ''Maternal Denning Habitat'' section for more detail).

Sea Ice Habitat

Overview of Arctic Sea Ice

According to the *Arctic Climate Impact Assessment* (ACIA 2005), approximately two-thirds of the Arctic is ocean, including the Arctic Ocean and its shelf seas plus the Nordic, Labrador, and Bering Seas (ACIA 2005, p. 454). Sea ice is the defining characteristic of the marine Arctic (ACIA 2005, p. 30). The Arctic sea ice environment is highly dynamic and follows annual patterns of expansion and contraction. Sea ice is typically at its maximum extent (the term ''extent'' is formally defined in the ''Observed Changes in Arctic Sea Ice'' section) in March and at its minimum extent in September (Parkinson et al. 1999, p. 20,840). The two primary forms of sea ice are seasonal (or first year) ice and perennial (or multi-year) ice (ACIA 2005, p. 30). Seasonal ice is in its first autumn/winter of growth or first spring/summer of melt (ACIA 2005, p. 30). It has been documented to vary in thickness from a few tenths of a meter near the southern margin of the sea ice to 2.5 m (8.2 ft) in the high Arctic at the end of winter (ACIA 2005, p. 30), with some ice also that is thinner and some limited amount of ice that can be much thicker, especially in areas with ridging (C. Parkinson, NASA, in litt. to the Service, November 2007). If first-year ice survives the summer melt, it becomes multi-year ice. This ice tends to develop a distinctive hummocky appearance through thermal weathering, becoming harder and almost salt-free over several years (ACIA 2005, p. 30). Sea ice near the shore thickens in shallow waters during the winter, and portions become grounded. Such ice is known as shore-fast ice, land-fast ice, or simply fast ice (ACIA 2005, p. 30). Fast ice is found along much of the Siberian coast, the White Sea (an inlet of the Barents Sea), north of Greenland, the Canadian Archipelago, Hudson Bay, and north of Alaska (ACIA 2005, p. 457).

Pack ice consists of seasonal (or first-year) and multi-year ice that is in constant motion caused by winds and currents (USFWS 1995, pp. 7–9). Pack ice is used by polar bears for traveling, feeding, and denning, and it is the primary summer habitat for polar bears, including the Southern Beaufort Sea and Chukchi Sea populations, as first year ice retreats and melts with the onset of spring (see ''Polar Bear-Sea Ice Habitat Relationships'' section for more detail on ice types used by polar bears). Movements of sea ice are related to winds, currents, and seasonal temperature fluctuations that in turn promote its formation and degradation. Ice flow in the Arctic often includes a clockwise circulation of sea ice within the Canada Basin and a transpolar drift stream that carries sea ice from the Siberian shelves to the Barents Sea and Fram Strait.

Sea ice is an important component of the Arctic climate system (ACIA 2005, p. 456). It is an effective insulator between the oceans and the atmosphere. It also strongly reduces the ocean-atmosphere heat exchange and reduces wind stirring of the ocean. In contrast to the dark ocean, pond-free sea ice (i.e., sea ice that has no meltwater ponds on the surface) reflects most of the solar radiation back into space. Together with snow cover, sea ice greatly restricts the penetration of light into the sea, and it also provides a surface for particle and snow deposition (ACIA 2005, p. 456). Its effects can extend far south of the Arctic, perhaps globally, e.g., through impacting deepwater formation that influences global ocean circulation (ACIA 2005, p. 32).

Sea ice is also an important environmental factor in Arctic marine ecosystems. ''Several physical factors combine to make arctic marine systems unique including: a very high proportion of continental shelves and shallow water; a dramatic seasonality and overall low level of sunlight; extremely low water temperatures; presence of extensive areas of multi-year and seasonal sea-ice cover; and a strong influence from freshwater, coming from rivers and ice melt'' (ACIA 2005, p. 454). Ice cover is an important physical characteristic, affecting heat exchange between water and atmosphere, and light penetration to organisms in the water below. It also helps determine the depth of the mixed layer, and provides a biological habitat above, within, and beneath the ice. The marginal ice zone, at the edge of the pack ice, is important for plankton production and plankton-feeding fish (ACIA 2005, p. 456)

Observed Changes in Arctic Sea Ice

Sea ice is the defining physical characteristic of the marine Arctic environment and has a strong seasonal cycle (ACIA 2005, p. 30). There is considerable inter-annual variability both in the maximum and minimum extent of sea ice, but it is typically at its maximum extent in March and minimum extent in September (Parkinson et al. 1999, p. 20, 840). In addition, there are decadal and inter-decadal fluctuations to sea ice extent due to changes in atmospheric pressure patterns and their associated winds, river runoff, and influx of Atlantic and Pacific waters (Gloersen 1995, p. 505; Mysak and Manak 1989, p. 402; Kwok 2000, p. 776; Parkinson 2000b, p. 10; Polyakov et al. 2003, p. 2,080; Rigor et al. 2002, p. 2,660; Zakharov 1994, p. 42). Sea ice ''extent'' is normally defined as the area of the ocean with at least 15 percent ice coverage, and sea ice ''area'' is normally defined as the integral sum of areas actually covered by sea ice

(Parkinson et al. 1999). ''Area'' is a more precise measure of the areal extent of the ice itself, since it takes into account the fraction of leads (linear openings or cracks in the ice) within the ice, but ''extent'' is more reliably observed (Zhang and Walsh 2006). The following sections discuss specific aspects of observed sea ice changes of relevance to polar bears.

Summer Sea Ice

Summer sea ice area and sea ice extent are important factors for polar bear survival (see ''Polar Bear-Sea Ice Habitat Relationships'' section). Seasonal or first-year ice that remains at the end of the summer melt becomes multi-year (or perennial) ice. The amount and thickness of perennial ice is an important determinant of future sea ice conditions (i.e., gain or loss of ice) (Holland and Bitz 2003; Bitz and Roe 2004). Much of the following discussion focuses on summer sea ice extent (rather than area).

Prior to the early 1970s, ice extent was measured with visible-band satellite imagery and aircraft and ship reports. With the advent of passive microwave (PM) satellite observations, beginning in December 1972 with a single channel instrument and then more reliably in October 1978 with a multi-channel instrument, we have a more accurate, 3-decade record of changes in summer sea ice extent and area. Over the period since October 1978, successive papers have documented an overall downward trend in Arctic sea ice extent and area. For example, Parkinson et al. (1999) calculated Arctic sea ice extents, areas, and trends for late 1978 through the end of 1996, and documented a decrease in summer sea ice extent of 4.5 percent per decade. Comiso (2002) documented a decline of September minimum sea ice extent of 6.7 percent plus or minus 2.4 percent per decade from 1981 through 2000. Stroeve et al. (2005) analyzed data from 1978 through 2004, and calculated a decline in minimum sea ice extent of 7.7 percent plus or minus 3 percent per decade. Comiso (2006, p. 72) included observations for 2005, and calculated a per-decade decline in minimum sea ice extent of up to 9.8 percent plus or minus 1.5 percent. Most recently, Stroeve et al. (2007, pp. 1–5) estimated a 9.1 percent per-decade decline in September sea ice extent for 1979–2006, while Serreze et al. (2007, pp. 1,533–1,536) calculated a per-decade decline of 8.6 percent plus or minus 2.9 percent for the same parameter over the same time period. These estimates differ only because Serreze et al. (2007, pp. 1,533–1,536) normalized the trend by the 1979–2000 mean, in order to be consistent with how the National Snow and Ice Data Center [1] calculates its estimates (J. Stroeve, in litt. to the Service, November 2007). This decline translates to a decrease of 60,421 sq km (23,328 sq mi) per year (NSIDC Press Release, October 3, 2006).

The rate of decrease in September sea ice extent appears to have accelerated in recent years, although the acceleration to date has not been shown to be statistically significant (C. Bitz, in litt. to the Service, November 2007). The years 2002 through 2007 all exceeded previous record lows (Stroeve et al. 2005; Comiso 2006; Stroeve et al. 2007, pp. 1–5; Serreze et al. 2007, pp. 1,533–1,536; NSIDC Press Release, October 1, 2007), and 2002, 2005, and 2007 had successively lower record-breaking minimum extent values (*http://www.nsidc.org*). The 2005 absolute minimum sea ice extent of 5.32 million sq km (2.05 million sq mi) for the entire Arctic Ocean was a 21 percent reduction compared to the mean for 1979 to 2000 (Serreze et al. 2007, pp. 1,533–1,536). Nghiem et al. (2006) documented an almost 50 percent reduction in perennial (multi-year) sea ice extent in the East Arctic Ocean (0 to 180 degrees east longitude) between 2004 and 2005, while the West Arctic Ocean (0 and 180 degrees west longitude) had a slight gain during the same period, followed by an almost 70 percent decline from October 2005 to April 2006. Nghiem et al. (2007) found that the extent of perennial sea ice was significantly reduced by 23 percent between March 2005 and March 2007 as observed by the QuikSCAT/SeaWinds satellite scatterometer. Nghiem et al. (2006) presaged the extensive decline in September sea ice extent in 2007 when they stated: ''With the East Arctic Ocean dominated by seasonal ice, a strong summer melt may open a vast ice-free region with a possible record minimum ice extent largely confined to the West Arctic Ocean.''

Arctic sea ice declined rapidly to unprecedented low extents in summer 2007 (Stroeve et al. 2008). On August 16–17, 2007, Arctic sea ice surpassed the previous single-day (absolute minimum) record for the lowest extent ever measured by satellite (set in 2005), and the sea ice was still melting (NSIDC Arctic Sea Ice News, August 17, 2007). On September 16, 2007 (the end of the melt season), the 5-day running mean sea ice extent reported by NSIDC was 4.13 million sq km (1.59 million sq mi), an all-time record low. This was 23 percent lower than the previous record minimum reported in 2005 (see Figure 3) (Stroeve et al. 2008) and 39 percent below the long-term average from 1979 to 2000 (see Figure 4) (NSIDC Press Release, October 1, 2007). Arctic sea ice receded so much in 2007 that the so-called ''Northwest Passage'' through the straits of the Canadian Arctic Archipelago completely opened for the first time in recorded history (NSIDC Press Release, October 1, 2007). Based on a time-series of data from the Hadley Centre, extending back before the advent of the PM satellite era, sea ice extent in mid-September 2007 may have fallen by as much as 50 percent from the 1950s to 1970s (Stroeve et al. 2008). The minimum September Arctic sea ice extent since 1979 is now declining at a rate of approximately 10.7 percent per decade (Stroeve et al. 2008), or approximately 72,000 sq km (28,000 sq mi) per year (see Figure 3 below) (NSIDC Press Release, October 1, 2007).

[1] The NSIDC is part of the University of Colorado Cooperative Institute for Research in Environmental Sciences (CIRES), is funded largely by the National Aeronautics and Space Administration (NASA), and is affiliated with the National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Center through a cooperative agreement. A large part of NSIDC is the Polar Distributed Active Archive Center, which is funded by NASA.

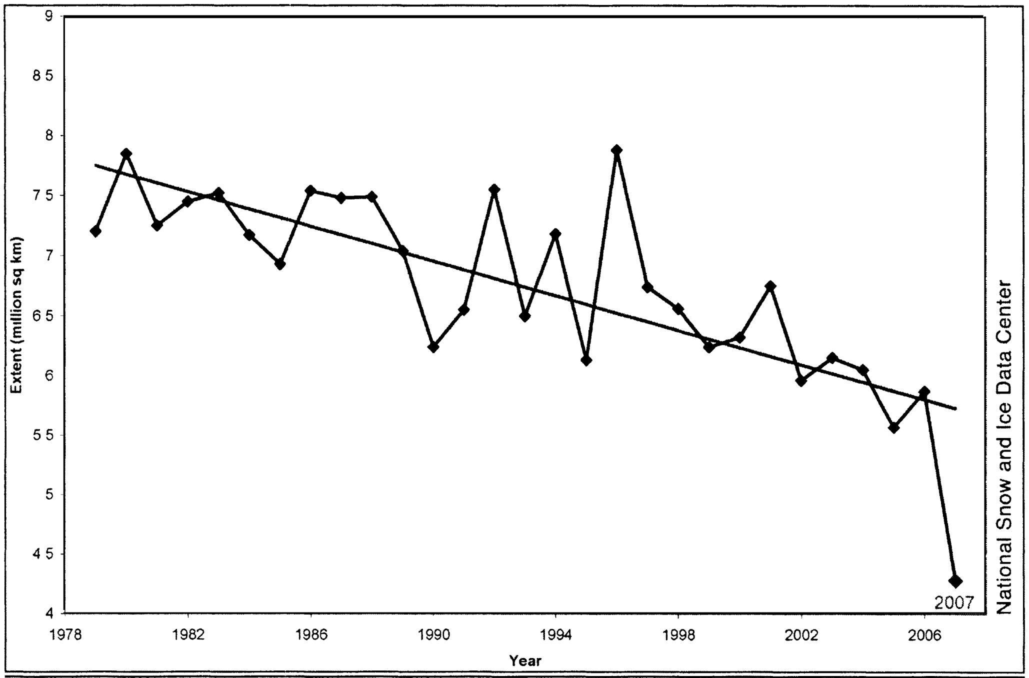


Figure 3. Trends in sea ice cover in the Arctic in September, 1978-2007 (NSIDC Press Release, October 1, 2007).

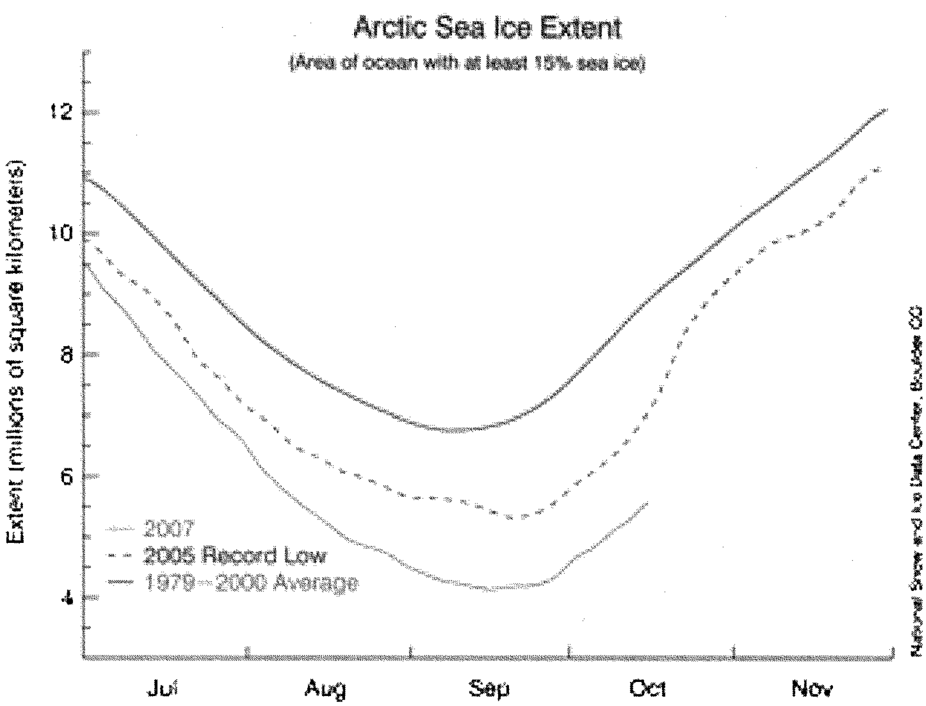


Figure 4. Time series plots showing 2007 minimum Arctic sea ice extent compared with other years. The times series for 2007 (bottom line) is far below the previous record year of 2005, shown as a dashed line. The 1979-2000 average is the top line (NSIDC Arctic Sea Ice News, October 17, 2007).

In August 2007, Arctic sea ice area (recall that ''area'' is a different metric than ''extent'' used in the preceding paragraphs) also broke the record for the minimum Arctic sea ice area in the period since the satellite PM record began in the 1970s (University of Illinois Polar Research Group 2007 web site; *http://arctic.atmos.uiuc.edu/cryosphere/*). The new record was set a full month before the historic summer minimum typically occurs, and the record minimum continued to decrease over the next several weeks (University of Illinois Polar Research Group 2007 web site). The Arctic sea ice area reached an historic minimum of 2.92 million sq km (1.13 million sq mi) on September 16, 2007, which was 27 percent lower than the previous (2005) record Arctic ice minimum area (University of Illinois Polar Research Group 2007 web site). In previous record sea ice minimum years, ice area anomalies were confined to certain sectors (North Atlantic, Beaufort/Bering Sea, etc.), but the character of the 2007 summer sea ice melt was unique in that it was both dramatic and covered the entire Arctic Basin. Atlantic, Pacific, and the central Arctic sectors all showed large negative sea ice area anomalies (University of Illinois Polar Research Group 2007 web site).

Two key factors contributed to the September 2007 extreme sea ice minimum: thinning of the pack ice in recent decades and an unusual pattern of atmospheric circulation (Stroeve et al. 2008). Spring 2007 started out with less ice and thinner ice than normal. Ice thickness estimates from the ICESat satellite laser altimeter instrument indicated ice thicknesses over the Arctic Basin in March 2007 of only 1 to 2 m (3.3 to 6.6 ft) (J. Stroeve, in litt. to the Service, November 2007). Thinner ice takes less energy to melt than thicker ice, so the stage was set for low levels of sea ice in summer 2007 (J. Stroeve, quoted in NSIDC Press Release, October 1, 2007). In general, older sea ice is thicker than younger ice. Maslanik et al. (2007) used an ice-tracking computer algorithm to estimate changes in the distribution of multi-year sea ice of various ages. They estimated: that the area of sea ice at least 5 years old decreased by 56 percent between 1985 and 2007; that ice at least 7 years old decreased from 21 percent of the ice cover in 1988 to 5 percent in 2007; and that sea ice at least 9 years old essentially disappeared from the central Arctic Basin. Maslanik et al. (2007) attributed thinning in recent decades to both ocean-atmospheric circulation patterns and warmer temperatures. Loss of older ice in the late 1980s to mid-1990s was accentuated by the positive phase of the Arctic Oscillation during that period, leading to increased ice export through the Fram Strait (Stroeve et al. 2008). Another significant change since the late 1990s has been the role of the Beaufort Gyre, ''the dominant wind and ice drift regime in the central Arctic'' (Maslanik et al. 2007). ''Since the late 1990s * * * ice typically has not survived the transit through the southern portion of the Beaufort Gyre,'' thus not allowing the ice to circulate in its formerly typical clockwise pattern for years while it aged and thickened (Maslanik et al. 2007). Temperature changes in the Arctic are discussed in detail in the section entitled ''Air and Sea Temperatures.''

Another factor that contributed to the sea ice loss in the summer of 2007 was an unusual atmospheric pattern, with persistent high atmospheric pressures over the central Arctic Ocean and lower pressures over Siberia (Stroeve et al. 2008). The skies were fairly clear under the high-pressure cell, promoting strong melt. At the same time, the pattern of winds pumped warm air into the region. While the warm winds fostered further melt, they also helped push ice away from the Siberian shore.

Winter Sea Ice

The maximum extent of Arctic winter sea ice cover, as documented with PM satellite data, has been declining at a lower rate than summer sea ice (Parkinson et al. 1999, p. 20,840; Richter-Menge et al. 2006, p. 16), but that rate appears to have accelerated in recent years. Parkinson and Cavalieri (2002, p. 441) reported that winter sea ice cover declined at a rate of 1.8 percent plus or minus 0.6 percent per decade for the period 1979 through 1999. More recently, Richter-Menge et al. (2006, p. 16) reported that March sea ice extent was declining at a rate of 2 percent per decade based on data from 1979–2005, Comiso (2006) calculated a decline of 1.9 plus or minus 0.5 percent per decade for 1979–2006, and J. Stroeve (in litt. to the Service, November 2007) calculated a decline of 2.5 percent per decade, also for 1979–2005.

In 2005 and 2006, winter maximum sea ice extent set record lows for the era of PM satellite monitoring (October 1978 to present). The 2005 record low winter maximum preceded the then-record low summer minimum during the same year, while winter sea ice extent in 2006 was even lower than that of 2005 (Comiso 2006). The winter 2007 Arctic sea ice maximum was the second-lowest in the satellite record, narrowly missing the March 2006 record (NSIDC Press Release, April 4, 2007). J. Stroeve (in litt. to the Service, November 2007) calculated a rate of decline of 3.0 plus or minus 0.8 percent per decade for 1979–2007.

Cumulative Annual Sea Ice

Parkinson et al. (1999) documented that Arctic sea ice extent for all seasons (i.e., annual sea ice extent) declined at a rate of 2.8 percent per decade for the period November 1978 through December 1996, with considerable regional variation (the greatest absolute declines were documented for the Kara and Barents Sea, followed by the Seas of Okhotsk and Japan, the Arctic Ocean, Greenland Sea, Hudson Bay, and Canadian Archipelago; percentage declines were greatest in the Seas of Okhotsk and Japan, at 20.1 percent per decade, and the Kara and Barents Seas, at 10.5 percent per decade). More recently, Comiso and Nishio (2008) utilized satellite data gathered from late 1978 into 2006, and estimated an annual rate decline of 3.4 percent plus or minus 0.2 percent per decade. They also found regions where higher negative trends were apparent, including the Greenland Sea (8.0 percent per decade), the Kara/Barents Seas (7.2 percent per decade), the Okhotsk Sea (8.7 percent per decade), and Baffin Bay/Labrador Sea (8.6 percent per decade). Comiso et al. (2008) included satellite data from 1979 through early September 2007 in their analyses. They found that the trend of the entire sea ice cover (seasonal and perennial sea ice) has accelerated from a decline of about 3 percent per decade in 1979–1996 to a decline of about 10 percent per decade in the last 10 years. Statistically significant negative trends in Arctic sea ice extent now occur n all calendar months (Serreze et al. 2007, pp. 1,533–1,536).

Sea Ice Thickness

Sea ice thickness is an important element of the Arctic climate system. The sea ice thickness distribution influences the sea ice mass budget and ice/ocean/atmosphere exchange (Holland et al. 2006a). Sea ice thickness has primarily been measured with upward-looking sonar on submarines and on moored buoys; this sonar provides information on ice draft, the component of the total ice thickness (about 90 percent) that projects below the water surface (Serreze et al. 2007, pp. 1,533–1,536). Rothrock et al. (1999, p. 3,469) compared sea-ice draft data acquired on submarine cruises between 1993 and 1997 with similar data acquired between 1958 and 1976, and concluded that the mean sea-ice draft at the end of the melt season (i.e., perennial or multi-year ice) had decreased by about 1.3 m (4.3 ft) in most of the deep water portion of the Arctic Ocean. One limitation of submarine sonar data is sparse sampling, which complicates interpretation of the results (Serreze et al. 2007, pp. 1,533–1,536). Holloway and Sou (2002) noted concerns regarding the temporal and spatial sampling of ice thickness data used in Rothrock et al. (1999), and concluded from their modeling exercise that ''a robust characterization over the half-century time series consists of increasing volume to the mid-1960s, decadal variability without significant trend from the mid-1960s to the mid-1980s, then a loss of volume from the mid-1980s to the mid-1990s.'' Rothrock et al. (2003, p. 28) conducted further analysis of the submarine-acquired data in conjunction with model simulations and review of other modeling studies, and concluded that all models agree that sea ice thickness decreased between 0.6 and 0.9 m (2 and 3 ft) from 1987 to 1996. Their model showed a modest recovery in thickness from 1996 to 1999. Yu et al. (2004, p. 11) further analyzed submarine sonar data and concluded that total ice volume decreased by 32 percent from the 1960s and 1970s to the 1990s in the central Arctic Basin.

Fowler et al. (2004) utilized a new technique for combining remotely-sensed sea ice motion and sea ice extent to ''track'' the evolution of sea ice in the Arctic region from October 1978 through March 2003. Their analysis revealed that the area of the oldest sea ice (i.e., sea ice older than 4 years) was decreasing in the Arctic Basin and being replaced by younger (first-year) ice. The extent of the older ice was retreating to a relatively small area north of the Canadian Archipelago, with narrow bands spreading out across the central Arctic (Fowler et al. 2004, pp. 71–74). More recently, Maslanik et al. (2007) documented a substantial decline in the percent coverage of old ice within the central Arctic Basin. In 1987, 57 percent of the ice pack in this area was 5 or more years old, with 25 percent of this ice at least 9 years old. By 2007, only 7 percent of the ice pack in this area was 5 or more years old, and ice at least 9 years old had completely disappeared. This is significant because older ice is thicker than younger ice, and therefore requires more energy to melt. The reduction in the older ice types in the Arctic Basin translates into a reduction in mean ice thickness from 2.6 m in March 1987 to 2.0 m in March 2007 (Stroeve et al. 2008).

Kwok (2007, p. 1) studied six annual cycles of perennial (multi-year) Arctic sea ice coverage, from 2000 to 2006, and found that after the 2005 summer melt, only about four percent of the thin, first-year ice that formed the previous winter survived to replenish the multi-year sea ice area (NASA/JPL News Release, April 3, 2007). That was the smallest amount of multi-year ice replenishment documented in the study, and resulted in perennial ice coverage in January 2006 that was 14 percent smaller than in January 2005. Kwok (2007, p. 1) attributed the decline to unusually high amounts of ice exported from the Arctic in the summer of 2005, and also to an unusually warm winter and summer prior to September 2005.

Length of the Melt Period

The length of the melt period (or season) affects sea ice cover (extent and area) and sea ice thickness (Hakkinen and Mellor 1990; Laxon et al. 2003). In general terms, earlier onset of melt and lengthening of the melt season result in decreased total sea ice cover at the end of summer (i.e., the end of the melt season) (Stroeve et al. 2005, p. 3). Belchansky et al. (2004, p. 1) found that changes in multi-year ice area measured in January were significantly correlated with duration of the intervening melt season. Kwok found a correlation between the number of freezing and melting temperature days and area of multi-year sea ice replenished in a year (NASA/JPL News Release, April 3, 2007).

Comiso (2003, p. 3,506), using data for the period 1981–2001, calculated that the Arctic sea ice melt season was increasing at a rate of 10 to 17 days per decade during that period. Including additional years in his analyses, Comiso (2005, p. 50) subsequently found that the length of the melt season was increasing at a rate of approximately 13.1 days per decade. Stroeve et al. (2006 pp. 367–374) analyzed melt season duration and melt onset and freeze-up dates from satellite passive microwave data for the period 1979 through 2005, and found that the Arctic is experiencing an overall lengthening of the melt season at a rate of about 2 weeks per decade.

The NSIDC documented a trend of earlier onset of the melt season for the years 2002 through 2005; the melt season arrived earliest in 2005, occurring approximately 17 days before the mean date of onset of the melt season (NSIDC 2005, p. 6). In 2007, in addition to the record-breaking September minimum sea ice extent, NSIDC scientists noted that the date of the lowest sea ice extent shifted to later in the year (NSIDC Press Release, October 1, 2007). The minimum sea ice extent occurred on September 16, 2007; from 1979 to 2000, the minimum usually occurred on September 12. This is consistent with a lengthening of the melt season.

Parkinson (2000) documented a clear decrease in the length of the sea ice season throughout the Greenland Sea, Kara and Barents Seas, Sea of Okhotsk, and most of the central Arctic Basin. On the basis of observational data, Stirling et al. (cited in Derocher et al. 2004) calculated that break-up of the annual ice in Western Hudson Bay is occurring approximately 2.5 weeks earlier than it did 30 years ago. Consistent with these results, Stirling and Parkinson (2006) analyzed satellite data for Western Hudson Bay for November 1978 through 2004 and found that, on average, ice break-up has been occurring about 7 to 8 days earlier per decade. Stirling and Parkinson (2006) also investigated ice break-up in Foxe Basin, Baffin Bay, Davis Strait, and Eastern Hudson Bay in Canada. They found that ice break-up in Foxe Basin has been occurring about 6 days earlier each decade and ice break-up in Baffin Bay has been occurring 6 to 7 days earlier per decade. Long-term results from Davis Strait were not conclusive, particularly because the maximum percentage of ice cover in Davis Strait varies considerably more between years than in western Hudson Bay, Foxe Basin, or Baffin Bay. Conversely, Stirling and Parkinson (2006) documented a negative short-term trend from 1991 to 2004 in Davis Strait. In eastern Hudson Bay, there was not a statistically significant trend toward earlier break-up.

Understanding Observed Declines in Arctic Sea Ice

The observed declines in the extent of Arctic sea ice are well documented, and more pronounced in the summer than in the winter. There is also evidence that the rate of sea ice decline is increasing. This decline in sea ice is of great importance to our determination regarding the status of the polar bear. Understanding the causes of the decline is also of great importance in assessing what the future might hold for Arctic sea ice, and, thus, considerable effort has been devoted to enhancing our understanding. This understanding will inform our determination regarding the status of the polar bear within the foreseeable future as determined in this rule.

In general terms, sea ice declines can be attributed to three conflated factors: warming, atmospheric changes (including circulation and clouds), and changes in oceanic circulation (Stroeve and Maslowski 2007). Serreze et al.

(2007, pp. 1,533–1,536) characterize the decline of sea ice as a conflation of thermodynamic and dynamic processes: ''Thermodynamic processes involve changes in surface air temperature (SAT), radiative fluxes, and ocean conditions. Dynamic processes involve changes in ice circulation in response to winds and ocean currents.'' In the following paragraphs we discuss warming, changes in the atmosphere, and changes in oceanic circulation, followed by a synthesis. It is critically important that we understand the dynamic forces that govern all aspects of sea ice given the polar bear's almost exclusive reliance on this habitat.

Air and Sea Temperatures

Estimated rates of change in surface air temperature (SAT) over the Arctic Ocean over the past 100 or more years vary depending on the time period, season, and data source used (Serreze et al. 2007, pp. 1,533–1,536). Serreze et al. (2007, pp. 1,533–1,536) note that, although natural variability plays a large role in SAT variations, the overall pattern has been one of recent warming.

Polyakov et al. (2003) compiled SAT trends for the maritime Arctic for the period 1875 through 2000 (as measured by coastal land stations, drifting ice stations, and Russian North Pole stations) and found that, since 1875, the Arctic has warmed by 1.2 degrees Celsius (C), an average warming of 0.095 degree C per decade over the entire period, and an average warming of 0.05 ± 0.04 degree C per decade during the 20th century. The increases were greatest in winter and spring, and there were two relative maxima during the century (the late 1930s and the 1990s). The ACIA analyzed land-surface air temperature trends as recorded in the Global Historical Climatology Network (GHCN) database, and documented a statistically significant warming trend of 0.09 degree C per decade during the period 1900–2003 (ACIA 2005, p. 35). For periods since 1950, the rate of temperature increase in the marine Arctic documented in the GHCN (ACIA 2005, p. 35) is similar to the increase noted by Polyakov et al. (2003).

Rigor et al. (2000) documented positive trends in SAT for 1979 to 1997; the trends were greatest and most widespread in spring. Comiso (2006) analyzed data from the Advanced Very High Resolution Radiometer (AVHRR) for 1981 to 2005, and documented an overall warming trend of 0.54 ± 0.11 degrees C per decade over sea ice. Comiso noted that ''it is apparent that significant warming has been occurring in the Arctic but not uniformly from one region to another.'' The Serreze et al. (2007, pp. 1,533–1,536) assessment of data sets from the National Centers for Environmental Prediction and the National Center for Atmospheric Research indicated strong surface and low-level warming for the period 2000 to 2006 relative to 1979 to 1999, consistent with the observed sea ice losses.

Stroeve and Maslowski (2007) noted that anomalously high temperatures have been consistent throughout the Arctic since 2002. Further support for warming comes from studies indicating earlier onset of spring melt and lengthening of the melt season (e.g., Stroeve et al. 2006, pp. 367–374), and data that point to increased downward radiation toward the surface, which is linked to increased cloud cover and water vapor (Francis and Hunter 2006, cited in Serreze et al. 2007, pp. 1,533–1,536).

According to the IPCC AR4 (IPCC 2007, p. 36), 11 of 12 years from 1995 to 2006 (the exception being 1996) were among the 12 warmest years on record since 1850; 2005 and 1998 were the warmest two years in the instrumental global surface air temperature record since 1850. Surface temperatures in 1998 were enhanced by the major 1997–1998 El Niño but no such large-scale atmospheric anomaly was present in 2005. The IPCC AR4 concludes that the ''warming in the last 30 years is widespread over the globe, and is greatest at higher northern latitudes (IPCC 2007, p. 37).'' Further, the IPCC AR4 states that greatest warming has occurred in the northern hemisphere winter (December, January, February) and spring (March, April, May). Average Arctic temperatures have been increasing at almost twice the rate of the rest of the world in the past 100 years. However, Arctic temperatures are highly variable. A slightly longer Arctic warm period, almost as warm as the present, was observed from 1925 to 1945, but its geographical distribution appears to have been different from the recent warming since its extent was not global.

Finally, Comiso (2005, p. 43) determined that for each 1 degree C increase in surface temperature (global average) there is a corresponding decrease in perennial sea ice cover of about 1.48 million sq km (0.57 million sq mi).

Changes in Atmospheric Circulation

Links have also been established between sea ice loss and changes in sea ice circulation associated with the behavior of key atmospheric patterns, including the Arctic Oscillation (AO; also called the Northern Annular Mode (NAM)) (e.g., Thompson and Wallace 2000; Limpasuvan and Hartmann 2000) and the more regional, but closely related North Atlantic Oscillation (NAO; e.g., Hurrell 1995). First described in 1998 by atmospheric scientists David Thompson and John Wallace, the Arctic Oscillation is a measure of air-pressure and wind patterns in the Arctic. In the so-called ''positive phase'' (or high phase), air pressure over the Arctic is lower than normal and strong westerly winds occur in the upper atmosphere at high latitudes. In the so-called ''negative phase'' (or low phase), air pressure over the Arctic is higher than normal, and the westerly winds are weaker.

Rigor et al. (2002, cited in Stroeve and Maslowski 2007) showed that when the AO is positive in winter, altered wind patterns result in more offshore ice motion and ice divergence along the Siberian and Alaskan coastlines; this leads to the production of more extensive areas of thinner, first-year ice that requires less energy to melt. Rigor and Wallace (2004, cited in Deweaver 2007) suggested that the recent reduction in September ice extent is a delayed reaction to the export of multi-year ice during the high-AO winters of 1989 through 1995. They estimated that the recovery of sea ice to its normal extent should take between 10 and 15 years. However, Rigor and Wallace (2004) estimated that the combined winter and summer AO-indices can explain less than 20 percent of the variance in summer sea ice extent in the western Arctic Ocean where most of the recent reductions in sea ice cover have occurred. The notion that AO-related export of multi-year ice from the Arctic is the principal cause of observed declines in Arctic sea ice extent has been questioned by several authors, including Overland and Wang (2005), Comiso (2006), Stroeve and Maslowski (2007), Serreze et al. (2007, pp. 1,533–1,536), and Stroeve et al. (2008) who note that sea ice extent has not recovered despite the return of the AO to a more neutral state since the late 1990s. Overland and Wang (2005) noted that the return of the AO to a more neutral state was accompanied by southerly wind anomalies from 2000–2005 which contributed to reducing the ice cover over time and ''conditioning'' the Arctic for the extensive summer sea ice reduction in 2007 (J. Overland NOAA, pers. comm. to FWS, 2007). Maslanik et al. (2007) reached a similar conclusion that despite the return of the AO to a more neutral state, wind and ice transport patterns that favor reduced ice cover in the western and central Arctic continued to play a role in the loss of sea ice in those regions. Maslanik et al.

(2007) believe that circulation patterns such as the Beaufort Gyre, which in the past helped to maintain old ice in the Arctic Basin, are now acting to export ice, as the multi-year ice is no longer surviving the transport through the Chukchi and East Siberian Seas.

According to DeWeaver (2007): ''Recognizing the need to incorporate AO variability into considerations of recent sea ice decline, Lindsay and Zhang (2005) used an ocean-sea ice model to reconstruct the sea ice behavior of the satellite era and identify separate contributions from ice motion and thermodynamics. Similar experiments with similar results were also reported by Rothrock and Zhang (2005) and Koberle and Gerdes (2003).'' Rothrock and Zhang (2005, cited in Serreze et al. 2007, pp. 1,533–1,536), using a coupled ice-ocean model, argued that although wind forcing was the dominant driver of declining ice thickness and volume from the late 1980s through the mid-1990s, the ice response to generally rising air temperatures was more steadily downward over the study period (1948 to 1999). ''In other words, without wind forcing, there would still have been a downward trend in ice extent, albeit smaller than that observed'' (Serreze et al. 2007, pp. 1,533–1,536). Lindsay and Zhang (2005, cited in Serreze et al. 2007, pp. 1,533–1,536) came to similar conclusions in their modeling study: ''Rising air temperature reduced ice thickness, but changes in circulation also flushed some of the thicker ice out of the Arctic, leading to more open water in summer and stronger absorption of solar radiation in the upper (shallower depths of the) ocean. With more heat in the ocean, thinner ice grows in autumn and winter.''

Changes in Oceanic Circulation

According to Serreze et al. (2007, pp. 1,533–1,536), it appears that changes in ocean heat transport have played a role in declining Arctic sea ice extent in recent years. Warm Atlantic waters enter the Arctic Ocean through the Fram Strait and Barents Sea (Serreze et al. 2007, pp. 1,533–1,536). This water is denser than colder, fresher (less dense) Arctic surface waters, and sinks (subducts) to form an intermediate layer between depths of 100 and 800 m (328 and 2,624 ft) (Quadfasel et al. 1991) with a core temperature significantly above freezing (DeWeaver 2007; Serreze et al. 2007, pp. 1,533–1,536). Hydrographic data show increased import of Atlantic-derived waters in the early to mid-1990s and warming of this inflow (Dickson et al. 2000; Visbeck et al. 2002). This trend has continued, characterized by pronounced pulses of warm inflow (Serreze et al. 2007, pp. 1,533–1,536). For example, strong ocean warming in the Eurasian Basin of the Arctic Ocean in 2004 can be traced to a pulse entering the Norwegian Sea in 1997–1998 and passing through Fram Strait in 1999 (Polyakov et al. 2007). The anomaly found in 2004 was tracked through the Arctic system and took about 1.5 years to travel from the Norwegian Sea to the Fram Strait region, and an additional 4.5–5 years to reach the Laptev Sea slope (Polyakov et al. 2007).

Polyakov et al. (2007) reported that mooring-based records and oceanographic surveys suggest that a new pulse of anomalously warm water entered the Arctic Ocean in 2004. Further Polyakov et al. (2007) stated that: ''combined with data from the previous warm anomaly * * * this information provides evidence that the Nansen Basin of the Arctic Ocean entered a new warm state. These two warm anomalies are progressing towards the Arctic Ocean interior * * * but still have not reached the North Pole observational site. Thus, observations suggest that the new anomalies will soon enter the central Arctic Ocean, leading to further warming of the polar basin. More recent data, from summer 2005, showed another warm anomaly set to enter the Arctic Ocean through the Fram Strait (Walczowski and Piechura 2006). These inflows may promote ice melt and discourage ice growth along the Atlantic ice margin (Serreze et al. 2007, pp. 1,533–1,536).

Once Atlantic water enters the Arctic Ocean, the cold halocline layer (CHL) separating the Atlantic and surface waters largely insulates the ice from the heat of the Atlantic layer. Observations suggest a retreat of the CHL in the Eurasian basin in the 1990s (Steele and Boyd 1998, cited in Serreze et al. 2007, pp. 1,533–1,536). This likely increased Atlantic layer heat loss and ice-ocean heat exchange (Serreze et al. 2007, pp. 1,533–1,536), which would serve to erode the edge of the sea ice on a year-round basis (C. Bitz, in litt. to the Service, November 2007). Partial recovery of the CHL has been observed since 1998 (Boyd et al. 2002, cited in Serreze et al. 2007, pp. 1,533–1,536), and future behavior of the CHL is an uncertainty in projections of future sea ice loss (Serreze et al. 2007, pp. 1,533–1,536).

Synthesis

From the previous discussion, surface air temperature warming, changes in atmospheric circulation, and changes in oceanic circulation have all played a role in observed declines of Arctic sea ice extent in recent years.

According to DeWeaver (2007): ''Lindsay and Zhang (2005) propose a three-part explanation of sea ice decline,'' which incorporates both natural AO variability and warming climate. In their explanation, a warming climate preconditions the ice for decline as warmer winters thin the ice, but the loss of ice extent is triggered by natural variability such as flushing by the AO. Sea ice loss continues after the flushing because of the sea-ice albedo feedback mechanism which warms the sea even further. In recent years, flushing of sea ice has continued through other mechanisms despite a relaxation of the AO since the late 1990s. The sea-ice albedo feedback effect is the result of a reduction in the extent of brighter, more reflective sea ice or snow, which reflects solar energy back into the atmosphere, and a corresponding increase in the extent of darker, more absorbing water or land that absorbs more of the sun's energy. This greater absorption of energy causes faster melting, which in turn causes more warming, and thus creates a self-reinforcing cycle or feedback loop that becomes amplified and accelerates with time. Lindsay and Zhang (2005, p. 4,892) suggest that the sea-ice albedo feedback mechanism caused a tipping point in Arctic sea ice thinning in the late 1980s, sustaining a continual decline in sea ice cover that cannot easily be reversed. DeWeaver (2007) believes that the work of Lindsay and Zhang (2005) suggests that the observed record of sea ice decline is best interpreted as a combination of internal variability and external forcing (via GHGs), and raises the possibility that the two factors may act in concert rather than as independent agents.

Evidence that warming resulting from GHG forcing has contributed to sea ice declines comes largely from model simulations of the late 20th century climate. Serreze et al. (2007, pp. 1,533–1,536) summarized results from Holland et al. (2006, pp. 1–5) and Stroeve et al. (2007, pp. 1–5), and concluded that the qualitative agreement between model results and actual observations of sea ice declines over the PM satellite era is strong evidence that there is a forced component to the decline. This is because each of these models would be in its own phase of natural variability and thus could show an increase or decrease in sea ice, but the fact that they all show a decrease indicates that more than natural variability is involved, i.e., that external forcing by GHGs is a factor. In addition, the model results do not show a decline if they are not forced with the observed GHGs. Serreze et al.

(2007, pp. 1,533–1,536) concluded: ''These results provide strong evidence that, despite prominent contributions of natural variability in the observed record, GHG loading has played a role.''

Hegerl et al. (2007) used a new approach to reconstruct and attribute a 1,500-year temperature record for the Northern Hemisphere. Based on their analysis to detect and attribute temperature change over that period, they estimated that about a third of the warming in the first half of the 20th century can be attributed to anthropogenic GHG emissions. In addition, they estimated that the magnitude of the anthropogenic signal is consistent with most of the warming in the second half of the 20th century being anthropogenic.

Observed Changes in Other Key Parameters

Snow Cover on Ice

Northern Hemisphere snow cover, as documented by satellite over the 1966 to 2005 period, decreased in every month except November and December, with a step like drop of 5 percent in the annual mean in the late 1980s (IPCC 2007, p. 43). April snow cover extent in the Northern Hemisphere is strongly correlated with temperature in the region between 40 and 60 degrees N Latitude; this reflects the feedback between snow and temperature (IPCC 2007, p. 43).

The presence of snow on sea ice plays an important role in the Arctic climate system (Powell et al. 2006). Arctic sea ice is covered by snow most of the year, except when the ice first forms and during the summer after the snow has melted (Sturm et al. 2006). Warren et al. (1999, cited in IPCC 2007 Chapter 4) analyzed 37 years (1954–1991) of snow depth and density measurements made at Soviet drifting stations on multi-year Arctic sea ice. They found a weak negative trend for all months, with the largest being a decrease of 8 cm (3.2 in) (23 percent) in May.

Precipitation

The Arctic Climate Impact Assessment (2005) concluded that ''overall, it is probable that there was an increase in arctic precipitation over the past century.'' An analysis of data in the Global Historical Climatology Network (GHCN) database indicated a significant positive trend of 1.4 percent per decade (ACIA 2005) for the period 1900 through 2003. New et al. (2001, cited in ACIA 2005)) used uncorrected records and found that terrestrial precipitation averaged over the 60 degree to 80 degree N latitude band exhibited an increase of 0.8 percent per decade over the period from 1900 to 1998. In general, the greatest increases were observed in autumn and winter (Serreze et al. 2000). According to the ACIA (2005) calculations: (1) during the Arctic warming in the first half of the 20th century (1900–1945), precipitation increased by about 2 percent per decade, with significant positive trends in Alaska and the Nordic region; (2) during the two decades of Arctic cooling (1946–1965), the high-latitude precipitation increase was roughly 1 percent per decade, but there were large regional contrasts with strongly decreasing values in western Alaska, the North Atlantic region, and parts of Russia; and (3) since 1966, annual precipitation has increased at about the same rate as during the first half of the 20th century. The ACIA report (2005) notes that these trends are in general agreement with results from a number of regional studies (e.g., Karl et al. 1993; Mekis and Hogg 1999; Groisman and Rankova 2001; Hanssen-Bauer et al. 1997; Førland et al. 1997; Hanssen-Bauer and Førland 1998). In addition to the increase, changes in the characteristics of precipitation have also been observed (ACIA 2005). Much of the precipitation increase appears to be coming as rain, mostly in winter and to a lesser extent in autumn and spring. The increasing winter rains, which fall on top of existing snow, cause faster snowmelt. Increased rain in late winter and early spring could affect the thermal properties of polar bear dens (Derocher et al. 2004), thereby negatively impacting cub survival. Increased rain in late winter and early spring may even cause den collapse (Stirling and Smith 2004).

According to the IPCC AR4 (2007, pp. 256–258), distinct upward trends in precipitation are evident in many regions at higher latitudes, especially from 30 to 85 degrees N latitude. Winter precipitation has increased at high latitudes, although uncertainties exist because of changes in undercatch, especially as snow changes to rain (IPCC 2007, p. 258). Annual precipitation for the circumpolar region north of 50 degrees N has increased during the past 50 years by approximately 4 percent but this increase has not been homogeneous in time and space (Groisman et al. 2003, 2005, both cited in IPCC 2007, p. 258). According to the IPCC AR4: ''Statistically significant increases were documented over Fennoscandia, coastal regions of northern North America (Groisman et al. 2005), most of Canada (particularly northern regions) up until at least 1995 when the analysis ended (Stone et al. 2000), the permafrost-free zone of Russia (Groisman and Rankova 2001) and the entire Great Russian Plain (Groisman et al. 2005, 2007).'' That these trends are real, extending from North America to Europe across the North Atlantic, is also supported by evidence of ocean freshening caused by increased freshwater run-off (IPCC 2007, p. 258).

Rain-on-snow events have increased across much of the Arctic. For example, over the past 50 years in western Russia, rain-on-snow events have increased by 50 percent (ACIA 2005). Groisman et al. (2003) considered rain-on-snow trends over a 50-year period (1950–2000) in high latitudes in the northern hemisphere and found an increasing trend in western Russia and decreases in western Canada (the decreasing Canadian trend was attributed to decreasing snow pack). Putkonen and Roe (2003), working on Spitsbergen Island, where the occurrence of winter rain-on-snow events is controlled by the North Atlantic Oscillation, demonstrated that these events are capable of influencing mean winter soil temperatures and affecting ungulate survival. These authors include the results of a climate modeling effort (using the earlier-generation Geophysical Fluid Dynamics Laboratory climate model and a 1 percent per year increase in CO_2 forcing scenario) that predicted a 40 percent increase in the worldwide area of land affected by rain-on-snow events from 1980–1989 to 2080–2089. Rennert et al. (2008) discussed the significance of rain-on-snow events to ungulate survival in the Arctic, and used the dataset European Center for Medium-range Weather Forecasting (ECMWF) European 40 Year (ERA40) Reanalysis (Uppala et al. 2005) to create a climatology of rain-on-snow events for thresholds that impact ungulate populations and permafrost. In addition to contributing to increased incidence of polar bear den collapse, increased rain-on-snow events during the late winter or early spring could also damage or eliminate snow-covered pupping lairs of ringed seals (the polar bear's principal prey), thereby increasing pup exposure and the risk of hypothermia, and facilitating predation by polar bears and Arctic foxes. This could negatively impact ringed seal recruitment.

Projected Changes in Arctic Sea Ice

Background

To make projections about future ecosystem effects that could result from climate change, one must first make projections of changes in physical climate parameters based on changes in external factors that can affect the physical climate (ACIA 2005). Climate models use the laws of physics to simulate the main components of the climate system (the atmosphere, ocean, land surface, and sea ice) (DeWeaver 2007), and make projections of future climate scenarios-plausible representations of future climate-that are consistent with assumptions about future emissions of GHGs and other pollutants (these assumptions are called ''emissions scenarios'') and with present understanding of the effects of increased atmospheric concentrations of these components on the climate (ACIA 2005).

Virtually all climate models use emissions scenarios developed as part of the IPCC effort; specifically the IPCC's *Special Report on Emissions Scenarios* (SRES) (IPCC 2000) details a number of plausible future emissions scenarios based on assumptions on how societies, economies, and energy technologies are likely to evolve. The SRES emissions scenarios were built around four narrative storylines that describe the possible evolution of the world in the 21st century (ACIA 2005, p.119). Around these four narrative storylines the SRES constructed six scenario groups and 40 different emissions scenarios. Six scenarios (A1B, A1T, A1FI, A2, B1, and B2) were then chosen as illustrative ''marker'' scenarios. These scenarios have been used to estimate a range of future GHG emissions that affect the climate. The scenarios are described on page 18 of the *AR4 Working Group I: Summary for Policymakers* (IPCC 2007), and in greater detail in the SRES Report (IPCC 2000).

The most commonly-used scenarios for current-generation climate modeling are the B1, A1B, and A2 scenarios. In the B1 scenario, CO_2 concentration is around 549 parts per million (ppm) by 2100; this is often termed a 'low' scenario. In the A1B scenario, CO_2 concentration is around 717 ppm by the end of the century; this is a 'medium' or 'middle-of-the-road' scenario. In the A2 scenario, CO_2 concentration is around 856 ppm at the end of the 21st century; this is considered a 'high' scenario with respect to GHG concentrations. It is important to note that the SRES scenarios include no additional mitigation initiatives, which means that no scenarios are included that explicitly assume the implementation of the United Nations Framework Convention on Climate Change (UNFCC) or the emission targets of the Kyoto Protocol.

Of the various types of climate models, the Atmosphere-Ocean General Circulation Models (AOGCMs, also known as General Circulation Models (GCMs)) are acknowledged as the principal and most rapidly-developing tools for simulating the response of the global climate system to various GHG and aerosol emission scenarios. The climates simulated by these models have been verified against observations in several model intercomparison programs (e.g., Achuta Rao et al. 2004; Randall et al. 2007) and have been found to be generally realistic (DeWeaver 2007). Additional confidence in model simulations comes from experiments with a hierarchy of simpler models, in which the dominant processes represented by climate models (e.g., heat and momentum transport by mid-latitude weather systems) can be isolated and studied (DeWeaver 2007).

For projected changes in climate and Arctic sea ice conditions, our proposed rule (72 FR 1064) relied primarily on results in the IPCC's *Third Assessment Report* (TAR) (IPCC 2001b), the *Arctic Climate Impact Assessment* (ACIA 2005, p. 99), and selected peer-reviewed papers (e.g., Johannessen et al. 2004; Holland et al. 2006, pp. 1–5). The IPCC TAR used results derived from 9-AOGCM ensemble (i.e, averaged results from 9 AOGCMs) and three SRES emissions scenarios (A2, B2, and IS92a). The ACIA (2005, p. 99) used a 5-AOGCM ensemble under two SRES emissions scenarios (A2 and B2); however, the B2 emissions scenario was chosen as the primary scenario for use in ACIA analyses (ACIA 2005). These reports relied on ensembles rather than single models, because ''no one model can be chosen as 'best' and it is important to use results from a range of models'' (IPCC 2001, Chapter 8). The other peer-reviewed papers used in the proposed rule (72 FR 1064) tend to report more-detailed results from a one or two model simulations using one SRES scenario.

After the proposed rule was published (72 FR 1064), the IPCC released its *Fourth Assessment Report* (AR4) (IPCC 2007), a detailed assessment of current and predicted future climates around the globe. Projected changes in climate and Arctic sea ice conditions presented in the IPCC AR4 have been used extensively in this final rule. The IPCC AR4 used results from state-of-the-art climate models that have been substantially improved over the models used in the IPCC TAR and ACIA reports (M. Holland, NCAR, in litt. to the Service, 2007; DeWeaver 2007). In addition, the IPCC AR4 used results from a greater number of models (23) than either the IPCC TAR or ACIA reports. ''This larger number of models running the same experiments allows better quantification of the multi-model signal as well as uncertainty regarding spread across the models, and also points the way to probabilistic estimates of future climate change'' (IPCC 2007, p. 761). Finally, the IPCC AR4 used a greater number of emissions scenarios (4) than either the IPCC TAR or ACIA reports. The emission scenarios considered in the AR4 include A2, A1B, and B1, as well as a ''year 2000 constant concentration'' scenario; this choice was made solely due to the limited computational resources for multi-model simulations using comprehensive AOGCMs, and ''does not imply any preference or qualification of these three scenarios over the others'' (IPCC 2007, p.761). For all of these reasons, there is considerable confidence that the AOGCMs used in the IPCC AR4 provide credible quantitative estimates of future climate change, particularly at continental scales and above (IPCC 2007, p. 591), and we have determined that these results are rightly included in the category of best available scientific information upon which to base a listing decision for the polar bear.

In addition to the IPCC AR4 results, this final rule utilizes results from a large number of peer-reviewed papers (e.g., Parkinson et al. 2006; Zhang and Walsh 2006; Arzel et al. 2006; Stroeve et al. 2007, pp. 1–5; Holland et al. 2006, pp. 1–5; Wang et al. 2007, pp. 1,093–1,107; Overland and Wang 2007a, pp. 1–7; Chapman and Walsh 2007) that provide more detailed information on climate change projections for the Arctic.

Uncertainty in Climate Models

The fundamental physical laws reflected in climate models are well established, and the models are broadly successful in simulating present-day climate and recent climate change (IPCC 2007, cited in DeWeaver 2007). For Arctic sea ice, model simulations unanimously project declines in areal coverage and thickness due to increased GHG concentrations (DeWeaver 2007). They also agree that GHG-induced warming will be largest in the high northern latitudes and that the loss of sea ice will be much larger in summer than in winter (Meehl et al. 2007, cited in DeWeaver 2007). However, despite the qualitative agreement among climate model projections, individual model results for Arctic sea ice decline span a considerable range (DeWeaver 2007). Thus, projections from models are often expressed in terms of the typical behavior of a group (ensemble) of simulations (e.g., Arzel et al. 2006; Flato et al. 2004; Holland et al. 2006, pp. 1–5).

DeWeaver (2007) presents a detailed analysis of uncertainty associated with climate models and their projections for Arctic sea ice conditions. He concludes that two main sources of uncertainty should be considered in assessing Arctic sea ice simulations: uncertainties in the construction of climate models and unpredictable natural variability of the climate system. DeWeaver (2007) states that while most aspects of climate simulations have some degree of uncertainty, projections of Arctic climate change have relatively higher uncertainty. This higher level of uncertainty is, to some extent, a consequence of the smaller spatial scale of the Arctic, since climate simulations are believed to be more reliable at continental and larger scales (Meehl et al. 2007, IPCC 2007, both cited in DeWeaver 2007). The uncertainty is also a consequence of the complex processes that control the sea ice, and the difficulty of representing these processes in climate models. The same processes which make Arctic sea ice highly sensitive to climate change, the ice-albedo feedback in particular, also make sea ice simulations sensitive to any uncertainties in model physics (e.g., the representation of Arctic clouds) (DeWeaver 2007).

DeWeaver (2007) also discusses natural variability of the climate system. He states that the atmosphere, ocean, and sea ice comprise a ''nonlinear chaotic system'' with a high level of natural variability unrelated to external climate forcing. Thus, even if climate models perfectly represented all climate system physics and dynamics, inherent climate unpredictability would limit our ability to issue highly, detailed forecasts of climate change, particularly at regional and local spatial scales, into the middle and distant future (DeWeaver 2007).

DeWeaver (2007) states that the uncertainty in model simulations should be assessed through detailed model-to-model and model-to-observation comparisons of sea ice properties like thickness and coverage. In principle, inter-model sea ice variations are attributable to differences in model construction, but attempts to relate simulation differences to specific model differences generally have not been successful (e.g., Flato et al. 2004, cited in DeWeaver 2007). A practical consequence of uncertainty in climate model simulations of sea ice is that a mean and spread of an ensemble of simulations should be considered in deciding the likely fate of Arctic sea ice. Some model-to-model variation (or spread) in future sea ice behaviors is expected even among high-quality simulations due to natural variability, but spread that is a consequence of poor simulation quality should be avoided. Thus, it is desirable to define a selection criterion for membership in the ensemble, so that only those models that demonstrate sufficient credibility in present-day sea ice simulation are included. Fidelity in sea ice hindcasts (i.e., the ability of models to accurately simulate past to present-day sea ice conditions) is an important consideration. This same perspective is shared by other researchers, including Overland and Wang (2007a, p. 1), who state: ''Our experience (Overland and Wang 2007b) as well as others (Knutti et al. 2006) suggest that one method to increase confidence in climate projections is to constrain the number of models by removal of major outliers through validating historical simulations against observations. This requirement is especially important for the Arctic.''

Projection Results in the IPCC TAR and ACIA

This section briefly summarizes the climate model projections of the IPCC TAR and the ACIA, the principal reports used in the proposed rule (72 FR 1064), while the following section presents detailed results published subsequent to those reports, including in the IPCC AR4.

All models in the IPCC TAR predicted continued Arctic warming and continued decreases in the Arctic sea ice cover in the 21st century due to increasing global temperatures, although the level of increase varied between models. The TAR projected a global mean temperature increase of 1.4 degree C by the mid-21st century compared to the present climate for both the A2 and B2 scenarios (IPCC 2001b). Toward the end of the 21st century (2071 to 2100), the mean change in global average surface air temperature, relative to the period 1961–1990, was projected to be 3.0 degrees C (with a range of 1.3 to 4.5 degrees C) for the A2 scenario, and 2.2 degrees C (with a range of 0.9 to 3.4 degrees C) for the B2 scenario. Relative to glacier and sea ice change, the TAR reported that ''The representation of sea-ice processes continues to improve, with several climate models now incorporating physically based treatments of ice dynamics * * *. Glaciers and ice caps will continue their widespread retreat during the 21st century and Northern Hemisphere snow cover and sea ice are projected to decrease further.''

The ACIA concluded that, for both the A2 and B2 emissions scenarios, models projected mean temperature increases of 2.5 degrees C for the region north of 60 degrees N latitude by the mid-21st century (ACIA 2005, p. 100). By the end of the 21st century, Arctic temperature increases were projected to be 7 degrees C and 5 degrees C for the A2 and B2 scenarios, respectively, compared to the present climate (ACIA 2005, p. 100). Greater warming was projected for the autumn and winter than for the summer (ACIA 2005, p. 100).

The ACIA utilized projections from the five ACIA-designated AOGCMs to evaluate changes in sea ice conditions for three points in time (2020, 2050, and 2080) relative to the climatological baseline (2000) (ACIA 2005, p. 192). In 2020, the duration of the sea ice freezing period was projected to be shorter by 10 days; winter sea ice extent was expected to decline by 6 to 10 percent from baseline conditions; summer sea ice extent was expected to decline such that continental shelves were likely to be ice free; and there would be some reduction in multi-year ice, especially on shelves (ACIA 2005, Table 9.4). In 2050, the duration of the sea ice freezing period was projected to be shorter by 15 to 20 days; winter sea ice extent was expected to decline by 15 to 20 percent; summer sea ice extent was expected to decline 30 to 50 percent from baseline conditions; and there would be significant loss of multi-year ice, with no multi-year ice on shelves. In 2080, the duration of the sea ice freezing period was projected to be shorter by 20 to 30 days; winter sea ice extent was expected to decline such that there probably would be open areas in the high Arctic (Barents Sea and possibly Nansen Basin); summer sea ice extent was expected to decline 50 to 100 percent from baseline conditions; and there would be little or no multi-year ice.

According to ACIA (2005, p. 193), one model indicated an ice-free Arctic during September by the mid-21st century, but this model simulated less than half of the observed September sea-ice extent at the start of the 21st century. None of the other models projected ice-free summers in the Arctic by 2100, although the sea-ice extent projected by two models decreased to about one-third of initial (2000) and observed September values by 2100.

Projection Results in the IPCC AR4 and Additional Projections

The IPCC AR4, released a few months after publication of our proposed listing rule for the polar bear (72 FR 1064), presents results from state-of-the-art climate models that are substantially improved over models used in the IPCC TAR and ACIA reports (M. Holland, NCAR, in litt. to the Service FWS, 2007; DeWeaver 2007). Results of the AR4 are presented in this section, followed by discussion of several key, peer-reviewed articles that discuss results presented in the AR4 in greater detail or use AR4 simulations to conduct additional, in-depth analyses.

In regard to surface air temperature changes, the IPCC AR4 states that the range of expected globally averaged surface air temperature warming shows limited sensitivity to the choice of SRES emissions scenarios for the early 21st century (between 0.64 and 0.69 degrees C for 2011 to 2030 compared to 1980 to 1999, a range of only 0.05 °C), largely due to climate change that is already committed (IPCC 2007, p. 749). By the mid-21st century (2046–2065), the choice of SRES scenario becomes more important for globally averaged surface air temperature warming (with increases of 1.3 degree C for the B1 scenario, 1.8 degree C for A1B, and 1.7 degree C for A2). During this time period, about a third of that warming is projected to be due to climate change that is already committed (IPCC 2007, p. 749).

The ''limited sensitivity'' of the results is because the state-of-the-art climate models used in the AR4 have known physics in connecting increases in GHGs to temperature increases through radiation processes (Overland and Wang 2007a, pp. 1–7, cited in J. Overland, NOAA, in litt. to the Service, 2007), and the GHG levels used in the SRES emissions scenarios are relatively similar until around 2040–2050 (see Figure 5). Because increases in GHGs have lag effects on climate and projections of GHG emissions can be extrapolated with greater confidence over the next few decades, model results projecting out for the next 40 to 50 years (near-term climate change estimates) have greater credibility than results projected much further into the future (long-term climate change) (J. Overland, NOAA, in litt. to the Service, 2007). Thus, the uncertainty associated with emissions is relatively smaller for the 45-year ''foreseeable future'' for the polar bear listing. After 2050, uncertainty associated with various climate mechanisms and policy/societal changes begins to increase, as reflected in the larger confidence intervals around the trend lines in Figure 5 beyond 2050.

Summary for Policymakers IPCC WGI Fourth Assessment Report

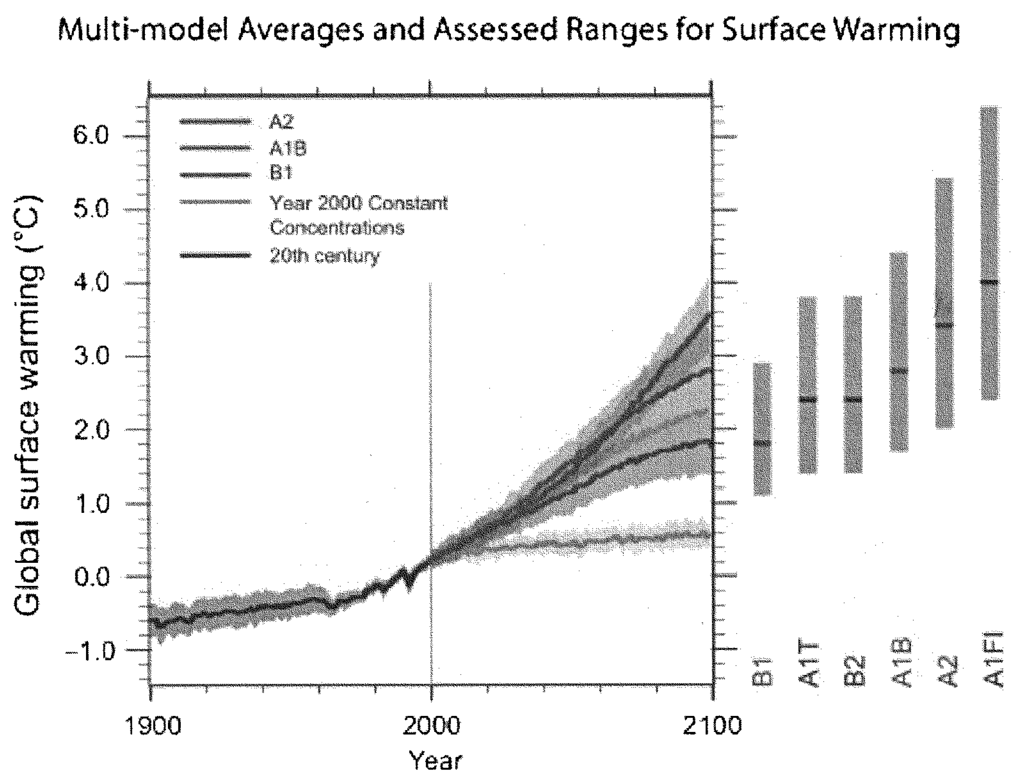


FIGURE SPM-5. Solid lines are multi-model global averages of surface warming (relative to 1980-99) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the plus/minus one standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The gray bars at right indicate the best estimate (solid line within each bar) and the *likely* range assessed for the six SRES marker scenarios. The assessment of the best estimate and *likely* ranges in the gray bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}

Figure 5. Average projected global surface warming for SRES emissions scenarios in a multiple model ensemble (from IPCC 2007, p. 14).

However, even if GHG emissions had stabilized at 2000 levels, the global climate system would already be committed to a warming trend of about 0.1 degree C per decade over the next two decades, in the absence of large changes in volcanic or solar forcing. Meehl et al. (2006) conducted climate change scenario simulations using the Community Climate System Model, version 3 (CCSM3, National Center for Atmospheric Research), with all GHG emissions stabilized at 2000 levels, and found that the global climate system would already be committed to 0.40 degree C more warming by the end of the 21st century.

With respect to warming in the Arctic itself, the AR4 concludes: ''At the end of the 21st century, the projected annual warming in the Arctic is 5 degrees C, estimated by the multi-model A1B ensemble mean projection'' (see IPCC 2007, p. 908, Fig. 11.21). The across-model range for the A1B scenario varied from 2.8 to 7.8 degrees C. Larger mean warming was found for the A2 scenario (5.9 degrees C), and smaller mean warming was found for the B1 scenario (3.4 degrees C); both with proportional across-model ranges. Chapman and Walsh (2007, cited IPCC 2007, p. 904) concluded that the across-model and across-scenario variability in the projected temperatures are both considerable and of comparable amplitude.

In regard to changes in sea ice, the IPCC AR4 concludes that, under the A1B, A2, and B1 SRES emissions scenarios, large parts of the Arctic Ocean are expected to be seasonally ice free by the end of the 21st century (IPCC 2007, p. 73). Some projections using the A2 and A1B scenarios achieve a seasonally ice-free Arctic by as early as 2080–2090 (IPCC 2007, p.771, Figure 10.13a, b). Sea ice reductions are greater in summer than winter, thus it is summer sea ice cover that is projected to be lost in some models by 2080–2090, not winter sea ice cover. The reduction in sea ice cover is accelerated by positive feedbacks in the climate system, including the ice-albedo feedback (which allows open water to receive more heat from the sun during summer, the insulating effect of sea ice is reduced and the increase in ocean heat transport to the Arctic further reduces ice cover) (IPCC 2007, p. 73).

While the conclusions of the IPCC TAR and AR4 are similar with respect to the Arctic, the confidence level associated with independent reviews of AR4 is greater, owing to improvements in the models used and the greater number of models and emissions scenarios considered (J. Overland, NOAA, in litt. to the Service, 2007). Climate models still have challenges modeling some of the regional differences caused by changing decadal climate patterns (e.g., Arctic Oscillation). To help improve the models further, the evaluation of AR4 models has been on-going both for how well they represent conditions in the 20th century and how their predicted results for the 21st century compare (Parkinson et al. 2006; Zhang and Walsh 2006; Arzel et al. 2006; Stroeve et al. 2007, pp. 1–5; Holland et al. 2006, pp. 1–5; Wang et al. 2007, pp. 1,093–1,107; Chapman and Walsh 2007).

Arzel et al. (2006) and Zhang and Walsh (2006) evaluate the sea ice results from the IPCC AR4 models in more detail. Arzel et al. (2006) investigated projected changes in sea ice extent and volume simulated by 13 AOGCMs (also known as GCMs) driven by the SRES A1B emissions scenario. They found that the models projected an average relative decrease in sea ice extent of 15.4 percent in March, 61.7 percent in September, and 27.7 percent on an annual basis when comparing the periods 1981–2000 and 2081–2100; the average relative decrease in sea ice volume was 47.8 percent in March, 78.9 percent in September, and 58.8 percent on an annual basis when comparing the periods 1981–2000 and 2081–2100. More than half the models (7 of 13) reach ice-free September conditions by 2100, as reported in some previous studies (Gregory et al. 2002, Johannessen et al. 2004, both cited in Arzel et al. 2006).

Zhang and Walsh (2006) investigated changes in sea ice area simulated by 14 AOGCMs driven by the SRES A1B, A2, and B1 emissions scenarios. They found that the annual mean sea ice area during the period 2080–2100 would be decreased by 31.1 percent in the A1B scenario, 33.4 percent in the A2 scenario, and 21.6 percent in the B1 scenario relative to the observed sea ice area during the period 1979–1999. They further determined that the area of multi-year sea ice during the period 2080–2100 would be decreased by 59.7 percent in the A1B scenario, 65.0 percent in the A2 scenario, and 45.8 percent in the B1 scenario relative to the ensemble mean multi-year sea ice area during the period 1979–1999.

Dumas et al. (2006) generated projections of future landfast ice thickness and duration for nine sites in the Canadian Arctic and one site on the Labrador coast using the Canadian Centre for Climate Modelling and Analysis global climate model (CGCM2). For the Canadian Arctic sites the mean maximum ice thickness is projected to decrease by roughly 30 cm (11.8 in) from 1970–1989 to 2041–2060 and by roughly 50–55 cm (19.7–21.7 in) from 1970–1989 to 2081–2100. Further, they projected a reduction in the duration of sea ice cover of 1 and 2 months by 2041–2060 and 2081–2100, respectively, from the baseline period of 1970–1989. In addition simulated changes in freeze-up and break-up revealed a 52-day later freeze-up and 30-day earlier break-up by 2081–2100.

Holland et al. (2006, pp. 1–5) analyzed an ensemble of seven projections of Arctic summer sea ice from the Community Climate System Model, version 3 (CCSM3; National Center for Atmospheric Research, USA) utilizing the SRES A1B emissions scenario. CCSM3 is the model that performed best in simulating the actual observations for Arctic ice extent over the PM satellite era (Stroeve et al. 2007, pp. 1–5). Holland et al. (2006, pp. 1–5) found that the CCSM3 simulations compared well to actual observations for Arctic ice extent over the PM satellite era, including the rate of its recent retreat. They also found that the simulations did not project that sea ice retreat would continue at a constant rate into the future. Instead, the CCSM3 simulations indicate abrupt shifts in the ice cover, with one CCSM3 simulation showing an abrupt transition starting around 2024 with continued rapid retreat for around 5 years. Every CCSM3 run had at least one abrupt event (an abrupt event being defined as a time when a 5-year running mean exceeded three times the 2001–2005 observed retreat) in the 21st century, indicating that near ice-free Septembers could be reached within 30–50 years from now.

Holland et al. (2006, pp. 1–5) also discussed results from 15 additional models used in the IPCC AR4, and concluded that 6 of 15 other models ''exhibit abrupt September ice retreat in the A1B scenario runs.'' The length of the transition varied from 3 to 8 years among the models. Thus, in these model simulations, it was found that once the Arctic ice pack thins to a vulnerable state, natural variability can trigger an abrupt loss of the ice cover so that seasonally ice-free conditions can happen within a decade's time (J. Stroeve, in litt. to the Service, November 2007).

Finally, Holland et al. (2006, pp. 1–5) noted that the emissions scenario used in the model affected the likelihood of future abrupt transitions. In models using the SRES B1 scenario (i.e., with GHG levels increasing at a slower rate), only 3 of 15 models show abrupt declines lasting from 3 to 5 years. In models using the A2 scenario (i.e., with

GHG levels increasing at a faster rate), 7 of 11 models with available data obtain an abrupt retreat in the ice cover; the abrupt events last from 3 to 10 years (Holland et al. 2006, pp. 1–5).

In order to increase confidence in climate model projections, several studies have sought to constrain the number of models used by validating climate change in the models simulations against actual observations (Knutti et al. 2006; Hall and Ou 2006). The concept is to create a shorter list of ''higher confidence'' models by removing outlier model projections that do not perform well when compared to 20th century observational data (Overland and Wang 2007a, pp. 1–7). This has been done for temperatures (Wang et al. 2007, pp. 1,093–1,107), sea ice (Overland and Wang 2007a, pp. 1–7; Stroeve et al. 2007, pp. 1–5), and sea level pressure (SLP; defined as atmospheric pressure at sea level) and precipitation (Walsh and Chapman, pers. comm. with J. Overland, NOAA, cited in litt. to the Service, 2007).

Overland and Wang (2007a, pp. 1–7) investigated future regional reductions in September sea ice area utilizing a subset of AR4 models that closely simulate observed regional ice concentrations for 1979–1999 and were driven by the A1B emissions scenario. They used a selection criterion, similar to Stroeve et al. (2007, pp. 1–5), to constrain the number of models used by removing outliers so as to increase confidence in the projections used. Out of an initial set of 20 potential models, 11 models were retained for the Arctic-wide area, 4 were retained for the Kara/Laptev Sea area, 8 were retained for the East Siberian/Chukchi Sea, and 11 were retained for the Beaufort Sea (Overland and Wang 2007a, pp. 1–7). Using these constrained subsets, Overland and Wang (2007a, pp. 1–7) found that there is: ''considerable evidence for loss of sea ice area of greater than 40 percent by 2050 in summer for the marginal seas of the Arctic basin. This conclusion is supported by consistency in the selection of the same models across different regions, and the importance of thinning ice and increased open water at mid-century to the rate of ice loss.'' More specifically, Overland and Wang (2007a, pp. 1–7) found that ''By 2050, 7 of 11 models estimate a loss of 40 percent or greater of summer Arctic ice area. Six of 8 models show a greater than 40 percent ice loss in the East Siberian/Chukchi Seas and 7 of 11 models show this loss for the Beaufort Sea. The percentage of models with major ice loss could be considered higher, as two of the models that retain sea ice are from the same Canadian source and thus cannot be considered to be completely independent. These results present a consistent picture: there is a substantial loss of sea ice for most models and regions by 2050'' (see Figure 6). With less confidence, they found that the Bering, Okhotsk, and Barents seas have a similar 40 percent loss of sea ice area by 2050 in winter; Baffin Bay/Labrador shows little change compared to current conditions (Overland and Wang 2007a, pp. 1–7). Overland and Wang (2007a, pp. 1–7) also note that the CCSM3 model (Holland et al. 2006, pp. 1–5) is one of the models with the most rapid ice loss in the 21st century; this model is also one of the best at simulating historical 20th century observations (also see Figure 12 in DeWeaver (2007)).

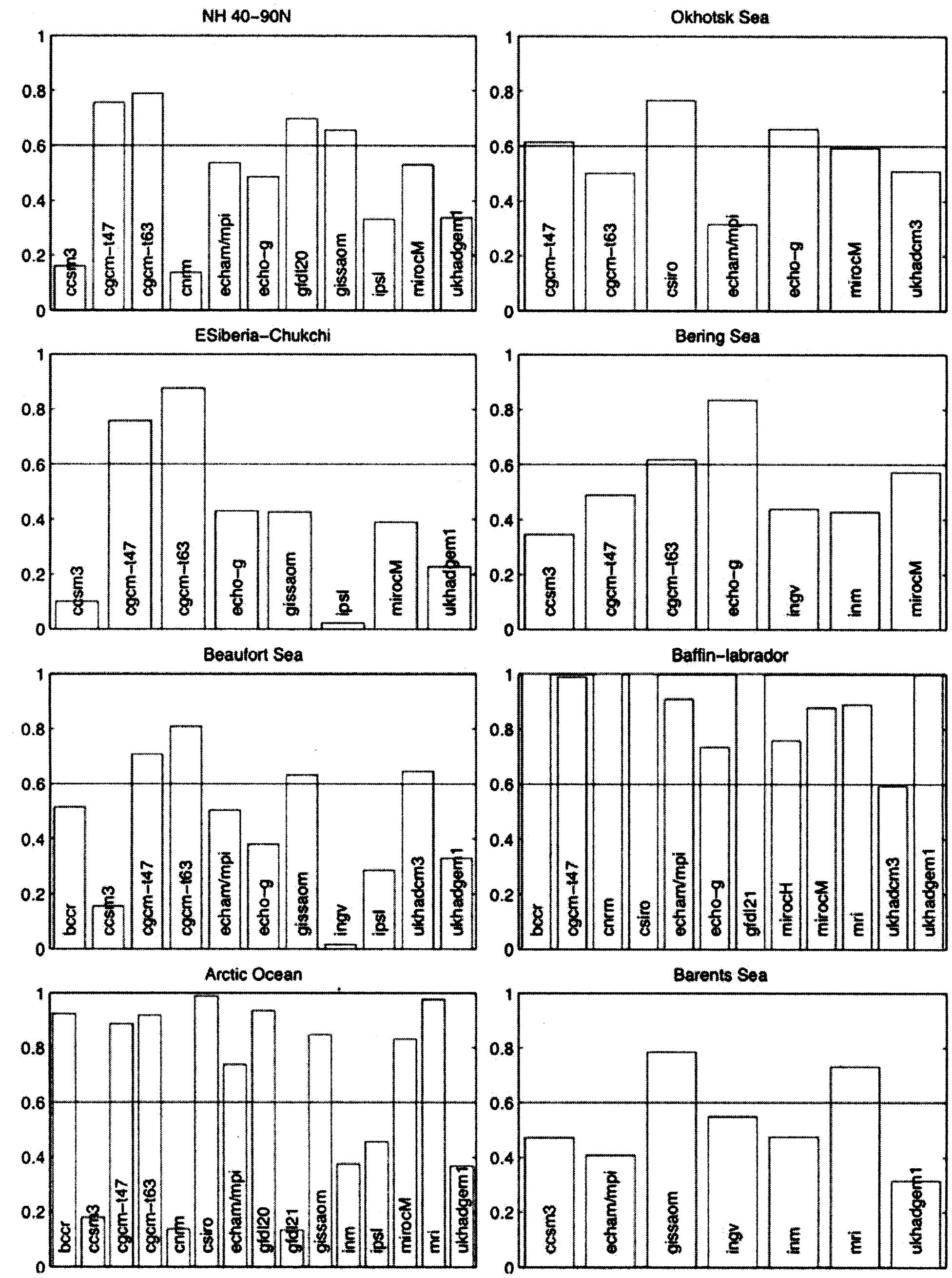


Figure 6. Change of summer sea ice area between 1979–1999 and 2045–2054, given as a fraction of ice remaining in various water bodies, and the northern hemisphere as a whole (NH 40-90N). The models that passed the selection criteria are shown for each water body. The line in each plot indicates a 40 percent reduction in the area of summer sea ice at 2050 versus the baseline period of 1979-1999 (figure from Overland and Wang 2007a, pp. 1-7, used with permission).

DeWeaver (2007), applying a similar conceptual approach as Overland and Wang (2007a, pp. 1–7) and Stroeve et al. (2007, pp. 1–5), used a selection criterion to construct an ensemble of 10 climate models that most accurately depicted sea-ice extent, from the 20 models that contributed sea ice data to the AR4. This 10-model ensemble was used by the USGS for assessing potential polar bear habitat loss (Durner et al. 2007). DeWeaver's selection criterion was to include only those models for which the mean 1953–1995 simulated September sea ice extent is within 20 percent of its actual observed value (as taken from the Hadley Center Sea Ice and Sea Surface Temperature (HadISST) data set (Raynor et al. 2003)). DeWeaver (2007) then investigated the future performance of his 10-model ensemble driven by the SRES A1B emissions scenario. He found that: all 10 models projected declines of September sea ice extent of over 30 percent by the middle of the 21st century (i.e., 2045–2055); 4 of 10 models projected declines September sea ice in excess of 80 percent by mid-21st century; and 7 of 10 models lose over 97 percent of their September sea ice by the end of the 21st century (i.e., 2090–2099) (DeWeaver 2007).

Stroeve et al. (2007, pp. 1–5) compared observed Arctic sea ice extent from 1953–2006 with 20th and 21st century simulation results from an ensemble of 18 AR4 models forced with the SRES A1B emission scenario. Like Overland and Wang (2007a) and DeWeaver (2007), Stroeve et al. (2007, pp. 1–5) applied a selection criterion to limit the number of models used for comparison. Of the original 18 models in the ensemble, 13 were selected because their performance simulating 20th century September sea ice extent satisfied the selection criterion established by the authors (i.e., model simulations for the the period 1953–1995 had to be within 20 percent of observations). The observational record for the Arctic by Stroeve et al. (2007, pp. 1–5) made use of a blended record of PM satellite-era (post November 1978) and pre-PM satellite era data (early satellite observation, aircraft and ship reports) described by Meier et al. (2007, pp. 428–434) and spanning the years 1953–2006 (Stroeve et al. 2007, pp. 1–5).

Stroeve et al.'s (2007, pp. 1–5) results revealed that the observed trend of September sea ice from 1953–2006 (a decline of 7.8 $\pm$ 0.6 percent per decade) is three times larger than the 13-model mean trend (a decline of 2.5 $\pm$ 0.2 percent per decade). In addition, none of the 13 models or their individual ensemble members has trends in September sea ice as large as the observed trend for the entire observation period (1953–2006) or the 11-year period 1995–2006 (Stroeve et al. 2007, pp. 1–5) (see Figure 7). March sea ice trends are not as dramatic, but the modeled decreases are still smaller than observed (Stroeve et al. 2007, pp. 1–5). Stroeve et al. (2007, pp. 1–5) offer two alternative interpretations to explain the discrepancies between the modeled results and the observational record. The first is that the "observed September trend is a statistically rare event and imprints of natural variability strongly dominate over any effect of GHG loading" (Stroeve et al. 2007, pp. 1–5). The second is that, if one accepts that the suite of simulations is a representative sample, "the models are deficient in their response to anthropogenic forcing" (Stroeve et al. 2007, pp. 1–5). Although there is some evidence that natural variability is influencing the sea ice decrease, Stroeve et al. (2007, pp. 1–5) believe that "while IPCC AR4 models incorporate many improvements compared to their predecessors, shortcomings remain" (Stroeve et al. 2007, pp. 1–5) when they are applied to the Arctic climate system, particularly in modeling Arctic Oscillation variability and accurately parameterizing sea ice thickness.

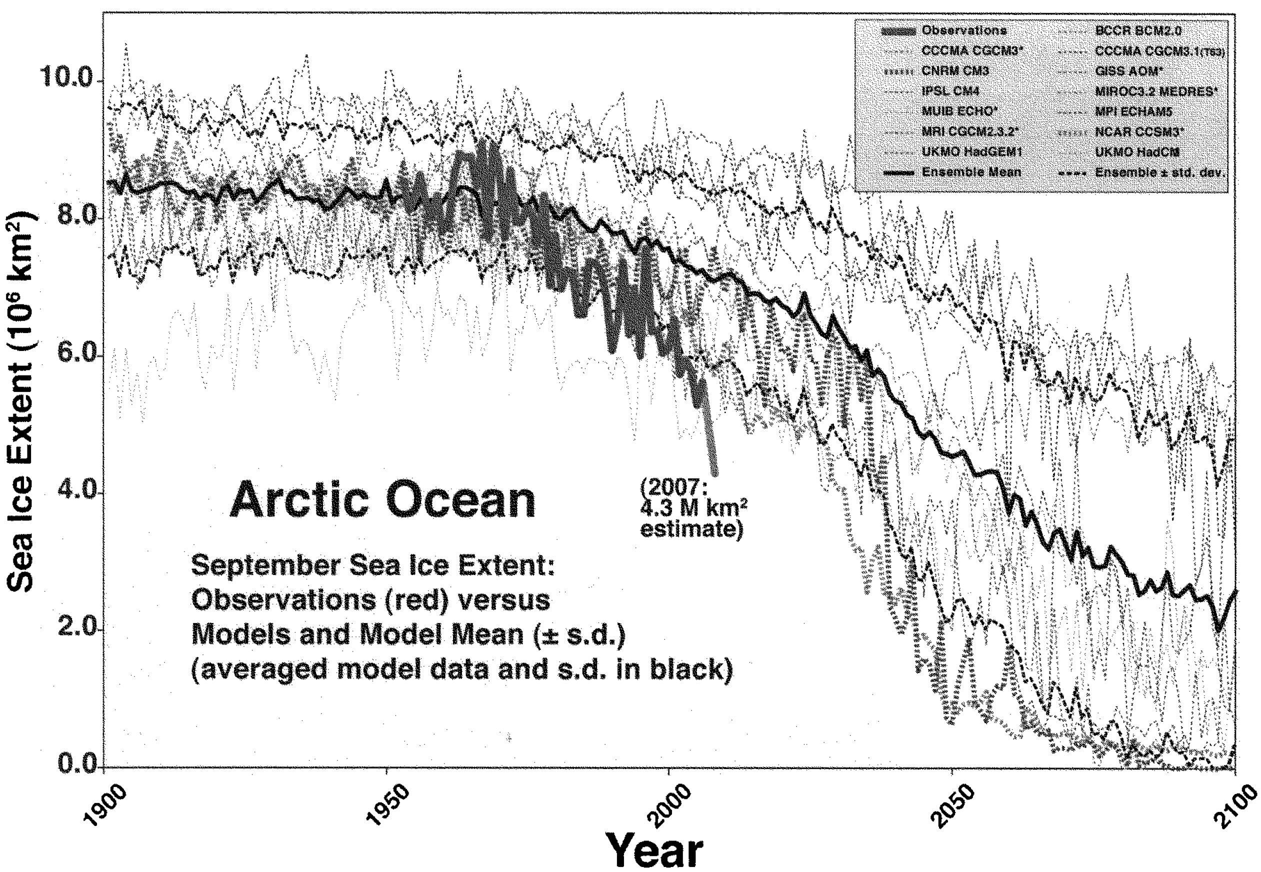


Figure 7. Arctic September sea ice extent. Comparison of observations with results of model runs (updated from Stroeve et al. 2007, pp. 1-5, used with permission).

The observational record indicates that current summer sea ice losses appear to be about 30 years ahead of the ensemble of modeled values, which suggests that a transition towards a seasonally ice-free Arctic might occur sooner than the models indicate (J. Stroeve, in litt. to the Service, November 2007). However, Stroeve et al. (2007, pp. 1–5) note that the two models that best match observations over the PM satellite era-CCSM3 and UKMO_HADGEM1 (Hadley Center for Climate Prediction and Research, UK)-incorporate relatively sophisticated sea ice models (McLaren et al. 2006 and Meehl et al. 2006, both cited in Stroeve et al. 2007, pp. 1–5). The same two models were mentioned by Gerdes and Koberle (2007) as having the most realistic sea ice thickness simulations. If only the results of CCSM3 are considered, as in Holland et al. (2006, pp. 1–5), model simulations compare well to actual observations for Arctic ice extent over the PM satellite era, including the rate of its recent retreat, and simulations of future conditions indicate that near ice-free Septembers could be reached within 30–50 years from now. If the record ice losses from the summer of 2007 are considered, it appears more likely the transition towards a seasonal ice cover will occur during the first half of this century (Stroeve et al. 2007, pp. 1–5) (see Figure 7). DeWeaver (2007) cautions that reliance on a multi-model ensemble is preferred to a single model, because the ensemble represents a balance between the desire to focus on the most credible models and the competing desire to retain a large enough sample to assess the spread of possible outcomes.

Projected Changes in Other Parameters

Air Temperature

As previously noted, IPCC AR4 simulations using a multi-model ensemble and the A1B emissions scenario project that, at the end of the 21st century (i.e., the period 2080–2099), the Arctic will be approximately 5 degrees C warmer, on an annual basis, than in the earlier part of 20th century (i.e., the period 1980–1999) (IPCC 2007, p. 904). Larger mean warming of 5.9 degrees C is projected for the A2 scenario, while smaller mean warming of 3.4 degrees C is projected for the B1 scenario. J. Overland (NOAA, in litt. to the Service, 2007) and associates recently estimated Arctic land temperatures north of 60 degrees N latitude out to 2050 for the 12 models selected in Wang et al. (2007, pp. 1,093–1,107). The average warming from this reduced set of models is an increase of 3 degrees C in surface temperatures; the range of model projections is 2–4 degrees C, which is an estimate of the range of uncertainly in scientists' ability to model Arctic climate. An increase in surface temperatures of 3 degrees C by 2050 will have a major impact on the timing of snowmelt timing (i.e., will lead to earlier snowmelt) (J. Overland, NOAA, in litt. to the Service, 2007).

Precipitation

The IPCC AR4 simulations show a general increase in precipitation over the Arctic at the end of the 21st century (i.e., the period 2080–2099) in comparison to the 20th century (i.e., the period 1980–1999) (IPCC 2007, p. 906). According to the AR4 report (IPCC 2007, p. 906), ''the precipitation increase is robust among the models and qualitatively well understood, attributed to the projected warming and related increased moisture convergence.'' Differences between the projections for different emissions scenarios are small in the first half of the 21st century but increase later. ''The spatial pattern of the projected change shows the greatest percentage increase over the Arctic Ocean (30 to 40 percent) and smallest (and even slight decrease) over the northern North Atlantic (less then 5 percent). By the end of the 21st century, the projected change in the annual mean arctic precipitation varies from 10 to 28 percent, with an ensemble median of 18 percent in the A1B scenario'' (IPCC 2007, p. 906). Larger mean precipitation increases are found for the A2 scenario with 22 percent; smaller mean precipitation increases are found for the B1 scenario with 13 percent. The percentage precipitation increase is largest in winter and smallest in summer, consistent with the projected warming. The across-model scatter of the precipitation projections is substantial.

Putkonen and Roe (2003) presented the results of a global climate modeling effort using an older simulation model (from the TAR era) that predicted a 40 percent increase in the worldwide area of land affected by rain-on-snow events from 1980–1989 to 2080–2089. Rennert et al. (2008) refined the estimate in Putkonen and Roe (2003) using daily data from a 5-member ensemble of the CCSM3 for the periods 1980–1999 and 2040–2059. The future scenario indicated increased frequency of rain-on-snow events in much of Alaska and far eastern Siberia. Decreases in rain-on-snow were shown broadly to be due to projected decreases in snow pack in the model, not a decrease in rain events.

Previous Federal Actions

Information about previous Federal actions for the polar bear can be found in our proposed rule and 12-month finding published in the **Federal Register** on January 9, 2007 (72 FR 1064), and the ''Summary of Comments and Recommendations'' section below.

On April 28, 2008, the United States District Court for the Northern District of California ordered us to publish the final determination on whether the polar bear should be listed as an endangered or threatened species by May 15, 2008. AS part of its order, the Court ordered us to waive the standard 30-day effective date for the final determination.

Summary of Comments and Recommendations

In the January 9, 2007, proposed rule to list the polar bear as a threatened species under the Act (72 FR 1064), we opened a 90-day public comment period and requested that all interested parties submit factual reports, information, and comments that might contribute to development of a final determination for polar bear. The public comment period closed on April 9, 2007. We contacted appropriate Federal and State agencies, Alaska Native Tribes and tribal organizations, governments of polar bear range countries (Canada, Russian Federation, Denmark (Greenland) and Norway), city governments, scientific organizations, peer reviewers (see additional discussion below regarding peer review of proposed rule), and other interested parties to request comments. The Secretary of the Interior also announced the proposed rule and public comment period in a press release issued on December 27, 2006. Newspaper articles appeared in the *Anchorage Daily News, Washington Post, New York Times, Los Angeles Times, Wall Street Journal,* and many local or regional papers across the country, as well as local, national, and international television and radio news programs that also notified the public about the proposed listing and comment period.

In response to requests from the public, public hearings were held in Washington, DC (March 5, 2007), Anchorage, Alaska (March 1, 2007), and Barrow, Alaska (March 7, 2007). These hearings were announced in the **Federal Register** of February 15, 2007 (72 FR 7381), and in the Legal Section of the *Anchorage Daily News* (February 2, 2007). For the Barrow, Alaska, public hearing we established teleconferencing capabilities to provide an opportunity to receive testimony from outlying communities. The communities of Kaktovik, Gambell, Kotzebue, Shishmaref, and Point Lay, Alaska, participated in this public hearing via teleconference. The public hearings were attended by a total of approximately 305 people.

In addition, the Secretary of the Interior, at the time the proposal to list the polar bear as a threatened species was announced, asked the U.S. Geological Survey (USGS) to assist the Service by collecting and analyzing scientific data and developing models and interpretations that would enhance the base of scientific data for the Service's use in developing the final decision. On September 7, 2007, the USGS provided the Service with its analyses in the form of nine scientific reports that analyze and integrate a series of studies on polar bear population dynamics, range-wide habitat use, and changing sea ice conditions in the Arctic. The Service, in turn, reopened the public comment period on September 20, 2007 (72 FR 53749), for 15 days to notify the public of the availability of these nine reports, to announce our intent to consider the reports in making our final listing determination, and to ask the public for comments on the reports. On the basis of numerous requests from the public, including the State of Alaska, the public comment period on the nine reports was extended until October 22, 2007 (72 FR 56979).

While some commenters provided extensive technical comments on the reports, a thorough evaluation of comments received found no significant scientific disagreement regarding the adequacy or accuracy of the scientific information used in the reports. In general, comments on the nine reports raised the following themes: assertions that loss of sea ice reflects natural variability and not a trend; current population status or demographics do not warrant listing; new information justifies listing as endangered; and additional information is needed because of uncertainty associated with future climate scenarios. Commenters also re-iterated concerns and issues raised during the public comment period on the proposed rule. New, supplementary information became available following publication of the proposed rule that supports the climate models used in the nine USGS reports, and helps clarify the relative contribution of natural variability in future climate scenarios provided by the climate models. Comments on the significance of the status and demographic information helped clarify our analyses. We find that the USGS reports, in concert with additional new information in the literature, clarify our understanding of polar bears and their environment and support our initial conclusions regarding the status of the species. We believe the information presented by USGS and other sources provides a broad and solid scientific basis for the analyses and findings in this rule. Technical comments received from the public on the USGS reports and our responses to those comments are available on our website at: *http://alaska.fws.gov/fisheries/mmm/polarbear/issues.htm.*

During the public comment periods, we received approximately 670,000 comments including letters and post cards (43,513), e-mail (626,947), and public hearing testimony (75). We received comments from Federal agencies, foreign governments, State agencies, Alaska Native Tribes and tribal organizations, Federal commissions, local governments, commercial and trade organizations, conservation organizations, non-governmental organizations, and private citizens.

Comments received provided a range of opinions on the proposed listing, as follows: (1) unequivocal support for the listing with no additional information included; (2) unequivocal support for the listing with additional information provided; (3) equivocal support for the listing with or without additional information included; (4) unequivocal opposition to the listing with no additional information included; and (5) unequivocal opposition to the listing with additional information included. Outside the public comment periods, we received an additional approximately 58,000 cards, petitions, and letters pertaining to the proposed listing of the polar bear as a threatened species. We reviewed those submissions in detail for content and found that they did not provide information that was substantively diiferent from what we had already received. Therefore, we determined that reopening the comment period was not necessary.

To accurately review and incorporate the publicly-provided information in our final determination, we worked with the eRulemaking Research Group, an academic research team at the University of Pittsburgh that has developed the *Rule-Writer's Workbench* (RWW) analytical software. The RWW enhanced our ability to review and consider the large numbers of comments, including large numbers of similar comments, on our proposed listing, allowing us to identify similar comments as well as individual ideas, data, recommendations, or suggestions on the proposed listing.

Peer Review of the Proposed Rule

In accordance with our policy published on July 1, 1994 (59 FR 34270), we solicited expert opinion on information contained in the proposed rule from 14 knowledgeable individuals with scientific expertise that includes familiarity with the polar bear, the geographic region in which the polar bear occurs, Arctic ecology, climatology, and Traditional Ecological Knowledge (TEK). The selected polar bear specialists included scientists from all polar bear range countries, and who work in both academia and in government. The selected climate scientists are all active in research and published in Arctic climate systems and sea ice dynamics. We sought expertise in TEK from internationally recognized native organizations.

We received responses from all 14 peer reviewers. Thirteen peer reviewers found that, in general, the proposed rule represented a thorough, clear, and balanced review of the best scientific information available from both published and unpublished sources of the current status of polar bears. The one exception expressed concern that the proposed rule was flawed, biased, and incomplete, that it would do nothing to address the underlying issues associated with global warming, and that a listing would be detrimental to the Inuit of the Arctic. In addition, peer reviewers stated that the background material on the ecology of polar bears represents a solid overview of the species' ecology relevant to the issue of population status. They also stated that information about the five natural or manmade factors that may already have affected polar bear populations, or may affect them in the future, is presented and evaluated in a fair and balanced way and is based on scientifically sound data. They further stated that the information as presented justified the conclusion that polar bears face threats throughout their range. Several peer reviewers provided additional insights to clarify points in the proposed rule, or references to recently-published studies that update material in the proposal.

Several peer reviewers referenced the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC AR4). Reports from Working Groups I, II, and III of the IPCC AR4 were published earlier in 2007, and the AR4 Synthesis Report was released in November 2007. The Working Group I report updates information in the proposed rule with considerable new observational information on global climate change, as well results from independent scientific review of the results from over 20 current-generation climate models. The significance of the Working Group I report, as noted by the peer reviewers with climatological expertise, is that the spatial resolution and physics of climate models have improved such that uncertainties associated with various model components, including prescribed ocean conditions, mobile sea ice, clouds/ radiation, and land/atmosphere exchanges, have been reduced significantly from previous-generation models (i.e., those used in the IPCC *Third Assessment Report*).

One peer reviewer recommended that appropriate effort should be made to integrate the existing sources of Alaska native and other indigenous traditional and contemporary ecological knowledge (TEK) into our final rule. In addition, the peer reviewer recommended that we actively conduct community outreach to obtain this information from Alaska villages located within the range of the polar bear.

One peer reviewer opposed the listing and asserted that existing regulatory mechanisms are adequate because the Inuit people will account for climate change in setting harvest quotas for polar bears.

Peer Review Comments

We reviewed all comments received from peer reviewers for substantive issues and new information regarding the proposed designation of the polar bear as a threatened species. Comments and responses have been consolidated into key issues in this section.

Comment PR1: The importance of sea ice to polar bears is not well articulated in the proposed rule, and the consequences of polar bears using land as an alternative ''platform'' are understated.

Our response: We recognize the vital importance of sea ice as habitat for polar bears. New information and analyses of specific sea ice characteristics important to polar bears has been prepared by USGS (Durner et al. 2007), and incorporated into this final rule. Projections of changes to sea ice and subsequent effects on resource values to polar bears during the foreseeable future have also been included in the analyses in this final rule (see ''Polar Bear—Sea Ice Habitat Relationships'' section). The consequences of prolonged use of terrestrial habitats by polar bears are also discussed in detail in the ''Effects of Sea Ice Habitat Change on Polar Bears'' section of this final rule. We believe that we have objectively assessed these consequences, and have not under- or overstated them.

Comment PR2: The importance of snow cover to successful reproduction by polar bears and their primary prey, ringed seals, should receive greater emphasis.

Our response: We recognize the importance of snow cover for denning polar bears and pupping ringed seals. Additional new information has been included in the sections on climate and the section ''Effects of Sea Ice Habitat Changes on Polar Bear Prey,'' ''Maternal Denning Habitat,'' and ''Access to and Alteration of Denning Areas'' sections.

Comment PR3: Harvest programs in Canada provide conservation benefits for polar bears and are therefore important to maintain. In addition, economic benefits from subsistence hunting and sport hunting occur.

Our response: We recognize the important contribution to conservation that scientifically based sustainable use programs can have. We further recognize the past significant benefits to polar bear management in Canada that have accrued as a result of the 1994 amendments to the MMPA that allow U.S. citizens who legally sport-harvest a polar bear from an MMPA-approved population in Canada to bring their trophies back into the United States. In addition, income from fees collected for trophies imported into the United States are directed by statute to support polar bear research and conservation programs that have resulted in conservation benefits to polar bears in the Chukchi Sea region.

We recognize that hunting provides direct economic benefits to local native communities that derive income from supporting and guiding hunters, and also to people who conduct sport hunting programs for U.S. citizens. However these benefits cannot be and have not been factored into our listing decision for the polar bear.

We note that, under the MMPA, the polar bear will be considered a ''depleted'' species on the effective date of this listing. As a depleted species, imports could only be authorized under the MMPA if the import enhanced the survival of the species or was for scientific research. Therefore, authorization for the import of sport-hunted trophies will no longer be available under section 104(c)(5) of the MMPA. Neither the Act nor the MMPA restricts take beyond the United States and the high seas, so otherwise legal take in Canada is not affected by the threatened listing.

Comment PR4: The ability of polar bears to adapt to a changing environment needs to be addressed directly, with a focus on the importance of rates of environmental change relative to polar bear generation time.

Our response: We have addressed this issue by adding a section to the final rule entitled ''Adaptation'' under ''Summary of Factors Affecting the Polar Bear.'' Information regarding how polar bears survived previous warming events is scant, but some evidence indicates that polar bears survived by altering their geographic range, rather than evolving through natural selection. The pace at which ice conditions are changing and the long generation time of polar bears appear to preclude adaptation of new physiological mechanisms and physical characteristics through natural selection. In addition, the known current physiological, physical, and behavioral characteristics of polar bears suggest that behavioral adaptation will be insufficient to prevent a pronounced reduction in polar bear distribution, and therefore abundance, as a result of declining sea ice. Current evidence suggests there is little likelihood that extended periods of torpor, consumption of terrestrial foods, or capture of seals in open water will be sufficient mechanisms to counter the loss of sea ice as a platform for hunting seals. Projections of population trends based upon habitat availability, as discussed in the USGS reports by Durner et al. (2007) and Amstrup et al. (2007) serve to further clarify the changes currently occurring, or expected to occur, as sea ice declines.

Comment PR5: Harvest levels for some polar bear populations in Nunavut (Canada) are not sustainable and should be discussed; however, these concerns do not materially alter the primary finding of the proposed rule.

Our response: Although we have some concerns about the current harvest levels for some polar populations in Nunavut, we agree that these concerns do not materially alter the primary finding of the proposed rule. As discussed in Factors B and D, impacts from sport hunting or harvest are not threats to the species throughout its range. We recognize that, as discussed in detail in this final rule, the management of polar bears in Canada and other countries is evolving. We believe that our evaluation of the management of the polar bear populations in Canada, which includes participation in the annual Canadian Polar Bear Technical Committee (PBTC) meeting, provides us with the best available information upon which to base future management decisions.

Comment PR6: The most important aspect relative to climate change is that the most recent assessment of the IPCC (AR4) includes projections that climate warming and sea ice decline are likely to continue. This new information as well as other new sea ice information needs to be incorporated into the final analysis.

Our response: We agree that new information on climate warming and sea ice decline, as discussed in the IPCC AR4 as well as numerous other recent scientific papers, is of great significance relative to assessing polar bear habitat and population status and trends. Our final analysis has been updated to incorporate this new information (see ''Sea Ice Habitat'' and ''Polar Bear—Sea Ice Habitat Relationships'' sections).

Comment PR7: Polar bear population status information needs to highlight areas of both population decline and population increase, and the relationship of the two to overall status of the species.

Our response: Our final analysis has been updated with new population information (see ''Current Population Status and Trend'' section).

Comment PR8: The Service did not consider the impacts of listing the polar bear on Inuit economies.

Our response: Under section 4(b)(1)(A) of the Act, we must base a listing decision solely on the best scientific and commercial data available as it relates to the listing five factors in section 4(a)(1) of the Act. The legislative history of this provision clearly states the intent of Congress to ensure that listing decisions are ''* * * based solely on biological criteria and to prevent non-biological criteria from affecting such decisions * * *'' (House of Representatives Report Number 97–835, 97th Congress, Second Session 19 (1982)). As further stated in the legislative history, ''* * * economic considerations have no relevance to determinations regarding the status of species * * *'' (Id. at 20).

Comment PR9: Concerning sport hunting, listing will not help reduce take of polar bears.

Our response: As discussed under Factors B and D below, we recognize that sport hunting or other forms of harvest (both legal and illegal) may be affecting several polar bear populations, but we have determined that overutilization is not a threat to the species throughout all or a significant portion of its range. Amstrup et al. (2007) found that the impact of harvest on the status of polar bear populations is far outweighed by the effects of sea ice losses projected into the future. In addition, we have concluded that, in general, national and local management regimes established for the sustainable harvest of polar bears are adequate. We have determined that polar bear harvest by itself, in the absence of declines due to changes in sea ice habitat, would not be a sufficient threat to justify listing the species in all or a significant portion of its range. However, we have also concluded that harvest may become a more important factor in the future for populations experiencing nutritional stress.

Comment PR10: Inuit will account for climate change in setting subsistence harvest quotas, thus the existing regulatory mechanism is adequate.

Our response: As discussed in this final rule (see ''Polar Bear—Sea Ice Habitat Relationships'' section), the loss of sea ice habitat is considered to threaten the polar bear throughout its range. Adjusting harvest levels based on the consequences of habitat loss and corresponding reduction in physical condition, recruitment, and survival rates is prudent and precautionary, and such adjustments may be addressed through existing and future harvest management regimes. However, we find that these steps will not be sufficient to offset population declines resulting from loss of sea ice habitat.

Comment PR11: The proposed rule does not adequately reflect the state of traditional and contemporary indigenous knowledge regarding polar bears and climate change.

Our response: We have further expanded this rule to include information obtained from Kavry's work in Chukotka, Russia (Kochnev et al. 2003) and Dowsley and Taylor's work in Nunavut, Canada (Dowsley and Taylor 2005), as well as information received during our public hearings. Additionally, we have reviewed information available on polar bears and climate change from the Alaska Native Science Commission (*http://www.nativescience.org/issues/climatechange.htm*). Discussion documents available on their web page generally support the conclusions reached in this document; for example, they observe that: ''Saami are seeing their reindeer grazing pastures change, Inuit are watching polar bears waste away because of a lack of sea ice, and peoples across the Arctic are reporting new species, particularly insects'' (*http://www.arcticpeoples.org/KeyIssues/ClimateChange/Start.html*). Thus, traditional and contemporary indigenous knowledge recognizes that climate-related changes are occurring in the Arctic and that these changes are negatively impacting polar bears.

Comment PR12: The proposed rule does not sufficiently question the reliability of scientific models used. Science is not capable of responding to vague terms such as ''it is likely'' ''foreseeable future.''

Our response: Literature used in the proposed rule was the best available peer-reviewed scientific information at the time. The proposed rule was based largely on results presented in the *Arctic Climate Impact Assessment* (ACIA 2005) and the IPCC *Third Assessment Report* (TAR) (IPCC 2001), plus several individual peer-reviewed journal articles. The ACIA and IPCC TAR are synthesis documents that present detailed information on climate observations and projections, and represent the consensus view of a large number of climate change scientists. Thus, they constituted the best scientific information available at the time the proposed rule was drafted. The proposed rule contained a determination of ''foreseeable future'' (i.e., 45 years) as it pertains to a possible listing of polar bears under the Act, and an explanation of how that 45-year timeframe was determined. This final rule contains the same determination of ''foreseeable future'' (i.e., 45 years), as well as an explanation of how that 45-year timeframe was determined (through a consideration of reliable data on changes currently being observed and projected for the polar bear's sea ice habitat, and supported by information on the life history (generation time) and population dynamics of polar bears). Thus, we disagree with the commenter that this is a vague term.

The final rule has been revised to reflect the most current scientific information, including the results of the IPCC AR4 plus a large number of peer-reviewed journal articles. The IPCC AR4 assigns specific probability values to terms such as ''unlikely,'' ''likely,'' and ''very likely.'' We have attempted to use those terms in a manner consistent with how they are used in the IPCC AR4.

We have taken our best effort to identify the limitations and uncertainties of the climate models and their projections used in the proposed rule. In this final rule, we have provided a more detailed discussion to ensure a balanced analysis regarding the causes and potential impacts of climate change, and have discussed the limitations and uncertainties in the information that provided the basis for our analysis and decision.

Public Comments

We reviewed all comments received from the public for substantive issues and new information regarding the proposed designation of the polar bear as a threatened species. Comments and responses have been consolidated into key issues in this section.

Issue 1: Polar Bear Population Decline

Comment 1: Current polar bear populations are stable or increasing and the polar bear occupies its entire historical range. As such, the polar bear is not in imminent danger of extinction and, therefore, should not be listed under the Act.

Our response: We agree that polar bears presently occupy their available range and that some polar bear populations are stable or increasing. As discussed in the ''Current Population Status and Trend'' section of the rule, two polar bear populations are designated by the PBSG as increasing (Viscount Melville Sound and M'Clintock Channel); six populations are stable (Northern Beaufort Sea, Southern Hudson Bay, Davis Strait, Lancaster Sound, Gulf of Bothia, Foxe Basin); five populations are declining (Southern Beaufort Sea, Norwegian Bay, Western Hudson Bay, Kane Basin, Baffin Bay), and six populations are designated as data deficient (Barents Sea, Kara Sea, Laptev Sea, Chukchi Sea, Arctic Basin, East Greenland) with no estimate of trend (Aars et al. 2006). The two populations with the most extensive time series of data, Western Hudson Bay and Southern Beaufort Sea, are considered to be declining. The two increasing populations (Viscount Melville Sound and M'Clintock Channel) were severely reduced in the past as a result of overharvest and are now recovering as a result of coordinated international efforts and harvest management.

The current status must be placed in perspective, however, as many populations were declining prior to 1973 due to severe overharvest. In the past, polar bears were harvested extensively throughout their range for the economic or trophy value of their pelts. In response to the population declines, five Arctic nations (Canada, Denmark on behalf of Greenland, Norway, Union of Soviet Socialist Republics, and the United States), recognized the polar bear as a significant resource and adopted an inter-governmental approach for the protection and conservation of the species and its habitat, the 1973 Agreement on the Conservation of Polar Bears (1973 Agreement). This agreement limited the use of polar bears for specific purposes, instructed the Parties to manage populations in accordance with sound conservation practices based on the best available scientific data, and called the range States to take appropriate action to protect the ecosystems upon which polar bears depend. In addition, Russia banned harvest in 1956, harvest quotas were established in Canada in 1968, and Norway banned hunting in 1973. With the passage of the MMPA in 1972, the United States banned sport hunting of polar bears and limited the hunt to Native people for subsistence purposes. As a result of these coordinated international efforts and harvest management leading to a reduction in harvest, polar bear numbers in some previously-depressed populations have grown during the past 30 years.

We have determined that listing the polar bear as a threatened species under the Act is appropriate, based on our evaluation of the actual and projected effects of the five listing factors on the species and its habitat. While polar bears are currently distributed throughout their range, the best available scientific information, including new USGS studies relating status and trends to loss of sea ice habitat (Durner et al. 2007; Amstrup et al. 2007), indicates that the polar bear is not currently in danger of extinction throughout all or a significant portion of their range, but are likely to become so within the 45-year ''foreseeable future'' that has been established for this rule. This satisfies the definition of a threatened species under the Act; consequently listing the species as threatened is appropriate. For additional information on factors affecting, or projected to affect, polar bears, please see the ''Summary of Factors Affecting the Polar Bear'' section of this final rule.

Comment 2: The perceived status of the Western Hudson Bay population is disputed because data are unreliable, earlier population estimates cannot be compared to current estimates, and factors other than climate change could contribute to declines in the Western Hudson Bay population.

Our response: The Western Hudson Bay population is the most extensively studied polar bear population in the world. Long-term demographic and vital rate (e.g., survival and recruitment) data on this population exceed those available for any other polar bear population. Regehr et al. (2007a) used the most advanced analysis methods available to conduct population analyses of the Western Hudson Bay population. Trend data demonstrate a statistically-significant population decline over time with a substantial level of precision. The authors attributed the population decline to increased natural mortality associated with earlier sea ice breakup and to the continued harvest of approximately 40 polar bears per year. Other factors such as the effects of research, tourism harassment, density dependence, or shifts in distribution were not demonstrated to impact this population. Regehr et al. (2007a) indicated that overharvest did not cause the population decline; however, as the population declined, harvest rates could have contributed to further depressing the population. Additional information has been included in the ''Western Hudson Bay'' section of this final rule that provides additional details on these points.

Comment 3: The apparent decline in the Southern Beaufort Sea population is not significantly different from the previous population estimate.

Our response: The Southern Beaufort Sea and Western Hudson Bay populations are the two most studied polar bear populations. Regehr et al. (2006) found no statistically significant difference between the most recent and earlier population estimates for the Southern Beaufort Sea population due to the large confidence interval for the earlier population estimate, which caused the confidence intervals for both estimates to overlap. However, we note that the Southern Beaufort Sea population has already experienced decreases in cub survival, significant decreases in body weights for adult males, and reduced skull measurements (Regehr et al. 2006; Rode et al. 2007). Similar changes were documented in the Western Hudson Bay population before a statistically significant decline in that population was documented (Regehr et al. 2007a). The status of the Southern Beaufort Sea population was determined to be declining on the basis of declines in vital rates, reductions in polar bear habitat in this area, and declines in polar bear condition, factors noted by both the Canadian Polar Bear Technical Committee (PBTC 2007) and the IUCN Polar Bear Specialist Group (Aars et al. 2006).

Comment 4: Population information from den surveys of the Chukchi Sea polar bear population is not sufficiently reliable to provide population estimates.

Our response: We recognize that the population estimates from previous den and aerial surveys of the Chukchi Sea population (Chelintsev 1977; Derocher et al. 1998; Stishov 1991a, b; Stishov et al. 1991) are quite dated and have such wide confidence intervals that they are of limited value in determining population levels or trends for management purposes. What the best available information indicates is that, while the status of the Chukchi Sea population is thought to have increased following a reduction of hunting pressure in the United States, this population is now thought to be declining due primarily to overharvest. Harvest levels for the past 10–15 years (150–200 bears per year), which includes the legal harvest in Alaska and an illegal harvest in Chukoktka, Russia, are probably unsustainable. This harvest level is close to or greater than the unsustainable harvest levels experienced prior to 1972 (when approximately 178 bears were taken per year). Furthermore, this population has also been subject to unprecedented summer/autumn sea ice recessions in recent years, resulting in a redistribution of more polar bears to terrestrial areas in some years. Please see additional discussion of this population in the ''Current Population Status and Trend'' section of this document.

Comment 5: Interpretation of population declines is questionable due, in some cases, to the age of the data and in other cases the need for caution due to perceived biases in data collection.

Our response: We used the best available scientific information in assessing population status, recognizing the limitations of some of the information. This final rule benefits from new information on several populations (Obbard et al. 2007; Stirling et al. 2007; Regehr et al. 2007a, b) and additional analyses of the relationship between polar bear populations and sea ice habitat (Durner et al. 2007). New information on population status and trends is included in the ''Current Population Status and Trend'' section of this rule.

Comment 6: Polar bear health and fitness parameters do not provide reliable insights into population trends.

Our response: We recognize there are limits associated with direct correlations between body condition and population dynamics; however changes in body condition have been shown to affect reproduction and survival, which in turn can have population level effects. For example, the survival of polar bear cubs-of-the-year has been directly linked to their weight and the weight of their mothers, with lower weights resulting in reduced survival (Derocher and Stirling 1996; Stirling et al. 1999). Changes in body condition indices were documented in the Western Hudson Bay population before a statistically significant decline in that population was documented (Regehr et al. 2007a). Thus, changes in these indices serve as an ''early warning'' that may signal imminent population declines. New information from Rode et al. (2007) on the relationship between polar bear body condition indices and sea ice cover is also included in the ''Effects of Sea Ice Habitat Change on Polar Bears'' section of this final rule.

Comment 7: Polar bears have survived previous warming events and therefore can adapt to current climate changes.

Our response: We have addressed this issue by adding two sections to the final rule entitled ''Adaptation'' and ''Previous Warming Periods and Polar Bears'' under ''Summary of Factors Affecting the Polar Bear.'' To summarize these sections, we find that the long generation time of polar bears and the known physiological and physical characteristics of polar bears significantly constrain their ability to adapt through behavioral modification or natural selection to the unprecedentedly rapid loss of sea ice habitat that is occurring and is projected to continue throughout the species' range. Derocher et al. (2004, p. 163, 172) suggest that this rate of change will limit the ability of polar bears to respond and survive in large numbers. In addition, polar bears today experience multiple stressors (e.g., harvest, contaminants, oil and gas development, and additional interactions with humans) that were not present during historical warming periods. Thus, both the cumulative effects of multiple stressors and the rapid rate of climate change today create a unique and unprecedented challenge for present-day polar bears in comparison to historical warming events. See also above response to Comment PR4.

Comment 8: Polar bears will adapt and alternative food sources will provide nutrition in the future. There are many food resources that polar bears could exploit as alternate food sources.

Our response: New prey species could become available to polar bears in some parts of their range as climate change affects prey species distributions. However, polar bears are uniquely adapted to hunting on ice and need relatively large, stable seal populations to survive (Stirling and Øritsland 1995). The best available evidence indicates that ice-dependent seals (also called ''ice seals'') are the only species that would be accessible in sufficient abundance to meet the high energetic requirements of polar bears. Polar bears are not adapted to hunt in open water, therefore, predation on pelagic (open-ocean) seals, walruses, and whales, is not likely due to the energetic effort needed to catch them in an open-water environment. Other ice-associated seals, such as harp or hooded seals, may expand their ranges and provide a near-term source of supplemental nutrition in some areas. Over the long term, however, extensive periods of open water may ultimately stress seals as sea ice (summer feeding habitat) retreats further north from southern rookeries. We found no new evidence suggesting that seal species with expanding ranges will be able to compensate for the nutritional loss of ringed seals throughout the polar bear's current range. Terrestrial food sources (e.g., animal carcasses, birds, musk oxen, vegetation) are not likely to be reliably available in sufficient amounts to provide the caloric value necessary to sustain polar bears. For additional information on this subject, please see the expanded discussion of ''Adaptation'' under ''Summary of Factors Affecting the Polar Bear.''

Comment 9: Commenters expressed a variety of opinions on the determination of ''foreseeable future'' for the polar bear, suggesting factors such as the number and length of generations as well as the timeframe over which the threat can be analyzed be used to identify an appropriate timeframe.

Our response: ''Foreseeable future'' for purposes of listing under the Act is determined on the basis of the best available scientific data. In this rule, it is based on the timeframe over which the best available scientific data allow us to reliably assess the effect of threats—principally sea ice loss—on the polar bear, and is supported by species-specific factors, including the species' life history characteristics (generation time) and population dynamics. The timeframe over which the best available scientific data allow us to reliably assess the effect of threats on the species is the critical component for determining the foreseeable future. In the case of the polar bear, the key threat is loss of sea ice, the species' primary habitat. Available information, including results of the IPCC AR4, indicates that climate change projections over the next 40–50 years are more reliable than projections over the next 80–90 years. On the basis of our analysis, as reinforced by conclusions of the IPCC AR4, we have determined that climate changes projected within the next 40–50 years are more reliable than projections for the second half of the 21stcentury, for a number of reasons (see section on ''Projected Changes in Arctic Sea Ice'' for a detailed explanation). For this final rule, we have also identified three polar bear generations (adapted from the IUCN Red List criteria) or 45 years as an appropriate timeframe over which to assess the effects of threats on polar bear populations. This timeframe is long enough to take into account multi-generational population dynamics, natural variation inherent with populations, environmental and habitat changes, and the capacity for ecological adaptation (Schliebe et al. 2006a). The 45-year timeframe coincides with the timeframe within which climate model projections are most reliable. This final rule provides a detailed explanation of the rationale for selecting 45 years as the foreseeable future, including its relationship to observed and projected changes in sea ice habitat (as well as the precision and certainty of the projected changes) and polar bear life history and population dynamics. Therefore, this period of time is supported by species-specific aspects of polar bears and the time frame of projected habitat loss with the greatest reliability.

One commenter erroneously identified Congressional intent to limit foreseeable future to 10 years. We reviewed the particular document provided by the commenter-a Congressional Question & Answer response, dated September 26, 1972, which was provided by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration's Deputy Administrator Pollock. Rather than expressing Congressional intent, this correspondence reflects the Commerce Department's perspective at that time about foreseeable future and not Congressional intent. Furthermore, Mr. Pollock's generic observations in 1972 are not relevant to the best scientific data available regarding the status of the polar bear, which has been recognized by leading polar bear biologists as having a high degree of reliability out to 2050.

Issue 2: Changes in Environmental Conditions

Comment 10: An increase in landfast ice will result in increased seal productivity and, therefore, increased feeding opportunities for polar bears.

Our response: We agree that future feeding opportunities for polar bears will in part relate to how climate change affects landfast ice because of its importance as a platform for ringed seal lairs. As long as landfast ice is available, ringed seals probably will be available to polar bears. Research by Rosing-Asvid (2006) documented a strong increase in the number of polar bears harvested in Greenland during milder climatic periods when ringed seal habitat was reduced (less ice cover) and lair densities were higher because seals were concentrated; these two factors provide better spring hunting for polar bears. In contrast to periodic warming, however, climate models project continued loss of sea ice and changes in precipitation patterns in the Arctic. Seal lairs require sufficient snow cover for lair construction and maintenance, and snow cover of adequate quality that persists long enough to allow pups to wean prior to onset of the melt period. Several studies described in this final rule have linked declines in ringed seal survival and recruitment with climate change that has resulted in increased rain events (which has lead to increased predation on seals) and decreased snowfall. Therefore, while polar bears may initially respond favorably to a warming climate due to an increased ability to capture seals, future reductions in seal populations will ultimately lead to declines in polar bear populations. Additional information was added to the section ''Effects of Sea Ice Habitat Changes on Polar Bear Prey'' to clarify this point.

Comment 11: Polar bears will have increased hunting opportunities as the amount of marginal, unconsolidated sea ice increases.

Our response: Marginal ice occurs at the edge of the polar basin pack ice; ice is considered unconsolidated when concentrations decline to less than 50 percent. The ability of polar bears to catch a sufficient number of seals in marginal sea ice will depend upon both the characteristics of the sea ice and the abundance of and access to prey. Loss of sea ice cover will reduce seal numbers and accessibility to polar bears, as discussed in ''Reduced prey availability'' section of this final rule. Even if ringed seals maintained their current population levels, which is unlikely, Harwood and Stirling (2000) suggest that ringed seals would remain near-shore in open water during summer ice recession, thereby limiting polar bear access to them. Benthic (ocean bottom) feeders, such as bearded seals and walruses, may also decrease in abundance and/or accessibility as ice recedes farther away from shallow continental shelf waters. Increased open water and reduced sea ice concentrations will provide seals with additional escape routes, diminish the need to maintain breathing holes, and serve to make their location less predictable and less accessible to polar bears, resulting in lowered hunting success. Polar bears would also incur higher energetic costs from additional movements required for hunting in or swimming through marginal, unconsolidated sea ice. Additional information from Derocher et al. (2004) was added to the section ''Effects of Sea Ice Habitat Changes on Polar Bear Prey'' to clarify this point.

Comment 12: Polar bears will benefit from increased marine productivity as ocean waters warm farther north.

Our response: If marine productivity in the Arctic increases, polar bears may benefit from increased seal productivity initially, provided that sea ice habitat remains available. As previously mentioned, polar bears need sea ice as a platform for hunting. Evidence from Western Hudson Bay, Southern Hudson Bay, and Southern Beaufort Sea populations indicates that reductions in polar bear body condition in these populations are the result of reductions in sea ice. Additional new information on the relationship between body condition, population parameters, and sea ice habitat for the Southern Beaufort Sea population (Rode et al. 2007) has been incorporated into the section on effects of sea ice change on polar bears.

The extent to which marine productivity increases may benefit polar bears will be influenced, in part, by ringed seals' access to prey. Arctic cod (*Boreogadus saida*), which are the dominant prey item in many areas, depend on sea ice cover for protection from predators (Gaston et al. 2003). In western Hudson Bay, Gaston et al. (2003) detected Arctic cod declines during periods of reduced sea ice habitat. Should Arctic cod abundance decline in other areas, we do not know whether ringed seals will be able to switch to other pelagic prey or whether alternate food sources will be adequate to replace the reductions in cod.

Comment 13: Sufficient habitat will remain in the Canadian Arctic and polar region to support polar bears for the next 40–50 years; therefore, listing is not necessary.

Our response: Both the percentage of sea ice habitat and the quality of that habitat will be significantly reduced from historic levels over the next 40–50 years (Meehl et al. 2007; Durner et al. 2007; IPCC 2007). New information on the extent and magnitude of sea ice loss is included previously in the section entitled ''Observed Changes in Arctic Sea Ice'' of this rule. Reductions in the area, timing, extent, and types of sea ice,among other effects, are expected to increase the energetic costs of movement and hunting to polar bears, reduce access to prey, and reduce access to denning areas. The ultimate effect of these impacts are likely to result in reductions in reproduction and survival, and corresponding decreases in population numbers. We agree that receding sea ice may affect archipelagic polar bear populations later than populations inhabiting the polar basin, because seasonal ice is projected to remain present longer in the archipelago than in other areas of the polar bear's range. The high Arctic archipelago is limited however, in its ability to sustain a large number of polar bears because: (1) changes in the extent of ice and precipitation patterns are already occurring in the region; (2) the area is characterized by lower prey productivity (e.g., lower seal densities); and (3) polar bears moving into this area would increase competition among bears and ultimately affect polar bear survival. In addition, a small, higher-density population of polar bears in the Canadian Arctic would be subject to increased vulnerability to perturbations such as disease or accidental oil discharge from vessels. Because of the habitat changes anticipated in the next 40–50 years, and the corresponding reductions in reproduction and survival, and, ultimately, population numbers, we have determined that the polar bear is likely to be in danger of extinction throughout all or a significant portion of its range by 2050.

Issue 3: Anthropogenic Effects

Comment 14: Disturbance from and cumulative effects of oil and gas activities in the Arctic are underestimated or incompletely addressed.

Our response: Oil and gas activities will likely continue in the future in the Arctic. Additional, updated information has been included in the section ''Oil and Gas Exploration, Development, and Production'' in Factor A. We acknowledge that disturbance from oil and gas activities can be direct or indirect and may, if not subject to appropriate mitigation measures, displace bears or their primary prey (ringed and bearded seals). Such disturbance may be critical for denning polar bears, who may abandon established dens before cubs are ready to leave due to direct disturbance. We note that incidental take of polar bears due to oil and gas activities in Alaska are evaluated and regulated under the MMPA (Sec. 101a(5)A) and incidental take regulations are in place based on an overall negligible effect finding. Standard and site specific mitigation measures are prescribed by the Service and implemented by the industry (see detailed discussion in the section ''Marine Mammal Protection Act of 1972, as amended'' under Factor D).

Indirect and cumulative effects of the myriad of activities associated with major oil and gas developments can be a concern regionally. However, the effects of oil and gas activities, such as oil spills, are generally associated with low probabilities of occurrence, and are generally localized in nature, We acknowledge that the sum total of documented impacts from these activities in the past have been minimal (see discussion in the ''Oil and Gas Exploration, Development, and Production'' section). Therefore, we do not believe that we have underestimated or incompletely addressed disturbance from or cumulative effects of oil and gas activities on polar bears, and have accurately portrayed the effect of oil and gas activities on the status of the species within the foreseeable future.

Comment 15: The potential effects of oil spills on polar bears are underestimated, particularly given the technical limitations of cleaning up an oil spill in broken ice.

Our response: We do not wish to minimize our concern for oil spills in the Arctic marine environment. We agree that the effects of a large volume oil spill to polar bears could be significant within the specific area of occurrence, but we believe that the probability of such a spill in Alaska is generally very low. At a regional level we have concerns over the high oil spill probabilities in the Chukchi Sea under hypothetical future development scenarios (Minerals Management Service (MMS) 2007). An oil spill in this area could have significant consequences to the Chukchi Sea polar bear population (MMS 2007). However, under the MMPA, since 1991 the oil and gas industry in Alaska has sought and obtained incidental take authorization for take of small numbers of polar bears. Incidental take cannot be authorized under the MMPA unless the Service finds that any take that is likely to occur will have no more than a negligible impact on the species. Through this authorization process, the Service has consistently found that a large oil spill is unlikely to occur. The oil and gas industry has incorporated technological and response measures that minimize the risk of an oil spill. A discussion of potential additive effects of mortalities associated with an oil spill in polar bear populations where harvest levels are close to the maximum sustained yield has been included in this final rule (see discussion in the ''Oil and Gas Exploration, Development, and Production'' section).

Comment 16: The effects to polar bears from contaminants other than hydrocarbons are underestimated.

Our response: We added information on the status of regulatory mechanisms pertaining to contaminants, which summarizes what is currently known about the potential threat of each class of contaminants with respect to current production and future trends in production and use. Based on a thorough review of the scientific information on their sources, pathways, geographical distribution, and biological effects, and as discussed in the analysis section of this final rule, we do not believe that contaminants currently threaten the polar bear.

Comment 17: Cumulative effects of threat factors on polar bear populations are important, and need a more indepth analysis than presented in the proposed rule.

Our response: The best available information on the potential cumulative effects from oil and gas activities in Alaska to polar bears and their habitat was incorporated into the final rule (National Research Council (NRC) 2003). We also considered the cumulative effects of hunting, contaminants, increased shipping, increases in epizootic events, and inadequacy of existing regulatory mechanisms in our analyses. We have determined that there are no known regulatory mechanisms in place at the national or international level that directly and effectively address the primary threat to polar bears-the rangewide loss of sea ice habitat within the foreseeable future. We also acknowledge that there are some existing regulatory mechanisms to address anthropogenic causes of climate change, and these mechanisms are not expected to be effective in counteracting the worldwide growth of GHG emissions within the foreseeable future. In addition, we have determined that overutilization does not currently threaten the species throughout all or a significant portion of its range. However, harvest is likely exacerbating the effects of habitat loss in several populations. In addition, continued harvest and increased mortality from bear-human encounters or other forms of mortality may become a more significant threat factor in the future, particularly for populations experiencing nutritional stress or declining population numbers as a consequence of habitat change. We have found that the other factors, while not currently rising to a level that threatens the species, may become more significant in the future as populations face stresses from habitat loss. Modeling of potential effects on polar bears of various factors (Amstrup et al. 2007) identified loss of sea ice habitat as the dominant threat. Therefore, our analysis in this final rule has focused primarily on the ongoing and projected effects of sea ice habitat loss on polar bears within the foreseeable future.

Issue 4: Harvest

Comment 18: Illegal taking of bears is a significant issue that needs additional management action.

Our response: We recognize that illegal take has an impact on some polar bear populations, especially for the Chukchi Sea population and possibly for other populations in Russia. We also believe that a better assessment of the magnitude of illegal take in Russia is needed, and that illegal harvest must be considered when developing sustainable harvest limits. We also conclude that increased use of coastal habitat by polar bears could increase the impact of illegal hunting in Russia, by bringing bears into more frequent contact with humans. However, available scientific information indicates that poaching and illegal international trade in bear parts do not threaten the species throughout all or a significant portion of its range.

Comment 19: The Service should not rely solely on the Bilateral Agreement to remedy illegal take in Russia. Listing under the Act is necessary to allow for continued legal subsistence hunting.

Our response: As discussed in the ''Summary of Factors Affecting the Polar Bear'' section of this rule, we have found that harvest and poaching affect some polar bear populations, but those effects are not significant enough to threaten the species throughout all or a significant portion of its range. To the extent that poaching is affecting local populations in Russia, the Service believes that the best tool to address these threats is the Agreement between the United States of America and the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population (Bilateral Agreement), which was developed and is supported by both government and Native entities and includes measures to reduce poaching. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) would address attempted international trade of unlawfully taken polar bears (or parts), and the MMPA would address attempted import into the United States of unlawfully taken animals or their parts. Subsistence hunting by natives in the United States is exempt from prohibitions under both the MMPA and the Act. Subsistence harvest does not require action under the Act to ensure its continuation into the future.

Comment 20: The Service should prohibit the importation into the United States of polar bear trophies taken in Canada, and should amend the MMPA to prohibit sport hunting of polar bears.

Our response: The polar bear is currently listed in Appendix II of CITES. Section 9(c)(2) of the Act provides that the non-commercial import of threatened and Appendix-II species, including their parts, that were taken in compliance with CITES is not presumed to be in violation of the Act. Thus, an import permit would not ordinarily be required under the Act. We note that the MMPA does not allow sport hunting of polar bears within the United States. In addition, we note that, under the MMPA, the polar bear will be considered a ''depleted'' species on the effective date of this listing. As a depleted species, imports could only be authorized under the MMPA if the import enhanced the survival of the species or was for scientific research. Therefore, authorization for the import of sport-hunted trophies would no longer be available under section 104(c)(5) of the MMPA.

Comment 21: The Service failed to consider the negative impacts of listing on the long-term management of polar bears developed in Canada that integrates subsistence harvest allocations with a token sport harvest.

Our response: We acknowledge the important contribution to conservation from scientifically-based sustainable use programs. Significant benefits to polar bear management in Canada have accrued as a result of the 1994 amendments to the MMPA that allow U.S. citizens who legally sport-harvest a polar bear from an MMPA-approved population in Canada to bring their trophies back into the United States. These benefits include economic revenues to native hunters and communities; enhanced funding a support for research; a United States conservation fund derived from permit fees that is used primarily on the Chukchi Sea population; and increased local support of scientifically-based conservation programs. Without this program, there would be a loss of funds derived from import fees; loss of economic incentives that promote habitat protection and maintain sustainable harvest levels in Canada; and loss of research opportunities in Canada and Russia, which are funded through sport-hunting revenue. While we recognize these benefits, the Service must list a species when the best scientific and commercial information available shows that the species meets the definition of endangered or threatened. The effect of the listing, in this case an end to the import provision under Section 104(c)(5) of the MMPA, is not one of the listing factors. Furthermore, the benefits accrued to the species through the import program do not offset or reduce the overall threat to polar bears from loss of sea ice habitat.

Comment 22: The Service should promulgate an exemption under section 4(d) of the Act that would allow importation of polar bear trophies.

Our response: We recognize the role that polar bear sport harvest has played in the support of subsistence, economic, and cultural values in northern communities, and we have supported the program where scientific data have been available to ensure sustainable harvest. We again note that, under the MMPA, the polar bear will be considered a ''depleted'' species on the effective date of this listing. The MMPA contains provisions that prevent the import of sport-hunted polar bear trophies from Canada once the species is designated as depleted. A 4(d) rule under the Act cannot affect existing requirements under the MMPA.

Comment 23: The rights of Alaska Natives to take polar bears should be protected.

Our response: We recognize the social and cultural importance of polar bears to coastal Alaska Native communities, and we anticipate continuing to work with the Alaska Native community in a co-management fashion to address subsistence-related issues. Section 101(b) of the MMPA already exempts take of polar bears by Native people for subsistence purposes as long as the take is not accomplished in a wasteful manner. Section 10(e) of the Act also provides an exemption for Alaska Natives that allows for taking as long as such taking is primarily for subsistence purposes and the taking is not accomplished in a wasteful manner. In addition, non-edible byproducts of species taken in accordance with the exemption, when made into authentic native articles of handicraft and clothing, may be transported, exchanged, or sold in interstate commerce. Since 1987, we have monitored the Alaska Native harvest of polar bears through our Marking, Tagging and Reporting program [50 CFR 18.23(f)]. The reported harvest of polar bears by Alaska Natives is 1,614 animals during this nearly 20-year period, of which 965 were taken from the Chukchi Sea population and 649 were taken from the Southern Beaufort Sea population.

Alaska Natives' harvest of polar bears from the Southern Beaufort and Chukchi Seas is not exclusive, since both of these populations are shared across international boundaries with Canada and Russia respectively, where indigenous populations in both countries also harvest animals. Since 1988, the Inuvialuit Game Council (IGC) (Canada) and the North Slope Borough (NSB) (Alaska) have implemented an Inuvialuit-Inupiat Polar Bear Management Agreement for harvest of polar bears in the Southern Beaufort

Sea. The focus of this agreement is to ensure that harvest of animals from this shared population is conducted in a sustainable manner. The Service works with the parties of this agreement, providing technical assistance and advice regarding, among other aspects, information on abundance estimates and sustainable harvest levels. We expect that future harvest levels may be adjusted as a result of discussions at the meeting between the IGC and NSB, held in February 2008.

We do have concerns regarding the harvest levels of polar bears from the Chukchi Sea, where a combination of Alaska Native harvest and harvest occurring in Russia may be negatively affecting this population. However, implementation of the recently ratified ''Agreement between the United States of America and the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population'' (Bilateral Agreement), with its provisions for establishment of a shared and enforced quota system between the United States and Russia, should ensure that harvest from the Chukchi Sea population is sustainable.

Comment 24: If the polar bear is listed, subsistence hunting should be given precedence over other forms of take.

Our response: As noted above, Alaska Native harvest of polar bears for subsistence is currently exempt under both the MMPA and the Act. Sport hunting of polar bears is not allowed in the United States under the MMPA, and take for other purposes is tightly restricted. For polar bears, the other primary type of take is incidental harassment during otherwise lawful activities. The Service has issued incidental take regulations under the MMPA since 1991, and these regulations include a finding that such takings will not have an adverse impact on the availability of polar bears for subsistence uses. Thus, the needs of the Alaska Native community, who rely in part on the subsistence harvest of polar bears, are addressed by existing provisions under both the MMPA and the Act.

Issue 5: Climate Change

Comment 25: The accuracy and completeness of future climate projections drawn from climate models are questionable due to the uncertainty or incompleteness of information used in the models.

Our response: Important new climate change information is included in this final rule. The Working Group I Report of the IPCC AR4, published in early 2007, is a key part of the new information, and represents a collaborative effort among climate scientists from around the world with broad scientific consensus on the findings. In addition, a number of recent publications are used in the final rule to supplement and expand upon results presented in the AR4; these include Parkinson et al. (2006), Zhang and Walsh (2006), Arzel et al. (2006), Stroeve et al. (2007, pp. 1–5), Wang et al. (2007, pp. 1,093–1,107), Chapman and Walsh (2007), Overland and Wang (2007a, pp. 1–7), DeWeaver (2007), and others. Information from these publications has been incorporated into appropriate sections of this final rule.

Atmosphere-ocean general circulation models (AOGCMs, also known as General Circulation Models (GCMs)) are used to provide a range of projections of future climate. GCMs have been consistently improved over the years, and the models used in the IPCC AR4 are significantly improved over those used in the IPCC TAR and the ACIA report. There is ''considerable confidence that the GCMs used in the AR4 provide credible quantitative estimates of future climate change, particularly at continental scales and above'' (IPCC 2007, p. 591). This confidence comes from the foundation of the models in accepted physical principles and from their ability to reproduce observed features of current climate and past climate changes. Additional confidence comes from considering the results of suites of models (called ensembles) rather than the output of a single model. Confidence in model outcomes is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation).

Despite improvements in GCMs in the last several years, these models still have difficulties with certain predictive capabilities. These difficulties are more pronounced at smaller spatial scales and longer time scales. Model accuracy is limited by important small-scale processes that cannot be represented explicitly in models and so must be included in approximate form as they interact with larger-scale features. This is partly due to limitations in computing power, but also results from limitations in scientific understanding or in the availability of detailed observations of some physical processes. Consequently, models continue to display a range of outcomes in response to specified initial conditions and forcing scenarios. Despite such uncertainties, all models predict substantial climate warming under GHG increases, and the magnitude of warming is consistent with independent estimates derived from observed climate changes and past climate reconstructions (IPCC 2007, p. 761; Overland and Wang 2007a, pp. 1–7; Stroeve et al. 2007, pp. 1–5).

We also note the caveat, expressed by many climate modelers and summarized by DeWeaver (2007), that, even if global climate models perfectly represent all climate system physics and dynamics, inherent climate variability would still limit the ability to issue accurate forecasts (predictions) of climate change, particularly at regional and local geographical scales and longer time scales. A forecast is a more-precise prediction of what will happen and when, while a projection is less precise, especially in terms of the timing of events. For example, it is difficult to accurately forecast the exact year that seasonal sea ice will disappear, but it is possible to project that sea ice will disappear within a 10–20 year window, especially if that projection is based on an ensemble of modeling results (i.e., results from several models averaged together). It is simply not possible to engineer all uncertainty out of climate models, such that accurate forecasts are possible. Climate scientists expend considerable energy in trying to understand and interpret that uncertainty. The section in this rule entitled ''Uncertainty in Climate Models'' discusses uncertainty in climate models in greater depth than is presented here.

In summary, confidence in GCMs comes from their physical basis and their ability to represent observed climate and past climate changes. Models have proven to be extremely important tools for simulating and understanding climate and climate change, and we find that they provide credible quantitative estimates of future climate change, particularly at larger geographical scales.

Comment 26: Commenters provided a number of regional examples to contradict the major conclusions regarding climate change.

Our response: As noted in our response to Comment 25, GCMs are less accurate in projecting climate change over finer geographic scales, such as the variability noted for some regions in the Arctic, than they are for addressing global or continental-level climate change. Climate change projections for the Barents Sea are difficult, for example, because regional physics includes both local winds and local currents. Cyclic processes, such as the North Atlantic Oscillation (NAO), can also drive regional variability. We agree with one commenter that the NAO is particularly strong for Greenland (Chylek et al. 2006). However, the natural variability associated with this phenomenon simply suggests that the future will also have large variability, but does not negate overall climate trends, because the basic physics of climate processes, including sea ice albedo feedback, are modeled in all major sectors of the Arctic Basin. The increased understanding of the basic physics related to climate processes and the inclusion of these parameters in current climate models, such as those used in the IPCC AR4, present a more complete, comprehensive, and accurate view of range-wide climate change than earlier models.

Comment 27: Other models should be used in the analysis of forecasted environmental and population changes including population viability assessment and precipitation models.

Our response: The Service has not relied upon the published results or use of a single climate model or single scenario in its analyses. Instead we have considered a variety of information derived from numerous climate model outputs. These include modeled changes in temperature, sea ice, snow cover, precipitation, freeze-up and breakup dates, and other environmental variables. The recent report of the IPCC AR4 provides a discussion of the climate models used, and why and how they resulted in improved analyses of climatic variable and future projections. Not only have the models themselves been improved, but many advances have been made in terms of how the model results were used. The AR4 utilized multiple results from single models (called multi-member ensembles) to, for example, test the sensitivity of response to initial conditions, as well as averaged results from multiple models (called multi-model ensembles). These two different types of ensembles allow more robust evaluation of the range of model results and more quantitative comparisons of model results against observed trends in a variety of parameters (e.g., sea ice extent, surface air temperature), and provide new information on simulated statistical variability. This final rule benefits from specific analyses of uncertainty associated with model prediction of Arctic sea ice decline (DeWeaver 2007; Overland and Wang 2007a, pp. 1–7), and identification of those models that best simulated observed changes in Arctic sea ice.

We also updated this final rule with information on recently completed population models (e.g., Hunter et al. 2007), habitat values and use models (Durner et al. 2007), and population projection models (Amstrup et al. 2007), which can be found in the ''Current Population Status and Trend'' section.

Comment 28: Future emission scenarios are unreliable or incomplete and use speculative carbon emission scenarios that inaccurately portray future levels.

Our response: Emissions scenarios used in climate modeling were developed by the IPCC and published in its Special Report on Emissions Scenarios in 2000. These emissions scenarios are representations of future levels of GHGs based on assumptions about plausible demographic, socioeconomic, and technological changes. The most recent, comprehensive climate projections in the IPCC AR4 used scenarios that represent a range of future emissions: low, medium, and high. The majority of models used a ''medium'' or ''middle-of-the-road'' scenario due to the limited computational resources for multi-model simulations using GCMs (IPCC 2007, p. 761). In addition, Zhang and Walsh (2006) use three emission scenarios representative of the suite of possibilities and DeWeaver (2007 p. 28), in subsequent analyses, used the A1B ''business as usual'' scenario as a representative of the medium-range forcing scenario, and other scenarios were not considered due to time constraints. Similarly, our final analysis considered a range of potential outcomes, based in part on the range of emission scenarios. For additional details see the previous section, ''Projected Changes in Arctic Sea Ice.''

We agree that emissions scenarios out to 2100 are less certain with regard to technology and economic growth than projections out to 2050. This is reflected in the larger confidence interval around the mean at 2100 than at 2050 in graphs of these emissions scenarios (see Figure SPM–5 in IPCC 2007). However, GHG loading in the atmosphere has considerable lags in its response, so that what has already been emitted and what can be extrapolated to be emitted in the next 15–20 years will have impacts out to 2050 and beyond (IPCC 2007, p. 749; J. Overland, NOAA, in litt. to the Service, 2007). This is reflected in the similarity of low, medium, and high SRES emissions scenarios out to about 2050 (see discussion of climate change under ''Factor A. Present or Threatened Destruction, Modification, or Curtailment of the Species' Habitat or Range''). Thus, the uncertainty associated with emissions is lower for the foreseeable future timeframe (45 years) for the polar bear listing than longer timeframes.

Comment 29: Atmospheric CO_2 is an indicator of global warming and not a major contributor.

Our response: Carbon dioxide (CO_2) is one of four principal anthropogenically-generated GHGs, the others being nitrous oxide (N_2O), methane (CH_4), and halocarbons (IPCC 2007, p. 135). The IPCC AR4 considers CO_2 to be the most important anthropogenic GHG (IPCC 2007, p. 136). The GHGs affect climate by altering incoming solar radiation and out-going thermal radiation, and thus altering the energy balance of the Earth-atmosphere system. Since the start of the industrial era, the effect of increased GHG concentrations in the atmosphere has been widespread warming of the climate, with disproportionate warming in large areas of the Arctic (IPCC 2007, p. 37). A net result of this warming is a loss of sea ice, with notable reductions in Arctic sea ice.

Comment 30: Atmospheric CO_2 levels are not greater today than during pre-industrial time.

Our response: The best available scientific evidence unequivocally contradicts this comment. Atmospheric concentration of carbon dioxide (CO_2) has increased significantly during the post-industrial period based on information from polar ice core records dating back at least 650,000 years. The recent rate of change is also dramatic and unprecedented, with the increase documented in the last 20 years exceeding any increase documented over a thousand-year period in the historic record (IPCC AR4, p. 115). Specifically, the concentration of atmospheric CO_2 has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005, with an annual growth rate larger during the last 10 years than it has been since continuous direct atmospheric measurements began in 1960. These increases are largely due to global increases in GHG emissions and land use changes such as deforestation and burning (IPCC 2007, pp. 25–26).

Comment 31: Consider the impacts of black carbon (soot) due to increased shipping as a factor affecting the increase in the melting of the sea ice.

Our response: We recognize that there are large uncertainties about the contribution of soot to snow melt patterns. A general understanding is that soot (from black carbon aerosols) deposited on snow reduces the surface albedo with a resulting increase in snow melt process (IPCC 2007, p. 30). Estimates of the amount of effect from all sources of soot have wide variance, and the exact contribution from increased shipping cannot be determined at this time.

Comment 32: Climate models do not adequately address naturally occurring phenomena.

Our response: In IPCC AR4 simulations, models were run with natural and anthropogenic (i.e., GHG) forcing for the period of the observational record (i.e., the 20th century). Results from different models and different runs of the same model can be used to simulate the observed range of natural variability in the 20th century (such as warm in 1930s and cool in the 1960s). Only when GHG forcing is added to natural variability, however, do the models simulate the warming observed in the later portion of the 20th century (Wang et al. 2007). This is shown for the Arctic by Wang et al. (2007, pp. 1,093–1,107). This separation is shown graphically in Figure SPM–4 of the IPCC AR4 (shown below, reproduced from IPCC 2007 with permission); note the separation of the model results with and without greenhouse gases at the end of the 20th century for different regions. Thus comparison of forced CO_2 trends and natural variability were central to the IPCC AR4 analyses, and are discussed in this final rule.

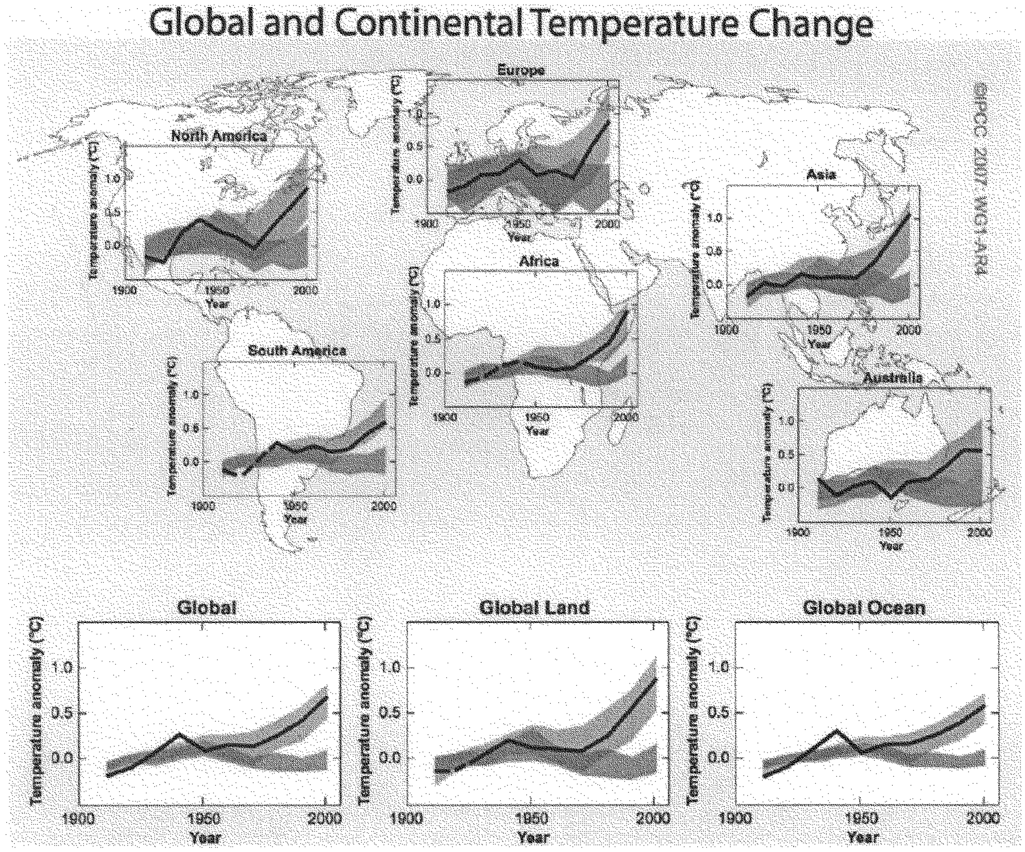


FIGURE SPM-4. Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906–2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. {FAQ 9.2, Figure 1}

Analyses of paleoclimate data increase confidence in the role of external influences on climate. The GCMs used to predict future climate provide insight into past climatic conditions of the Last Glacial Maximum and the mid-Holocene. While many aspects of these past climates are still uncertain, climate models reproduce key features by using boundary conditions and natural forcing factors for those periods. The IPCC AR4 concluded that a substantial fraction of the reconstructed Northern Hemisphere inter-decadal temperature variability of the seven centuries prior to 1950 is *very likely* attributable to natural external forcing, and it is *likely* that anthropogenic forcing contributed to the early 20th-century warming evident in these records (IPCC 2007).

Comment 33: Current climate patterns are part of the natural cycle and reflect natural variability.

Our response: Considered on a global scale, climate is subject to an inherent degree of natural variability. However, evidence of human influence on the recent evolution of climate has accumulated steadily during the past two decades. The IPCC AR4 has concluded that (1) most of the observed increase in globally-averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations; and (2) it is *likely* there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica) (IPCC 2007, p. 60).

Comment 34: There was a selective use of climate change information in the proposed rule, and the analysis ignored climate information about areas that are cooling.

Our response: We acknowledge that climate change and its effects on various physical processes (such as ice formation and advection, snowfall, precipitation) vary spatially and temporally, and that this has been considered in our analysis. While GCMs are more effective in characterizing climate change on larger scales, we have considered that the changes and effects are not uniform in their timing, location, or magnitude such as identified by Laidre et al. (2005) and Zhang and Walsh (2006). Indeed, the region southwest of Greenland does not show substantial warming by 2050 according to some climate projections. However, most polar bear habitat regions do show the substantial loss of sea ice by 2040–2050. While regional differences in climate change exist, this will not change the effect of climatic warming anticipated to occur within the foreseeable future within the range of polar bears. Updated information on regional climate variability has been added to the section ''Overview of Arctic Sea Ice Change.''

Comment 35: The world will be cooler by 2030 based on sunspot cycle phenomena, which is the most important determinant of global warming (e.g., Soon et al. 2005; Jiang et al. 2005).

Our response: The issue of solar influences, including sunspots, in climate change has been considered by many climate scientists, and there is considerable disagreement about any large magnitude of solar influences and their importance (Bertrand et al. 2002; IPCC 2007). The most current synthesis of the IPCC (AR4, p. 30) describes a well established, 11-year cycle with no significant long term trend based on new data obtained through significantly improved measurements over a 28-year period. Solar influence is considered in the IPCC models and is a small effect relative to volcanoes and CO_2 forcing in the later half of the 20th century. While more complex solar influences due to cosmic ray/ionosphere/cloud connections have been hypothesized, there is no clear demonstration of their having a large effect.

Comment 36: The IPCC report fails to give proper weight to the geological context and relationship to climate change.

Our response: Paleoclimatic events were analyzed in the IPCC AR4, which concluded that ''Confidence in the understanding of past climate change and changes in orbital forcing is strengthened by the improved ability of current models to simulate past climate conditions.'' Model results indicate that the Last Glacial Maximum (about 21,000 years ago) and the mid-Holocene (6,000 years ago) were different from the current climate not because of random variability, but because of altered seasonal and global forcing linked to known differences in the Earth's orbit. This additional information has been incorporated in this final rule.

Comment 37: Movement of sea ice from the Arctic depends on the Aleutian Low, Arctic Oscillation (AO), North Atlantic Oscillation (NAO), and Pacific Decadal Oscillation (PDO) rather than GHG emissions.

Our response: Sea ice is lost from the Arctic by a combination of dynamic and thermodynamic mechanisms. Not only is it lost by advection, but lost as a result of changes in surface air and water temperatures. Changes in surface air temperature are strongly influenced by warming linked to GHG emissions, while increases in water temperature are influenced by warming, the sea ice-albedo feedback mechanism, and the influx of warmer subpolar waters (largely in the North Atlantic) (Serreze et al. 2007). Recent studies (IPCC 2007, p. 355; Stroeve et al 2007; Overland and Wang 2007a, pp. 1–7) recognize considerable natural variability in the pattern of sea ice motion relative to the AO, NAO, and PDO, which will continue into the 21st century. However, the distribution of sea ice thickness is a factor in the amount of sea ice that is advected from the Arctic, and this distribution is significantly affected by surface air and water temperature.

Comment 38: Changes in the sea ice extent vary throughout the Arctic but overall extent has not changed in past 50 years.

Our response: All observational data collected since the 1950s points to a decline in both Arctic sea ice extent and area, as well as an increasing rate of decline over the past decade. While sea ice cover does have a component of natural variability, such variability does not account for the influence that increased air and water temperatures will have on sea ice in the future. The pattern of natural variability will continue, but will be in conjunction with the overall declining trend due to warming, and the combination could result in abrupt declines in sea ice cover faster than would be expected from GHG warming alone.

Comment 39: Evidence that does not support climate change was not included in the analyses.

Our response: We recognize that there are scientific differences of opinion on many aspects of climate change, including the role of natural variability in climate and also the uncertainties involved with both the observational record and climate change projections based on GCMs. We have reviewed a wide range of documents on climate change, including some that espouse the view that the Earth is experiencing natural cycles rather than directional climate change (e.g., Damon and Laut 2004; Foukal et al. 2006). We have consistently relied on synthesis documents (e.g., IPCC AR4; ACIA) that present the consensus view of a very large number of experts on climate change from around the world. We have found that these synthesis reports, as well as the scientific papers used in those reports or resulting from those reports, represent the best available scientific information we can use to inform our decision and have relied upon them and provided citation within our analysis.

Comment 40: Current conditions, based on past variation in Arctic sea ice and air temperatures, are by no means unprecedented and consequently the survival of polar bears and other marine mammals is not of concern.

Our response: We acknowledge that previous warming events (e.g., the Last Interglacial period (LIG), Holocene Thermal Maximum (HTM)) likely affected polar bears to some unknown degree. The fact that polar bears survived these events does not mean that they are not being affected by current sea ice and temperature changes. Indeed, the best available scientific information indicates that several populations are currently being negatively affected, and projections indicate that all populations will be negatively affected within the foreseeable future, such that the species will be in danger of extinction throughout all or a significant portion of its range within that timeframe. We have included additional information regarding previous warming events and an explanation of potential for polar bears to adapt in the section ''Effects of Sea Ice Habitat Changes on Polar Bear Prey.''

We agree that there is considerable natural variability and region-to-region differences in sea ice cover as documented by numerous journal articles and other references (Comiso 2001; Omstedt and Chen 2001; Jevrejeva 2001; Polyakov et al. 2003; Laidre and Heide-Jorgensen 2005). However, current conditions are unprecedented (IPCC 2007, p. 24). Climate scientists agree that atmospheric concentrations of

CO_2 and CH_4 far exceed the natural range over the last 650,000 years. The rate of growth in atmospheric concentration of GHGs is considered unprecedented (IPCC 2007, p. 24). The recent publication by Canadell et al. (2007) indicates that the growth rate of atmospheric CO_2 is increasing rapidly. An increasing CO_2 concentration is consistent with results of climate-carbon cycle models, but the magnitude of the observed atmospheric CO_2 concentration appears larger than that estimated by models. The authors suggest that these changes characterize a carbon cycle that is generating stronger-than-expected and sooner-than-expected climate forcing. What also is unprecedented is the potential for continued sea ice loss into the 21st century based on the physics of continued warming due to external forcing, and the accelerated impact of the ice albedo feedback as more open water areas open. Consideration of future loss of sea ice does not depend only on the sea ice observational record by itself. However, current sea ice loss, which now averages about 10 percent per decade over the last 25 years, plus the extreme loss of summer sea ice in 2007, is a warning sign that significant changes are underway, and data indicate that these extremes will continue into the foreseeable future.

Issue 6: Regulatory Mechanisms

Comment 41: Treaties, agreements, and regulatory mechanisms for population management of polar bears exist and are effective; thus there is no need to list the species under the Act.

Our response: The Service recognizes that existing polar bear management regulatory mechanisms currently in place have been effective tools in the conservation of the species; the ability of the species as a whole to increase in numbers from low populations, as discussed in our response to Comment 1, associated with over-hunting pressures of the mid 20th century attest to such effectiveness. As discussed under Factor D, there is a lack of regulatory mechanisms to address the loss of habitat due to reductions in sea ice. We acknowledge that progress is being made, and may continue to be made, to address climate change resulting from human activity; however, the current and expected impact to polar bear habitat indicates that in the foreseeable future, as defined in this rule, such efforts will not ameliorate loss of polar bear habitat or numbers of polar bears.

Comment 42: The Service did not consider existing local, State, National, and International efforts to address climate change (e.g., the Kyoto Protocol or United Nations Framework Convention on Climate Change) and is incorrect in concluding that there are no known regulatory mechanisms effectively addressing reductions in sea ice habitat. Furthermore, the Service failed to consider the probability of a global response to growing demands to deal with global climate change.

Our response: We have included discussion of domestic and international efforts to address climate change in the ''Inadequacy of Existing Regulatory Mechanisms'' (Factor D) section. While we note various efforts are ongoing, we conclude that such efforts have not yet proven to be effective at preventing loss of sea ice. The Service's ''Policy for Evaluation of Conservation Efforts When Making Listing Decisions'' (68 FR 15100) provides guidance for analyzing future conservation efforts and requires that the Service only rely on efforts that we have found will be both implemented and effective. While we note that efforts are being made to address climate change, we are unaware of any programs currently being shown to effectively reduce loss of polar bear ice habitat at a local, regional, or Arctic-wide scale.

Comment 43: The Service should evaluate the recent Supreme Court ruling that the U.S. Environmental Protection Agency (EPA) has the authority under the Clean Air Act to regulate GHGs.

Our response: The Service recognizes the leading role the EPA plays in implementing the Clean Air Act. However, specific considerations regarding the recent Supreme Court decision are beyond the scope of this decision.

Comment 44: The effort to list the polar bear is an inappropriate attempt to regulate GHG emissions. Any decision to limit GHG emissions should be debated in the open and not regulated through the ''back door'' by the Act.

Our response: The Service was petitioned to evaluate the status of polar bears under the Act. In doing so, we evaluated the best scientific and commercial information available on present and foreseeable future status of polar bears and their habitat as required by the Act. The role of the Service is to determine the appropriate biological status of the polar bear and that is the scope of this rule. Some commenters to the proposed rule suggested that the Service should require other agencies (e.g., the EPA) to regulate emissions from all sources, including automobiles and power plants. The science, law, and mission of the Service do not lead to such action. Climate change is a worldwide issue. A direct causal link between the effects of a specific action and ''take'' of a listed species is well beyond the current level of scientific understanding (see additional discussion of this topic under the ''Available Conservation Measures'' section).

Comment 45: Listing of the polar bear is more about the politics of global climate change than biology of polar bears.

Our response: The Service was petitioned to list polar bears under the Act and we evaluated the best available scientific and commercial information available on threats to polar bears and their habitat as required by the Act. The role of the Service is to determine the appropriate status of the polar bear under the Act, and that is the scope of this rule.

Issue 7: Listing Justification

Comment 46: Justification for listing is insufficient or limited to few populations, and thus range-wide listing is not warranted.

Our response: This document contains a detailed evaluation of the changing sea ice environment and research findings that describe the effect of environmental change on the declining physical condition of polar bears, corresponding declines in vital rates, and declines in population abundance. We acknowledge that the timing, rate and magnitude of impacts will not be the same for all polar bear populations. However, the best available scientific information indicates that several populations are currently being negatively affected, and projections indicate that all populations will be negatively affected within the foreseeable future, such that the species will be in danger of extinction throughout all or a significant portion of its range within that timeframe.

Since the proposed rule was published (72 FR 1064), the USGS completed additional analyses of population trajectories for the Southern Beaufort Sea population (Hunter et al. 2007), and updated population estimates for the Northern Beaufort Sea (Stirling et al. 2007) and Southern Hudson Bay (Obbard et al. 2007) populations (summarized in the ''Background'' section of this final rule). The USGS also has conducted additional modeling of habitat resource selection in a declining sea ice environment (Durner et al. 2007), and an evaluation of the levels of uncertainty or likelihood of outcomes for a variety of climate models (DeWeaver 2007). Information from these recent USGS analyses is included and cited within this rule and balanced with other published information evaluating current and projected polar bear status. In addition, since the publication of the proposed rule (72 FR 1064), the IPCC AR4 and numerous other publications related to climate change and modeled climate projections have become available in published form and are now included and cited within this rule.

We considered whether listing particular Distinct Population Segments (DPSs) is warranted, but we could not identify any geographic areas or populations that would qualify as a DPS under our 1996 DPS Policy (61 FR 4722), because there are no population segments that satisfy the criteria of the DPS Policy.

Finally, we analyzed the status of polar bears in portions of its range to determine if differential threat levels in those areas warrant a determination that the species is endangered rather than threatened in those areas. The overall direction and magnitude of threats to polar bears lead us to conclude that the species is threatened throughout its range, and that there are no significant portions of the range where the polar bear would be considered currently in danger of extinction.

On the basis of all these analyses, we have concluded that the best available scientific information supports a determination that the species is threatened throughout all of its range.

Comment 47: Traditional ecological knowledge (TEK) does not support the conclusion that polar bear populations are declining and negatively impacted by climate change.

Our response: We acknowledge that TEK may provide a relevant source of information on the ecology of polar bears obtained through direct individual observations. We have expanded and incorporated additional discussion of TEK into our determination. Additionally, we have received and reviewed comments from individuals with TEK on both climate change and polar bears. While there may be disagreement among individuals on the impacts of climate change on polar bears, we believe there is general scientific consensus that sea ice environment is diminishing.

Comment 48: Cannibalism, starvation, and drowning are naturally occurring events and should not be inferred as reasons for listing.

Our response: We agree that cannibalism, starvation, and drowning occur in nature; however, we have not found that these are mortality factors that threaten the species throughout all or a significant portion of its range. Rather, we find that recent research findings have identified the unusual nature of some reported mortalities, and that these events serve as indicators of stressed populations. The occurrence and anecdotal observation of these events and potential relationship to sea ice changes is a current cause for concern. In the future, these events may take on greater significance, especially for populations that may be experiencing nutritional stress or related changes in their environment.

Comment 49: The Service did not adequately consider polar bear use of marginal ice zones in the listing proposal.

Our response: Due to the dynamic and cyclic nature of sea ice formation and retreat, marginal ice zones occur on an annual basis within the circumpolar area and indeed are important habitat for polar bears. The timing of occurrence, location, and persistence of these zones over time are important considerations because they serve as platforms for polar bears to access prey. Marginal ice zones that are associated with shallow and productive nearshore waters are of greatest importance, while marginal ice zones that occur over the deeper, less productive central Arctic basin are not believed to provide values equivalent to the areas nearshore. New information on polar bear habitat selection and use (Durner et al. 2007) is included in this rule's sections ''Polar Bear-Sea Ice Habitat Relationships'' and ''Effects of Sea Ice Habitat Change on Polar Bears.''

Comment 50: The effects of climate change on polar bears will vary among populations.

Our response: We recognize that the effects of climate change will vary among polar bear populations, and have discussed those differences in detail in this final rule. We have determined that several populations are currently being negatively affected, and projections indicate that all populations will be negatively affected within the foreseeable future. Preliminary modeling analyses of future scenarios using a new approach (the Bayesian Network Model) describe four ''ecoregions'' based on current and projected sea ice conditions (Amstrup et al. 2007); a discussion of these analyses is included in Factor A of the ''Summary of Factors Affecting the Species.'' Consistent with other projections, the preliminary model projects that southern populations with seasonal ice-free conditions and open Arctic Basin populations in areas of ''divergent'' sea ice will be affected earliest and to the greatest extent,while populations in the Canadian archipelago populations and populations in areas of ''convergent ''sea ice'' will be affected later and to a lesser extent. These model projections indicate that impacts will happen at different times and rates in different regions. On the basis of the best available scientific information derived from this preliminary model and other extensive background information, we conclude that the species is not currently in danger of extinction throughout all or a significant portion of its range, but is very likely to become so within the foreseeable future. We have not identified any areas or populations that would qualify as Distinct Population Segments under our 1996 DPS Policy, or any significant portions of the polar bear's range that would qualify for listing as endangered (see response to Comment 47).

Comment 51: The 19 populations the Service has identified cannot be thought of as discrete or stationary geographic units, and polar bears should be considered as one Arctic population.

Our response: We agree that the boundaries of the 19 populations are not static or stationary. Intensive scientific study of movement patterns and genetic analysis reinforces boundaries of some populations while confirming that overlap and mixing occur among others. Neither movement nor genetic information is intended to mean that the boundaries are absolute or stationary geographic units; instead, they most accurately represent discrete functional management units based on generalized patterns of use.

Comment 52: The Service should evaluate the status of the polar bear in significant portions of the range or distinct population segments, due to regional differences in climate parameters, and therefore the response of polar bears.

Our response: We analyzed the status of polar bears by population and region in the section ''Demographic Effects of Sea Ice Changes on Polar Bear'' and considered how threats may differ between areas. We recognize that the level, rate, and timing of threats will be uneven across the Arctic and, thus, that polar bear populations will be affected at different rates and magnitudes depending on where they occur. We find that, although habitat (i.e., sea ice) changes may occur at different rates, the direction of change is the same. Accepted climate models (IPCC AR4 2007; DeWeaver 2007), based on their ability to simulate present day ice patterns, all project a unidirectional loss of sea ice. Similarly, new analyses of polar bear habitat distribution in the polar basin projected over time (Durner et al. 2007) found that while the rate of change in habitat varied between GCMs, all models projected habitat loss in the polar basin within the 45-year foreseeable future timeframe. Therefore, despite the regional variation in changes and response, we find that the primary threat (loss of habitat) is occurring and is projected to continue to occur throughout the Arctic. In addition, the USGS also examined how the effects of climate change will vary across time and space; their model projections also indicate that impacts will happen at different times and rates in different regions (Amstrup et al. 2007).

Recognizing the differences in the timing, rate, and magnitude of threats, we evaluated whether there were any specific areas or populations that may be disproportionately threatened such that they currently meet the definition of an endangered species versus a threatened species. We first considered whether listing one or more Distinct Population Segments (DPS) as endangered may be warranted. We then considered whether there are any significant portions of the polar bear's range (SPR) where listing the species as endangered may be warranted. In evaluating current status of all populations and projected sea ice changes and polar bear population projections, we were unable to identify any distinct population segments or significant portions of the range of the polar bear where the species is currently in danger of extinction. Rather, we have concluded that the polar bear is likely to become an endangered species throughout its range within the foreseeable future. Thus, we find that threatened status throughout the range is currently the most appropriate listing under the Act.

Comment 53: One commenter asserted that the best available scientific information indicates that polar bear populations in two ecoregions defined by Amstrup et al. (2007)—the Seasonal Ice ecoregion and the polar basin Divergent ecoregion—should be listed as endangered.

Our response: We separately evaluated whether polar bear populations in these two ecoregions qualify for a different status than polar bears in the remainder of the species' range. We determined that while these polar bears are likely to become in danger of extinction within the foreseeable future, they are not currently in danger of extinction. See our analysis in the section ''Distinct Population Segment (DPS) and Significant Portion of the Range (SPR) Evaluation.''

Comment 54: There is insufficient evidence to conclude that the polar bear will be threatened or extinct within three generations as no quantitative analysis or models of population numbers (or prey abundance) are offered.

Our response: New information on population status and trends for the Southern Beaufort Sea (Hunter et al. 2007; Regehr et al. 2007b) and updated population estimates for the Northern Beaufort Sea (Stirling et al. 2007) and Southern Hudson Bay (Obbard et al. 2007) populations is included in this rule along with range-wide population projections based on polar bear ecological relationship to sea ice and to changes in sea ice over time (Amstrup et al. 2007). These studies, plus the IPCC AR4, and additional analyses of climate change published within the last year, have added substantially to the final rule. Taken together, the new information builds on previous analyses to provide sufficient evidence to demonstrate that: (1) polar bears are sea ice-dependent species; (2) reductions in sea ice are occurring now and are very likely to continue to occur within the foreseeable future; (3) the linkage between reduced sea ice and population reductions has been established; (4) impacts on polar bear populations will vary in their timing and magnitude, but all populations will be affected within the foreseeable future; and (5) the rate and magnitude of the predicted changes in sea ice will make adaptation by polar bears unrealistic. On these bases, we have determined that the polar bear is not currently in danger of extinction throughout all or a significant portion of its range, but is likely to become so within the foreseeable future.

Comment 55: Perceptions differ as to whether polar bear populations will decline with loss of sea ice habitat.

Our response: Long-term data sets necessary to establish the linkage between population declines and climate change do not exist for all polar bear populations within the circumpolar Arctic. However, the best available scientific information indicates a link between polar bear vital rates or population declines and climate change. For two populations with extensive time series of data, Western Hudson Bay and Southern Beaufort Sea, either the population numbers or survival rates are declining and can be related to reductions in sea ice. In addition, scientific literature indicates that the Davis Strait, Baffin Bay, Foxe Basin, and the Eastern and Western Hudson Bay populations are expected to decline significantly in the foreseeable future based on reductions of sea ice projected in Holland et al. (2006, pp. 1–5). Additional population analyses (Regehr et al. 2007a, b; Hunter et al. 2007; Obbard et al. 2007) that further detail this relationship have been recently completed and are included in this final rule.

Comment 56: Factors supporting listing are cumulative and thus are unlikely to be quickly reversed. Polar bears are likely to become endangered within one to two decades.

Our response: We have concluded that habitat loss (Factor A) is the primary factor that threatens the polar bear throughout its range. We have also determined that there are no known regulatory mechanisms in place, and none that we are aware of that could be put in place, at the national or international level, that directly and effectively address the rangewide loss of sea ice habitat within the foreseeable future (Factor D). However, we have also concluded that other factors (e.g., overutilization) may interact with and exacerbate these primary threats (particularly habitat loss) within the 45-year foreseeable future.

Polar bear populations are being affected by habitat loss now, and will continue to be affected within the foreseeable future. We do not believe that the species is currently endangered, but we believe it is likely that the species will become endangered during the foreseeable future given current and projected trends; see detailed discussion under Factor A in the section ''Demographic Effects of Sea Ice Changes on Polar Bear''. We intend to continue to evaluate the status of polar bears and will review and amend the status determination if conditions warrant. Through 5-year reviews and international circumpolar monitoring, we will closely track the status of the polar bear over time.

Comment 57: Polar bears face unprecedented threats from climate change, environmental degradation, and hunting for subsistence and sport.

Our response: We agree in large part as noted in detail within this final rule, but clarify that hunting for subsistence or sport does not currently threaten the species in all or a significant portion of its range, and where we have concerns regarding the harvest we are hopeful that existing or newly established regulatory processes, e.g., the recently adopted Bilateral Agreement, will be adequate to ensure that harvest levels are sustainable and can be adjusted as our knowledge of population status changes over time. Please see the ''Summary of Factors Affecting the Polar Bear'' for additional discussion of these issues.

Issue 8: Listing Process

Comment 58: Listing the polar bear under the Act should be delayed until reassessment of the status of the species under Canada's Species at Risk Act (SARA) is completed.

Our response: When making listing decisions, section 4 of the Act establishes firm deadlines that must be followed, and does not allow for an extension unless there is substantial scientific disagreement regarding the sufficiency or accuracy of relevant data. Section 4(b) directs the Secretary to take into account any efforts being made by any State or foreign nation to protect the species under consideration; however, the Act does not allow the Secretary to defer a listing decision pending the outcome of any such efforts. The status of the polar bear under Canada's SARA is discussed under Factor D.

Comment 59: The Act was not designed to list species based on future status.

Our response: We agree. We have determined that the polar bear's current status is that it is ''likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.'' This is the definition of a threatened species under the Act, and we are accordingly designating the species as threatened.

Comment 60: Use of the IUCN Red Listing criteria for a listing determination under the Act is questionable, and should not be used.

Our response: While we may consider the opinions and recommendations of other experts (e.g., IUCN), the determination as to whether a species meets the definition of threatened or endangered must be made by the Service, and must be based upon the criteria and standards in the Act. After reviewing the best available scientific and commercial information, we have determined that the polar bear is threatened throughout its range, based upon an assessment of threats according to section 4 of the Act. While some aspects of our determination may be in line with the IUCN Red List criteria (e.g., we used some Red List criteria for determination of generation time), we have not used the Red List criteria as a standard for our determination. Rather, in accordance with the Act, we conducted our own analyses and made our own determination based on the beast available information. Please see the ''Summary of Factors Affecting the Species'' section for in-depth discussion.

Comment 61: The peer review process is flawed due to biases of the individual peer reviewers.

Our response: We conducted our peer review in accordance with our policy published on July 1, 1994 (59 FR 34270), and based on our implementation of the OMB Final Information Quality Bulletin for Peer Review, dated December 16, 2004. Peer reviewers were chosen based upon their ability to provide independent review, their standing as experts in their respective disciplines as demonstrated through publication of articles in peer reviewed or referred journals, and their stature promoting an international cross-section of views. Please see ''Peer Review'' section above for additional discussion.

Peer review comments are available to the public and have been posted on the Service's web site at: *http://alaska.fws.gov/fisheries/mmm/polarbear/issues.htm.* In addition to peer review comments, the Service also provides an open public comment process to ensure in part that any potential issues of bias are specifically identified to allow for the issue to be evaluated for merit. In our analysis of peer review and public comments we find that peer review comments were objective, balanced and without bias.

Comment 62: Requests were received for additional public hearings and extension of the public comment period.

Our response: Procedures for public participation and review in regard to proposed rules are provided at section 4(b)(5) of the Act, 50 CFR 424, and the Administrative Procedure Act (5 U.S.C. 551 et seq.)(APA). We are obligated to hold at least one public hearing on a listing proposal, if requested to do so within 45 days after the publication of the proposal (16 U.S.C. 1533(b)(5)(E)). As described above, in response to requests from the public, we held three public hearings. We were not able to hold a public hearing that could be easily accessed by each and every requester, as we received comments from throughout the United States and many other countries. We accepted and considered oral comments given at the public hearings, and we incorporated those comments into the administrative record for this action. In making our decision on the proposed rule, we gave written comments the same weight as oral comments presented at hearings. Furthermore, our regulations require a 60-day comment period on proposed rules (50 CFR 424.16(c)(2)), but the initial public comment period on the proposed rule to list the polar bear was open from January 9 to April 9, 2007, encompassing approximately 90 days. The comment period was reopened for comments on new scientific information from September 20 through October 22, 2007, an extra 32 days. We believe the original 90-day comment period, three public hearings, and second public comment period provided ample opportunity for public comment, as intended under the Act, our regulations, and the APA.

Comment 63: The Service's conclusion that this regulatory action does not constitute a significant energy action and that preparation of a ''Statement of Energy Effects'' is not required is flawed.

Our response: In 1982, the Act was amended by the United States Congress to clarify that listing and delisting determinations are to be based on the best scientific and commercial data available (Pub. L. 97–304, 96 Stat. 1411) to clarify that the determination was intended to be a biological decision and made without reference to economic or other non-biological factors. The specific language from the accompanying House Report (No. 97–567) stated, ''The principal purpose of the amendments to Section 4 is to ensure that decisions pertaining to the listing and delisting of species are based solely upon biological criteria and to prevent non-biological considerations from affecting such decisions.'' Further as noted in another U.S. House of Representatives Report, economic considerations have no relevance to determinations regarding the status of the species and the economic analysis requirements of Executive Order 12291, and such statutes as the Regulatory Flexibility Act and Paperwork Reduction Act, will not apply to any phase of the listing process.'' (H.R. Rep. No 835, 97th Cong., Sess. 19 (1982)). On the basis of the amendments to the Act put forth by Congress in 1982 and Congressional intent as evidenced in the quotation above, we have determined that the provisions of Executive Order 13211 ''Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use'' (66 FR 28355), do not apply to listing and delisting determinations under section 4 of the Act because of their economic basis. Therefore, Executive Order 13211 does not apply to this determination to list the polar bear as threatened throughout its range.

Comment 64: There is insufficient information to proceed with a listing, and thus our proposal was arbitrary and capricious.

Our response: Under the APA, a court may set aside an agency rulemaking if found to be, among other things, ''arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law'' (5 U.S.C. 706(2)(A)). The Endangered Species Act requires that listing decisions be based solely on the best scientific and commercial information available. We have used the best available scientific information throughout our analysis, and have taken a number of steps-as required by the Act and its implementing regulations, the APA, and our peer review policy—to ensure that our analysis of the available information was balanced and objective. The evaluation of information contained within the final rule and all other related documents (e.g., the Status Review (Schliebe et al. 2006a) is a result of multiple levels of review and validation of information. We sought peer review and public comment, and incorporated all additional information received through these processes, where applicable. These steps were transparent and made available to the public for inspection, review, and comment. We have determined that the best available scientific and commercial information is sufficient to find that the polar bear meets the definition of a threatened species under the Act.

Comment 65: The Service did not comply with the Information Quality Act and with the Service's Information Quality Guidelines.

Our response: The Information Quality Act requires Federal agencies to ensure the quality, objectivity, utility, and integrity of the information they disseminate. ''Utility'' refers to the usefulness of the information to its intended users, and ''integrity'' pertains to the protection of the information from unauthorized access or revision. According to OMB guidelines (67 FR 8452), technical information that has been subjected to formal, independent, external peer review, as is performed by scientific journals, is presumed to be of acceptable objectivity. Literature used in the proposed rule was considered the best available peer-reviewed literature at the time. In addition, our proposed rule was peer-reviewed by 14 experts in the field of polar bear biology and climatology. In instances where information used in the proposed rule has become outdated, this final rule has been revised to reflect the most current scientific information. Despite being peer-reviewed, most scientific information has some limitations and statements of absolute certainty are not possible. In this rule, and in accordance with our responsibilities under the Act, we sought to provide a balanced analysis by considering all available information relevant to the status of polar bears and potential impacts of climate change and by acknowledging and considering the limitations of the information that provided the basis for our analysis and decision-making (see ''Summary of Factors Affecting the Polar Bear'' and ''Issue 5: Climate Change'' for more information).

Comment 66: National Environmental Policy Act (NEPA) compliance is lacking, and an Environmental Impact Statement is needed as this is a significant Federal action.

Our response: The rule is exempt from NEPA procedures. In 1983, upon recommendation of the Council on Environmental Quality, the Service determined that NEPA documents are not required for regulations adopted pursuant to section 4(a) of the Act. A notice outlining the Service's reasons for this determination was published in the **Federal Register** on October 25, 1983 (48 FR 49244). A listing rule provides the appropriate and necessary prohibitions and authorizations for a species that has been determined to be threatened under section 4(a) of the Act. The opportunity for public comments-one of the goals of NEPA-is also already provided through section 4 rulemaking procedures. This determination was upheld in *Pacific Legal Foundation* v. *Andrus,* 657 F.2d 829 (6th Cir. 1981).

Comment 67: The Service should fulfill its requirement to have regular and meaningful consultation and collaboration with Alaska Native organizations in the development of this Federal action.

Our response: As detailed in the preamble to this section of the final rule, we actively engaged in government-to-government consultation with Alaska Native Tribes in accordance with E.O. 13175 and Secretarial Order 3225. Since 1997, the Service has worked closely with the Alaska Nanuuq Commission (Commission) on polar bear management and conservation for subsistence purposes. Not only was the Commission kept fully informed throughout the development of the proposed rule, but that organization was asked to serve as a peer reviewer of the Status Review (Schliebe et al. 2006a) and the proposed rule (72 FR 1064). Following publication of the proposed rule, the Service actively solicited comments from Alaska Natives living within the range of the polar bear. We received comments on the proposed rule from seven tribal associations. We held a public hearing in Barrow, Alaska, to enable Alaska Natives to provide oral comment. We invited the 15 villages in the Commission to participate in the hearing, and we offered the opportunity to provide oral comment via teleconference. Thus, we believe we have fulfilled our requirement to have regular and meaningful consultation and collaboration with Alaska Native organizations in the development of this final rule.

Comment 68: An Initial Regulatory Flexibility Analysis (IRFA) should be completed prior to the publication of a final rule.

Our response: Under the Regulatory Flexibility Act (5 U.S.C. 601 et seq., as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996), an IRFA is prepared in order to describe the effects of a rule on small entities (small businesses, small organizations, and small government jurisdictions). An IRFA is not prepared in a listing decision because we consider only the best available scientific information and do not consider economic impacts (please see response to Comment 70 for additional discussion).

Comment 69: Some commenters stated that the Service should designate critical habitat concurrent with this rulemaking; however, several other commenters disagreed.

Our response: Section 4(a)(3) of the Act requires that, to the maximum extent prudent and determinable, the Secretary designate critical habitat at the time the species is listed. Accordingly, we are not able to forego the process of designating critical habitat when doing so is prudent and critical habitat is determinable. Service regulations (50 CFR 424.12(a)) state that critical habitat is not determinable if information sufficient to perform required analyses of the impacts of designation is lacking or if the biological needs of the species are not sufficiently well known to permit identification of an area as critical habitat. Given the complexity and degree of uncertainty at this time as to which specific areas in Alaska might be essential to the conservation of the polar bear in the long-term under rapidly changing environmental conditions, we have determined that we will need additional time to conduct a thorough evaluation and peer review of a potential critical habitat designation. Thus, we are not publishing a proposed designation of critical habitat concurrently with this final listing rule, but we intend to publish a proposed designation in the very near future. Please see the ''Critical Habitat'' section below for further discussion.

Issue 9: Impacts of Listing

Comment 70: Several comments highlighted potential impacts of listing, such as economic consequences, additional regulatory burden, and conservation benefits. Other commenters noted that economic factors cannot be taken into consideration at this stage of the listing.

Our response: Under section 4(b)(1)(A) of the Act, we must base a listing decision solely on the best scientific and commercial data available. The legislative history of this provision clearly states the intent of Congress to ensure that listing decisions are ''* * * based solely on biological criteria and to prevent non-biological criteria from affecting such decisions * * *'' (see reponse to Comment PR8 for more details). Therefore, we did not consider the economic impacts of listing the polar bear. In our Notice of Interagency Cooperative Policy of Endangered Species Act Section 9 Prohibitions (59 FR 34272), we stated our policy to identify, to the extent known at the time a species is listed, specific activities that will not be considered likely to result in violation of section 9 of the Act. In accordance with that policy, we have published in this final rule a list of activities we believe will not result in violation of section 9 of the Act (see ''Available Conservation Measures'' section of this rule for further discussion). However, because the polar bear is listed as a threatened species and the provisions of section 4(d) of the Act authorize the Service to implement, by regulation, those measures included in section 9 of the Act that are deemed necessary and advisable to provide for the conservation of the species, please consult the special rule for the polar bear that is published in today's edition of the **Federal Register** for all of the prohibitions and exceptions that apply to this threatened species.

Comment 71: Several comments were received pertaining to the effectiveness of listing the polar bear under the Act, specifically whether listing would or would not contribute to the conservation of the species.

Our response: The potential efficacy of a listing action to conserve a species cannot be considered in making the listing decision. The Service must make its determination based on a consideration of the factors affecting the species, utilizing only the best scientific and commercial information available and is not able to consider other factors or impacts (see response to Comment 70 for additional discussion). Listing recognizes the status of the species and invokes the protection and considerations under the Act, including regulatory provisions, consideration of Federal activities that may affect the polar bear, potential critical habitat designation. The Service will also develop a recovery plan and a rangewide conservation strategy. Please see the responses to comments under ''Issue 10: Recovery'' as well as the ''Available Conservation Measures'' section of this rule for further discussion.

Comment 72: Listing under the Act may result in additional regulation of industry and development activities in the Arctic. A discussion of incidental take authorization should be included in the listing rule. Some comments reflected concern regarding the perceived economic implications of regulatory and administrative requirements stemming from listing.

Our response: Section 7(a)(2) of the Act, as amended, requires Federal agencies to consult with the Service to ensure that the actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of listed species. Informal consultation provides an opportunity for the action agency and the Service to explore ways to modify the action to reduce or avoid adverse effects to the listed species or designated critical habitat. In the event that adverse effects are unavoidable, formal consultation is required. Formal consultation is a process in which the Service determines if the action will result in incidental take of individuals, assesses the action's potential to jeopardize the continued existence of the species, and develops an incidental take statement. Formal consultation concludes when the Service issues a biological opinion, including any mandatory measures prescribed to reduce the amount or extent of incidental take of the action. In the case of marine mammals, the Service must also ensure compliance with regulations promulgated under section 101(a)(5) of the MMPA. Authorization of incidental take under the MMPA is discussed under Factor D. Actions that are already subject to section 7 consultation requirements in the Arctic, some of which may involve the polar bear, include, but are not limited to: Refuge operations and research permits; U.S. Army Corps of Engineers and Environmental Protection Agency permitting actions under the Clean Water Act and Clean Air Act; Bureau of Land Management land-use planning and management activities including onshore oil and gas leasing activities; Minerals Management Service administration of offshore oil and gas leasing activities; and Denali Commission funding of fueling and power generation projects.

Issue 10: Recovery

Comment 73: Several comments identified additional research needs related to polar bears, their prey, indigenous people, climate, and anthropogenic and cumulative effects on polar bears. Some specific recommendations include increased research and continued monitoring of polar bear populations and their prey, monitoring of polar bear harvest, and development of more comprehensive climate change models.

Our response: We agree that additional research would benefit the conservation of the polar bear. The Service will continue to work with the USGS, the State of Alaska, the IUCN/PBSG, independent scientists, indigenous people, and other interested parties to conduct research and monitoring on Alaska's shared polar bear populations. While the Service does not have appropriate resources or management responsibility for conducting climate research, we have and will continue to work with climatologists and experts from USGS, NASA, and NOAA to address polar bear-climate related issues. Furthermore, we will consider appropriate research and monitoring recommendations received from the public in the development of a rangewide conservation strategy.

Comment 74: Several commenters provided recommendations for recovery actions, to be considered both in addition to and in lieu of listing. Other commenters cited the need for immediate recovery planning and implementation upon completion of a final listing rule.

Our response: As discussed throughout this final rule, the Service has been working with Range countries on conservation actions for the polar bears for a number of years. Due to the significant threats to the polar bear's habitat, however, it is our determination that the polar bear meets the definition of a threatened species under the Act and requires listing. With completion of this final listing rule, the Service will continue and expand coordination with the Range countries regarding other appropriate international initiatives that would assist in the development of a rangewide conservation strategy. However, it must be recognized that the threats to the polar bear's habitat may only be addressed on a global level. Recovery planning under section 4(f) of the Act will be limited to areas under U.S. jurisdiction, since the preparation of a formal recovery plan would not promote the conservation of polar bears in foreign countries that are not subject to the implementation schedules and recovery goals established in such a plan. However, the Service will use its section 8 authorities to carry out conservation measures for polar bears in cooperation with foreign countries.

Summary of Factors Affecting the Polar Bear

Section 4 of the Act (16 U.S.C. 1533), and implementing regulations at 50 CFR part 424, set forth procedures for adding species to the Federal Lists of Endangered and Threatened Wildlife and Plants. Under section 4(a) of the Act, we may list a species on the basis of any of five factors, as follows: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence. In making this finding, the best scientific and commercial information available regarding the status and trends of the polar bear is considered in relation to the five factors provided in section 4(a)(1) of the Act.

In the context of the Act, the term ''endangered species'' means any species or subspecies or, for vertebrates, Distinct Population Segment (DPS), that is in danger of extinction throughout all or a significant portion of its range, and a ''threatened species'' is any species that is likely to become an endangered species within the foreseeable future. The Act does not define the term ''foreseeable future.'' For this final rule, we have identified 45 years as the foreseeable future for polar bears; our rationale for selecting this timeframe is presented in the following section.

Foreseeable Future

For this final rule, we have determined the ''foreseeable future'' in terms of the timeframe over which the best available scientific data allow us to reliably assess the effects of threats on the polar bear.

The principal threat to polar bears is the loss of their primary habitat-sea ice. The linkage between habitat loss and corresponding effects on polar bear populations was hypothesized in the past (Budyko 1966, p. 20; Lentfer 1972, p. 169; Tynan and DeMaster 1997, p. 315; Stirling and Derocher 1993, pp. 241–244; Derocher et al. 2004, p. 163), but is now becoming well established through long-term field studies that span multiple generations (Stirling et al. 1999, pp. 300–302; Stirling and Parkinson 2006, pp. 266–274; Regehr et al. 2006; Regehr et al. 2007a, 2007b; Rode et al. 2007, pp. 5–8; Hunter et al. 2007, pp. 8–14; Amstrup et al. 2007).

The timeframe over which the best available scientific data allows us to reliably assess the effect of threats on the species is the critical component for determining the foreseeable future. In the case of the polar bear, the key threat is loss of sea ice, the species' primary habitat. Sea ice is rapidly diminishing throughout the Arctic, and the best available evidence is that Arctic sea ice will continue to be affected by climate change. Recent comprehensive syntheses of climate change information (e.g., IPCC AR4) and additional modeling studies (e.g., Overland and Wang 2007a, pp. 1–7; Stroeve et al. 2007, pp. 1–5) show that, in general, the climate models that best simulate Arctic conditions all project significant losses of sea ice over the 21st century. A key issue in determining what timeframe to use for the foreseeable future has to do with the uncertainty associated with climate model projections at various points in the future. Virtually all of the climate model projections in the AR4 and other studies extend to the end of the 21st century, so we considered whether a longer timeframe for the foreseeable future was appropriate. The AR4 and other studies help clarify the scientific uncertainty associated with climate change projections, and allow us to make a more objective decision related to the timeframe over which we can reliably assess threats.

Available information indicates that climate change projections over the next 40–50 years are more reliable than projections over the next 80–90 years. This is illustrated in Figure 5 above. Examination of the trend lines for temperature using the three emissions scenarios, as shown in Figure 5, illustrates that temperature increases over the next 40–50 years are relatively insensitive to the SRES emissions scenario used to model the projected change (i.e., the lines in Figure 5 are very close to one another for the first 40–50 years). The ''limited sensitivity'' of the results is because the state-of-the-art climate models used in the AR4 have known physics connecting increases in GHGs to temperature increases through radiation processes (Overland and Wang 2007a, pp. 1–7, cited in J. Overland, NOAA, in litt. to the Service, 2007), and the GHG levels used in the SRES emissions scenarios follow similar trends until around 2040–2050. Because increases in GHGs have lag effects on climate and projections of GHG emissions can be extrapolated with greater confidence over the next few decades, model results projecting out for the next 40–50 years (near-term climate change estimates) have greater credibility than results projected much further into the future (long-term climate change) (J. Overland, NOAA, in litt. to the Service, 2007). Thus, the uncertainty associated with emissions is relatively smaller for the 45-year ''foreseeable future'' for the polar bear listing. After 2050, greater uncertainty associated with various climate mechanisms, including the carbon cycle, is reflected in the increasingly larger confidence intervals around temperature trend lines for each of the SRES emissions scenarios (see Figure 5). In addition, beyond 40–50 years, the trend lines diverge from one another due to differences among the SRES emissions scenarios. These SRES scenarios diverge because each makes different assumptions about the effects that population growth, potential technological improvements, societal and regulatory changes, and economic growth have on GHG emissions, and those differences are more pronounced after 2050. The divergence in the lines beyond 2050 is another source of uncertainty in that there is less confidence in what changes might take place to affect GHG emissions beyond 40–50 years from now.

The IPCC AR4 reaches a similar conclusion about the reliability of projection results over the short term (40–50 years) versus results over the long term (80–90 years) (IPCC 2007, p. 749) in discussing projected changes in surface air temperatures (SATs):

> ''There is close agreement of globally averaged SAT multi-model mean warming for the early 21st century for concentrations derived from the three non-mitigated IPCC Special Report on Emission Scenarios (SRES: B1, A1B and A2) scenarios (including only anthropogenic forcing) run by the AOGCMs * * * this warming rate is affected little by different scenario assumptions or different model sensitivities, and is consistent with that observed for the past few decades * * *. Possible future variations in natural forcings (e.g., a large volcanic eruption) could change those values somewhat, but about half of the early 21st-century warming is committed in the sense that it would occur even if atmospheric concentrations were held fixed at year 2000 values. By mid-century (2046–2065), the choice of scenario becomes more important for the magnitude of multi-model globally averaged SAT warming * * *. About a third of that warming is projected to be due to climate change that is already committed. By late century (2090–2099), differences between scenarios are large, and only about 20% of that warming arises from climate change that is already committed.''

On the basis of our analysis, reinforced by conclusions of the IPCC AR4, we have determined that climate changes projected within the next 40–50 years are more reliable than projections for the second half of the 21st century.

The 40–50 year timeframe for a reliable projection of threats to habitat corresponds closely to the timeframe of three polar bear generations (45 years), as determined by the method described in the following paragraph. Long-term studies have demonstrated, and world experts (e.g., PBSG) are in agreement, that three generations is an appropriate timespan to use to reliably assess the status of the polar bear and the effects of threats on population-level parameters (e.g., body condition indices, vital rates, and population numbers). This is based on the life history of the polar bear, the large natural variability associated with polar bear population processes, and the capacity of the species for ecological and behavioral adaptation (Schliebe et al. 2006a, pp. 59–60). Although not relied on as the basis for determining ''foreseeable future'' in this rule, the correspondence of this timeframe with important biological considerations provides greater confidence for this listing determination.

Polar bears are long-lived mammals, and adults typically have high survival rates. Both sexes can live 20 to 25 years (Stirling and Derocher 2007), but few polar bears in the wild live to be older than 20 years (Stirling 1988, p. 139; Stirling 1990, p. 225). Due to extremely low reproductive rates, polar bears require a high survival rate to maintain population levels. Survival rates increase up to a certain age, with cubs-of-the-year having the lowest rates and prime age adults (between 5 and 20 years of age) having survival rates that can exceed 90 percent. Generation length is the average age of parents of the current cohort; generation length therefore reflects the turnover rate of breeding individuals in a population. We adapted the criteria of the IUCN Red List process (IUCN 2004) for determining polar bear generation time in both the proposed rule (72 FR 1064) and this final rule. A generation span, as defined by IUCN, is calculated as the age of sexual maturity (5 years for polar bears) plus 50 percent of the length of the lifetime reproductive period (20 years for polar bears). The IUCN Red List process also uses a three-generation timeframe ''to scale the decline threshold for the species'' life history'' (IUCN 2004), recognizing that a maximum time cap is needed for assessments based on projections into the future because ''the distant future cannot be predicted with enough certainty to justify its use'' in determining whether a species is threatened or endangered. Based on these criteria, the length of one generation for the polar bear is 15 years, and, thus, three generations are 45 years.

The appropriate timeframe for assessing the effects of threats on polar bear population status must be determined on the basis of an assessment of the reliability of available biological and threat information at each step. For polar bear, the reliability of biological information and, therefore, population status projections, increases if a multigenerational analysis is used. In general, the reliability of information and projections increases with time, until a point when reliability begins to decline again due to uncertainty in projecting threats and corresponding responses by polar bear populations (S. Schliebe, pers. comm., 2008). This decline in reliability depends on the level of uncertainty associated with projected threats and their relationship to the population dynamics of the species. With polar bears, we expect the reliability of population status projections to diminish around 4–5 generations. Thus, ±3 generations is the optimal timeframe to reliably assess the status of the polar bear response to population-level threats. This progression can be illustrated by results from studies of the Western Hudson Bay polar bear population.

In western Hudson Bay, break-up of the annual sea ice now occurs approximately 2.5 weeks earlier than it did 30 years ago (see discussion of ''Western Hudson Bay'' population under Factor A and Stirling and Parkinson 2006, p. 265). Stirling and colleagues measured mean estimated mass of lone adult female polar bears from 1980 through 2004, and determined that their average weight declined by about 65 kg (143 lbs) over that period. Stirling and Parkinson (2006, p. 266) project that cub production could cease in 20 to 30 years if climate trends continue as projected by the IPCC. The overall timeframe covered by this scenario is 45–55 years, which is within the ±3 generation timeframe. In addition, Regehr et al. (2007a, p. 2,673) analyzed population trend data for 1987 through 2004 and documented a long-term, gradual decline in population size that is anticipated to continue into the future. These two lines of evidence indicate that the species will likely be in danger of extinction within the next 45 years. Beyond that timeframe, the population trend and threats information are too uncertain to reliably project the status of the species.

In summary, we considered the timeframe over which the best available scientific data allow us to reliably assess the effect of threats on the polar bear, and determined that there is substantial scientific reliability associated with climate model projections of sea ice change over the next 40–50 years. Confidence limits are much closer (i.e., more certain) for projections of the next 40–50 years and all projections agree that sea ice will continue to decrease. In comparison, periods beyond 50 years exhibit wider confidence limits, although all trends continue to express warming and loss of sea ice (IPCC 2007, p. 749; Overland and Wang 2007a, pp. 1–7; Stroeve et al. 2007, pp. 1–5). This timespan compares well with the 3-generation (45-year) timeframe over which we can reliably evaluate the effects of environmental change on polar bear life history and population parameters. Therefore, we believe that a 45-year foreseeable future is a reasonable and objective timeframe for analysis of whether polar bears are likely to become endangered.

This 45-year timeframe for assessing the status of the species is consistent with the work of the PBSG in reassessing the status of polar bears globally in June 2005 (Aars et al. 2006, p. 31) for purposes of IUCN Red List classification. More than 40 technical experts were involved in the PBSG review (including polar bear experts from the range countries and other invited polar bear specialists), and these PBSG technical experts supported the definition of a polar bear generation as 15 years, and the application of three generations as the appropriate timeframe over which to evaluate polar bear population trends for the purposes of IUCN Red List categorization. Although the Red List process is not the same as our evaluation for listing a species under the Act, the basic rationale for determining generation length and timeframe for analysis of threats is similar in both. None of the experts raised an issue with the 45-year timeframe for analysis of population trends.

In addition, when seeking peer review of both the *Status Review* (Schliebe et al. 2006a) and the proposed rule to list the polar bear as threatened (72 FR 1064), we specifically asked peer reviewers to comment on the 45-year foreseeable future and the method we used to derive that timeframe. All reviewers that commented on this subject indicated that a 45-year timeframe for the foreseeable future was appropriate, with the exception of one reviewer who thought the foreseeable future should be 100 years. Thus, both the independent reviews by PBSG and the input from peer reviewers corroborate our final decision and our rationale for using 45 years as the foreseeable future for the polar bear.

Our evaluation of the five factors with respect to polar bear populations is presented below. We considered all relevant available scientific and commercial information under each of the listing factors in the context of the present-day distribution of the polar bear.

Factor A. Present or Threatened Destruction, Modification, or Curtailment of the Polar Bear's Habitat or Range

Introduction

As described in detail in the ''Species Biology'' section of this rule, polar bears are evolutionarily adapted to life on sea ice (Stirling 1988, p. 24; Amstrup 2003, p. 587). They need sea ice as a platform for hunting, for seasonal movements, for travel to terrestrial denning areas, for resting, and for mating (Stirling and Derocher 1993, p. 241). Moore and Huntington (in press) classify polar bears as an ''ice-obligate'' species because of their reliance on sea ice as a platform for resting, breeding, and hunting. Laidre et al. (in press) similarly describe the polar bear as a species that principally relies on annual sea ice over the continental shelf and areas toward the southern extent of the edge of sea ice for foraging. Some polar bears use terrestrial habitats seasonally (e.g., for denning or for resting during open water periods). Open water by itself is not considered to be a habitat type frequently used by polar bears, because life functions such as feeding, reproduction, or resting do not occur in open water. However, open water is a fundamental part of the marine system that supports seal species, the principal prey of polar bears, and seasonally refreezes to form the ice needed by the bears (see ''Open Water Habitat'' section for more information). In addition, the extent of open water is important because vast areas of open water may limit a bear's ability to access sea ice or land (see ''Open Water Swimming'' section for more detail). Snow cover, both on land and on sea ice, is an important component of polar bear habitat in that it provides insulation and cover for young polar bears and ringed seals in snow dens or lairs on sea ice (see ''Maternal Denning Habitat'' section for more detail).

Previous Warming Periods and Polar Bears

Genetic evidence indicates that polar bears diverged from grizzly bears between 200,000–400,000 years ago (Talbot and Shields 1996a, p. 490; Talbot and Shields 1996b, p. 574); however, polar bears do not appear in the fossil record until the Last Interglacial Period (LIG) (115,000–140,000 years ago) (Kurten 1964, p. 25; Ingolfsson and Wiig 2007). Depending on the exact timing of their divergence, polar bears may have experienced several periods of climatic warming, including a period 115,000–140,000 years ago, a period of warming 4,000–12,000 years ago (Holocene Thermal Maximum), and most recently during medieval times (800 to 1200 A.D.). During these periods there is evidence suggesting that regional air temperatures were higher than present day and that sea ice and glacial ice were significantly reduced (Circumpolar Arctic PaleoEnvironments (CAPE) 2006, p. 1394; Jansen et al. 2007, p. 435, 468). This section considers historical information available on polar bears and the environmental conditions during these warming periods.

During the LIG (115,000–140,000 years ago), some regions of the world including parts of the Arctic experienced warmer than present day temperatures as well as greatly reduced sea ice in some areas, including what is now coastal Alaska and Greenland (Jansen et al. 2007, p. 453). CAPE (2006, p.1393) concludes that all sectors of the Arctic were warmer than present during the LIG, but that the magnitude of warming was not uniform across all regions of the Arctic. Summer temperature anomalies at lower Northern Hemisphere latitudes below the Arctic were not as pronounced as those at higher latitudes but still are estimated to have ranged from 0–2 degrees C above present (CAPE 2006, p. 1394). Furthermore, according to the IPCC, while the average temperature when considered globally during the LIG was not notably higher than present day, the rate of warming averaged 10 times slower than the rate of warming during the 20th century (Jansen et al. 2007, p. 453). However, the rate at which change occurred may have been more rapid regionally, particularly in the Arctic (CAPE 2006, p. 1394). While the specific responses of polar bears to regional changes in climate during the LIG are not known, they may have survived regional warming events by altering their distribution and/or retracting their range. Similar range retraction is projected for polar bears in the 21st century (Durner et al. 2007). However, the slower rate of climate change and more regional scale of change during the LIG suggest that polar bears had more opportunity to adapt during this time in comparison to the current observed and projected relatively rapid, global climate change (Jansen et al. 2007, p. 776; Lemke et al. 2007, p. 351).

The HTM 4,000–12,000 years ago also appears to have affected climate Arctic-wide, though summer temperature anomalies were lower than those that occurred during the LIG (CAPE 2006, p. 1394). Kaufman et al. (2003, p. 545) report that mean surface temperatures during the HTM were 1.6 ± 0.8 degrees C (range: 0.5–3 degrees C) higher in terrestrial habitats and 3.8 ± 1.9 degrees C at marine sites than present-day temperatures at 120 sites throughout the western Arctic (Northeast Russia to Iceland, including all of North America). Furthermore, Birks and Amman (2000, pp. 1,392–1,393) provide evidence that change in some areas may have been rapid, including an increase of 0.2–0.3 degrees C per 25 years in Norway and Switzerland. However, the timing of warming across the Arctic was not uniform, with Alaska and northwest Canada experiencing peak warming 4,000 years prior to northeast Canada (Kaufman et al. 2004, p. 529). Thus while regional changes in temperature are believed to have occurred, the IPCC concluded that annual global mean temperatures were not warmer than present day any time during the Holocene (Jansen et al. 2007, p. 465). While polar bears did experience warmer temperatures in their range during this time, the regional nature of warming that occurred may have aided their survival through this period in certain areas. However, the degree to which polar bears may have been impacted either regionally or Arctic-wide is unknown.

The most recent period of warming occurred during the Medieval period (generally considered to be the period from 950 to 1300 AD). This episode again appears to have been regional rather than global (Broecker 2001, p. 1,497; Jansen et al. 2007, p. 469); additionally, temperatures during this period are estimated to be 0.1–0.2 degrees C below the 1961 to 1990 mean and significantly below the instrumental data after 1980 (Jansen et al. 2007, p. 469). Thus, temperatures and rate of change estimated for this time period do not appear comparable to present day conditions.

Unfortunately, the limited scientific evidence currently available to us for these time periods does limit our ability to assess how polar bears responded to previous warming events. For example, while genetic analyses can be useful for identifying significant reductions in population size throughout a species' history (Hedrick 1996, p. 897; Driscoll et al. 2002, p. 414), most genetic studies of polar bears have focused on analyzing variation in micro-satellite DNA for the purposes of differentiating populations (i.e., identifying genetic structure; Paetkau et al. 1995, p. 347; Paetkau et al. 1999, p. 1,571; Cronin et al. 2006, p. 655). Additionally, genetic analyses for the purpose of identifying population bottlenecks require accurate quantification of mutation rates to determine how far back in time an event can be detected and a combination of mitochondrial and nuclear DNA analyses to eliminate potential alternative factors, other than a population bottleneck, that might result in or counteract low genetic variation (Driscoll et al. 2002, pp. 420–421; Hedrick 1996, p. 898; Nystrom et al. 2006, p. 84). The results of micro-satellite studies for polar bears have documented that within-population genetic variation is similar to black and grizzly bears (Amstrup 2003, p. 590), but that among populations, genetic structuring or diversity is low (Paetkau et al. 1995, p. 347; Cronin et al. 2006, pp. 658–659). The latter has been attributed with extensive population mixing associated with large home ranges and movement patterns, as well as the more recent divergence of polar bears in comparison to grizzly and black bears (Talbot and Shields 1996a, p. 490; Talbot and Shields 1996b, p. 574; Paetkau et al. 1999, p. 1,580). Inferring whether the degree of genetic variation from these studies is indicative of a population bottleneck, however, requires additional analyses that have yet to be conducted. Furthermore, the very limited fossil record of polar bears sheds little light on possible population-level responses of polar bears to previous warming events (Derocher et al. 2004, p. 163).

Thus, while polar bears as a species have survived at least one period of regional warming greater than present day, it is important to recognize that the degree that they were impacted is not known and there are differences between the circumstances surrounding historical periods of climate change and present day. First, the IPCC concludes that the current rate of global climate change is much more rapid and very unusual in the context of past changes (Jansen et al. 2007, p. 465). Although large variation in regional climate has been documented in the past 200,000 years, there is no evidence that mean global temperature increased at a faster rate than present warming (Jansen et al. 2007, p. 465), nor is there evidence that these changes occurred at the same time across regions. Furthermore, projected rates of future global change are much greater than rates of global temperature increase during the past 50 million years (Jansen et al. 2007, p. 465). Derocher et al. (2004, p. 163, 172) suggest that this rate of change will limit the ability of polar bears to respond and survive in large numbers. Secondly, polar bears today experience multiple stressors that were not present during historical warming periods. As explained further under Factors B, C, and E, polar bears today contend with harvest, contaminants, oil and gas development, and additional interactions with humans (Derocher et al. 2004, p. 172) that they did not experience in previous warming periods, whereas during the HTM, humans had just begun to colonize North America. Thus, both the cumulative effects of multiple stressors and the rapid rate of climate change today create a unique and unprecedented challenge for present-day polar bears in comparison to historical warming events.

Effects of Sea Ice Habitat Change on Polar Bears

Observed and predicted changes in sea ice cover, characteristics, and timing have profound effects on polar bears (Derocher and Stirling 1996, p. 1,250; Stirling et al. 1999, p. 294; Stirling and Parkinson 2006, p. 261; Regehr et al. 2007b, p. 18). As noted above, sea ice is a highly dynamic habitat with different types, forms, stages, and distributions that all operate as a complex matrix in determining biological productivity and use by marine organisms, including polar bears and their primary prey base, ice seal species. Polar bear use of sea ice is not uniform. Their preferred habitat is the annual ice located over the continental shelf and inter-island archipelagos that circle the Arctic basin. Ice seal species demonstrate a similar preference for these ice habitats.

In the Arctic, Hudson Bay, Canada has experienced some of the earliest ice changes due to its southerly location on a divide between a warming and a cooling region (Arctic Monitoring Assessment Program (AMAP) 2003, p. 22), making it an ideal area to study the impacts of climate change. In addition, Hudson Bay has the most extensive long-term data on the ecology of polar bears and is the location where the first evidence of major and ongoing impacts to polar bears from sea ice changes has been documented. Many researchers over the past 40 years have predicted an array of impacts to polar bears from climatic change that include adverse effects on denning, food chain disruption, and prey availability (Budyko 1966, p. 20; Lentfer 1972, p. 169; Tynan and DeMaster 1997, p. 315; Stirling and Derocher 1993, pp. 241–244). Stirling and Derocher (1993, p. 240) first noted changes, such as declining body condition, lowered reproductive rates, and reduced cub survival, in polar bears in western Hudson Bay; they attributed these changes to a changing ice environment. Subsequently, Stirling et al. (1999, p. 303) established a statistically significant link between climate change in western Hudson Bay, reduced ice presence, and observed declines in polar bear physical and reproductive parameters, including body condition (weight) and natality. More recently Stirling and Parkinson (2006, p. 266) established a statistically significant decline in weights of lone and suspected pregnant adult female polar bears in western Hudson Bay between 1988 and 2004. Reduced body weights of adult females during fall have been correlated with subsequent declines in cub survival (Atkinson and Ramsay 1995, p. 559; Derocher and Stirling 1996, p. 1,250; Derocher and Wiig 2002, p. 347).

Increased Polar Bear Movements

The best scientific data available suggest that polar bears are inefficient moving on land and expend approximately twice the average energy than other mammals when walking (Best 1982, p. 63; Hurst 1982, p. 273). However, further research is needed to better understand the energy dynamics of this highly mobile species. Studies have shown that, although sea ice circulation in the Arctic is clockwise, polar bears tend to walk against this movement to maintain a position near preferred habitat within large geographical home ranges (Mauritzen et al. 2003a, p. 111). Currently, ice thickness is diminishing (Rothrock et al. 2003, p. 3649; Yu et al. 2004) and movement of sea ice out of the polar region has occurred (Lindsay and Zhang 2005). As the climate warms, and less multi-year ice is present, we expect to see a decrease in the export of multi-year ice (e.g., Holland et al. 2006, pp. 1–5). Increased rate and extent of ice movements will, in turn, require additional efforts and energy expenditure by polar bears to maintain their position near preferred habitats (Derocher et al. 2004, p. 167). This may be an especially important consideration for females encumbered with small cubs. Ferguson et al. (2001, p. 51) found that polar bears inhabiting areas of highly dynamic ice had much larger activity areas and movement rates compared to those bears inhabiting more stable, persistent ice habitat.

Although polar bears are capable of living in areas of highly dynamic ice movement, they show inter-annual fidelity to the general location of preferred habitat (Mauritzen et al. 2003b, p. 122; Amstrup et al. 2000b, p. 963).

As sea ice becomes more fragmented, polar bears would likely use more energy to maintain contact with consolidated, higher concentration ice, because moving through highly fragmented sea ice is more energy-intensive than walking over consolidated sea ice (Derocher et al. 2004, p. 167). During summer periods, the remaining ice in much of the central polar basin is now positioned away from more productive continental shelf waters and occurs over much deeper, less productive waters, such as in the Beaufort and Chukchi Seas of Alaska. If the width of leads or extent of open water increases, the transit time for bears and the need to swim or to travel will increase (Derocher et al. 2004, p. 167). Derocher et al. (2004, p. 167) suggest that as habitat patch sizes decrease, available food resources are likely to decline, resulting in reduced residency time and increased movement rates. The consequences of increased energetic costs to polar bears from increased movements are likely to be reduced body weight and condition, and a corresponding reduction in survival and recruitment rates (Derocher et al. 2004, p. 167).

Additionally, as movement of sea ice increases and areas of unconsolidated ice also increase, some bears are likely to lose contact with the main body of ice and drift into unsuitable habitat from which it may be difficult to return (Derocher et al. 2004, p. 167). This has occurred historically in some areas such as Southwest Greenland as a result of the general drift pattern of sea ice in the area (Vibe 1967) and also occurs offshore of Newfoundland, Canada (Derocher et al. 2004, p. 167). Increased frequency of such events could negatively impact survival rates and contribute to population declines (Derocher et al. 2004, p. 167).

Polar Bear Seasonal Distribution Patterns Within Annual Activity Areas

Increasing temperatures and reductions in sea ice thickness and extent, coupled with seasonal retraction of sea ice poleward, will cause redistribution of polar bears seasonally into areas previously used either irregularly or infrequently. While polar bears have demonstrated a wide range of space-use patterns within and between populations, the continued retraction and fragmentation of sea ice habitats that is projected to occur will alter previous patterns of use seasonally and regionally. These changes have been documented at an early onset stage for a number of polar bear populations with the potential for large-scale shifts in distribution by the end of the 21st century (Durner et al. 2007, pp. 18–19).

This section provides examples of distribution changes and interrelated consequences. Recent studies indicate that polar bear movements and seasonal fidelity to certain habitat areas are changing and that these changes are strongly correlated to similar changes in sea ice and the ocean-ice system. Changes in movements and seasonal distributions can have effects on polar bear nutrition, body condition, and more significant longer term redistribution. Specifically, in western Hudson Bay, break-up of the annual sea ice now occurs approximately 2.5 weeks earlier than it did 30 years ago (Stirling et al. 1999, p. 299). The earlier spring break-up was highly correlated with dates that female polar bears came ashore (Stirling et al. 1999, p. 299). Declining reproductive rates, subadult survival, and body mass (weights) have occurred because of longer periods of fasting on land as a result of the progressively earlier break-up of the sea ice and the increase in spring temperatures (Stirling et al. 1999, p. 304; Derocher et al. 2004, p. 165).

Stirling et al. (1999, p. 304) cautioned that, although downward trends in the size of the Western Hudson Bay population had not been detected, if trends in life history parameters continued downward, ''they will eventually have a detrimental effect on the ability of the population to sustain itself.'' Subsequently, Parks et al. (2006, p. 1282) evaluated movement patterns of adult female polar bears satellite-collared from 1991 to 2004 with respect to their body condition. Reproductive status and variation in ice patterns were included in the analysis. Parks et al. (2006, p. 1281) found that movement patterns were not dependent on reproductive status of females but did change significantly with season. They found that annual distances moved had decreased in Hudson Bay since 1991. This suggested that declines in body condition were due to reduced prey consumption as opposed to increased energy output from movements (Parks et al. 2006, p. 281). More recently, Regehr et al. (2007a, p. 2,673) substantiated Stirling et al.'s (1999, p. 304) predictions, noting population declines in western Hudson Bay during analysis of data from an ongoing mark-recapture population study. Between 1987 and 2004, the number of polar bears in the Western Hudson Bay population declined from 1,194 to 935, a reduction of about 22 percent (Regehr et al. 2007a, p. 2,673). Progressive declines in the condition and survival of cubs, subadults, and bears 20 years of age and older appear to have been caused by progressively earlier sea ice break-up, and likely initiated the decline in population. Once the population began to decline, existing harvest rates contributed to the reduction in the size of the population (Regehr et al. 2007a, p. 2,680).

Since 2000, Schliebe et al. (2008) observed increased use of coastal areas by polar bears during the fall open-water period in the southern Beaufort Sea. High numbers of bears (a minimum of 120) were found to be using coastal areas during some years, where prior to the 1990s, according to native hunters, industrial workers, and researchers operating on the coast at this time of year, such observations of polar bears were rare. This study period (2000–2005) also included record minimal sea ice conditions for the month of September in 4 of the 6 survey years. Polar bear density along the mainland coast and on barrier islands during the fall open water period in the southern Beaufort Sea was related to distance from pack ice edge and the density of ringed seals over the continental shelf. The distance between pack ice edge and the mainland coast, as well as the length of time that these distances prevailed, was directly related to polar bear density onshore. As the sea ice retreated and the distance to the edge of the ice increased, the number of bears near shore increased. Conversely, as near-shore areas became frozen or sea ice advanced toward shore, the number of bears near shore decreased (Schliebe et al. 2008). The presence of subsistence-harvested bowhead whale carcasses and their relationship to polar bear distribution were also analyzed. These results suggest that, while seal densities near shore and availability of bowhead whale carcasses may play a role in polar bear distribution changes, that sea ice conditions (possibly similar to conditions observed in western Hudson Bay) are influencing the distribution of polar bears in the southern Beaufort Sea. They also suggest that increased polar bear use of coastal areas may continue if the summer retreat of the sea ice continues into the future as predicted (Serreze et al. 2000, p. 159; Serreze and Barry 2005).

Others have observed increased numbers of polar bears in novel habitats. During bowhead whale surveys conducted in the southern Beaufort Sea during September, Gleason et al. (2006)

observed a greater number of bears in open water and on land during surveys in 1997–2005, years when sea ice was often absent from their study area, compared to surveys conducted between 1979–1996, years when sea ice was a predominant habitat within their study area. Bears in open water likely did not select water as a choice habitat, but rather were swimming in an attempt to reach offshore pack ice or land. Their observation of a greater number of bears on land during the later period was concordant with the observations of Schliebe et al. (2008). Further, the findings of Gleason et al. (2006) coincide with the lack of pack ice (concentrations of greater than 50 percent) caused by a retraction of ice in the study area during the latter period (Stroeve et al. 2005, p. 2; Comiso 2003, p. 3,509; Comiso 2005, p. 52). The findings of Gleason et al. (2006) confirm an increasing use of coastal areas by polar bears in the southern Beaufort Sea in recent years and a decline in ice habitat near shore. The immediate causes for changes in polar bear distribution are thought to be (1) retraction of pack ice far to the north for greater periods of time in the fall and (2) later freeze-up of coastal waters.

Other polar bear populations exhibiting seasonal distribution changes with larger numbers of bears on shore have been reported. Stirling and Parkinson (2006, pp. 261–275) provide an analysis of pack ice and polar bear distribution changes for the Baffin Bay, Davis Strait, Foxe Basin, and Hudson Bay populations. They indicate that earlier sea ice break-up will likely result in longer periods of fasting for polar bears during the extended open-water season. This may explain why more polar bears have been observed near communities and hunting camps in recent years. Seasonal distribution changes of polar bears have been noted during a similar period of time for the northern coast of Chukotka (Kochnev 2006, p. 162) and on Wrangel Island, Russia (Kochnev 2006, p. 162; N. Ovsyanikov, Russian Federation Nature Reserves, pers. comm.). The relationship between the maximum number of polar bears, the number of dead walruses, and the distance to the ice edge from Wrangel Island was evaluated. The subsequent results revealed that the most significant correlation was between bear numbers and distance to the ice-edge (Kochnev 2006, p. 162), which again supports the observation that when sea ice retreats far off shore, the numbers of bears present or stranded on land appears to increase.

In Baffin Bay, traditional Inuit knowledge studies and anecdotal reports indicate that in many areas greater numbers of bears are being encountered on land during the summer and fall open-water seasons (Dowsley 2005, p. 2). Interviews with elders and senior hunters (Dowsley and Taylor 2005, p. 2) in three communities in Nunavut, Canada, revealed that most respondents (83 percent) believed that the population of polar bears had increased. The increase was attributed to more bears seen near communities, cabins, and camps; hunters also encountered bear sign (e.g., tracks, scat) in areas not previously used by bears. Some people interviewed noted that these observations could reflect a change in bear behavior rather than an increase in population. Many (62 percent) respondents believed that bears were less fearful of humans now than 15 years ago. Most (57 percent) respondents reported bears to be skinnier now, and five people in one community reported an increase in fighting among bears. Respondents also discussed climate change, and they indicated that there was more variability in the sea ice environment in recent years than in the past. Some respondents indicated a general trend for ice floe edge to be closer to the shore than in the past, the sea ice to be thinner, fewer icebergs to be present, and glaciers to be receding. Fewer grounded icebergs, from which shorefast ice forms and extends, were thought to be partially responsible for the shift of the ice edge nearer to shore. Respondents were uncertain if climate change was affecting polar bears or what form the effects may be taking (Dowsley 2005, p. 1). Also, results from an interview survey of 72 experienced polar bear hunters in Northwest Greenland in February 2006 indicate that during the last 10–20 years, polar bears have occurred closer to the coast. Several of those interviewed believed the change in distribution represented an increase in the population size (e.g., Kane Basin and Baffin Bay), although others suggested that it may be an effect of a decrease in the sea ice (Born et al., in prep).

Recently Vladilen Kavry, former Chair of the Union of Marine Mammal Hunters of Chukotka, Russia, Polar Bear Commission, conducted a series of traditional ecological knowledge interviews with indigenous Chukotka coastal residents regarding their impression of environmental changes based on their lifetime of observations (Russian Conservation News No. 41 Spring/Summer 2006). The interviewees included 17 men and women representing different age and ethnic groups (Chukchi, Siberian Yupik, and Russian) in Chukotka, Russia. Respondents noted that across the region there was a changing seasonal weather pattern with increased unpredictability and instability of weather. Respondents noted shorter winters, observing that the fall-winter transition was occurring later, and spring weather was arriving earlier. Many described these differences as resulting in a one-month-later change in the advent of fall and one-month-earlier advent of spring. One 71-year-old Chukchi hunter believed that winter was delayed two months and indicated that the winter frosts that had previously occurred in September were now taking place in November. He also noted that thunderstorms were more frequent. Another 64-year-old hunter noted uncharacteristic snow storms and blizzards as well as wintertime rains. He also noted that access to sea ice by hunters was now delayed from the normal access date of November to approximately one month later into December. This individual also noted that blizzards and weather patterns had changed and that snow is more abundant and wind patterns caused snow drifts to occur in locations not previously observed. With increased spring temperatures, lagoons and rivers are melting earlier. The sea ice extent has declined and the quality of ice changed. The timing of fall sea ice freezing is delayed two months into November. The absence of sea ice in the summer is thought to have caused walrus to use land haulouts for resting in greater frequency and numbers than in the past.

Stirling and Parkinson (2006, p. 263) evaluated sea ice conditions and distribution of polar bears in five populations in Canada: Western Hudson Bay, Eastern Hudson Bay, Baffin Bay, Foxe Basin, and Davis Strait. Their analysis of satellite imagery beginning in the 1970s indicates that the sea ice is breaking up at progressively earlier dates, so bears must fast for longer periods of time during the open-water season. Stirling and Parkinson (2006, pp. 271–272) point out that long-term data on population size and body condition of bears from the Western Hudson Bay population, and population and harvest data from the Baffin Bay population, indicate that these populations are declining or likely to be declining. The authors indicate that as bears in these populations become more nutritionally stressed, the numbers of animals will decline, and the declines will probably be significant. Based on the recent findings of Holland et al.

(2006, pp. 1–5) regarding sea ice changes, these events are predicted to occur within the foreseeable future as defined in this rule (Stirling, pers. comm. 2006).

Seasonal polar bear distribution changes noted above, the negative effect of reduced access to primary prey, and prolonged use of terrestrial habitat are a concern for polar bears. Although polar bears have been observed using terrestrial food items such as blueberries (*Vaccinium sp.*), snow geese (*Anser caerulescens*), and reindeer (*Rangifer tarandus*), these alternate foods are not believed to represent significant sources of energy (Ramsay and Hobson 1991, p. 600; Derocher et al. 2004, p. 169) because they do not provide the high fat, high caloric food source that seals do. Also, the potential inefficiency of polar bear locomotion on land noted above may explain why polar bears are not known to regularly hunt musk oxen (*Ovibos moschatus*) or snow geese, despite their occurrence as potential prey in many areas (Lunn and Stirling 1985, p. 2,295). The energy needed to catch such species would almost certainly exceed the amount of energy a kill would provide (Lunn and Stirling 1985, p. 2,295). Consequently, greater use of terrestrial habitats as a result of reduced presence of sea ice seasonally will not offset energy losses resulting from decreased seal consumption. Nutritional stress appears to be the only possible result.

Effects of Sea Ice Habitat Changes on Polar Bear Prey

Reduced Seal Productivity

Polar bear populations are known to fluctuate with prey abundance (Stirling and Lunn 1997, p. 177). Declines in ringed and bearded seal numbers and productivity have resulted in marked declines in polar bear populations (Stirling 1980, p. 309; Stirling and Øritsland 1995, p. 2,609; Stirling 2002, p. 68). Thus, changes in ringed seal productivity have the potential to affect polar bears directly as a result of reduced predation on seal pups and indirectly through reduced recruitment of this important prey species. Ringed seal productivity is dependent on the availability of secure habitat for birth lairs and rearing young and, as a result, is susceptible to changes in sea ice and snow dynamics. Ringed seal pups are the smallest of the seals and survive because they are born in snow lairs (subnivian dens) that afford protection from the elements and from predation (Hall 1866; Chapskii 1940; McLaren 1958; Smith and Stirling 1975, all cited in Kelly 2001, p. 47). Pups are born between mid-March and mid-April, nursed for about 6 weeks, and weaned prior to spring break-up in June (Smith 1980, p. 2,201; Stirling 2002, p. 67). During this time period, both ringed seal pups and adults are hunted by polar bears (Smith 1980, p. 2,201). Stirling and Lunn (1997, p. 177) found that ringed seal young-of-the-year represented the majority of the polar bear diet, although the availability of ringed seal pups from about mid-April to ice break up sometime in July (Stirling and Lunn 1997, p. 176) is also important to polar bears.

In many areas, ringed seals prefer to create birth lairs in areas of accumulated snow on stable, shore-fast ice over continental shelves along Arctic coasts, bays, and inter-island channels (Smith and Hammill 1981, p. 966). While some authors suggest that landfast ice is the preferred pupping habitat of ringed seals due to its stability throughout the pupping and nursing period (McLaren 1958, p. 26; Burns 1970, p. 445), others have documented ringed seal pupping on drifting pack ice both nearshore and offshore (Burns 1970; Smith 1987; Finley et al. 1983, p. 162; Wiig et al. 1999, p. 595; Lydersen et al. 2004). Either of these habitats can be affected by earlier warming and break-up in the spring, which shortens the length of time pups have to grow and mature (Kelly 2001, p. 48; Smith and Harwood 2001). Harwood et al. (2000, pp. 11–12) reported that an early spring break-up negatively impacted the growth, condition, and apparent survival of unweaned ringed seal pups. Early break-up was believed to have interrupted lactation in adult females, which in turn, negatively affected the condition and growth of pups. Earlier ice break-ups similar to those documented by Harwood et al. (2000, p. 11) and Ferguson et al. (2005, p. 131) are predicted to occur more frequently with warming temperatures, and result in a predicted decrease in productivity and abundance of ringed seals (Ferguson et al. 2005, p. 131; Kelly 2001). Additionally, high fidelity to birthing sites exhibited by ringed seals makes them more susceptible to localized impacts from birth lair snow degradation, harvest, or human activities (Kelly 2006, p. 15).

Unusually heavy ice has also been documented to result in markedly lower productivity of ringed seals and reduced polar bear productivity (Stirling 2002, p. 59). While reduced ice thickness associated with warming in some areas could be expected to improve seal productivity, the transitory and localized benefits of reduced ice thickness on ringed seals are expected to be outweighed by the negative effects of increased vulnerability of seal pups to predation and thermoregulatory costs (Derocher et al. 2004, p. 168). The number of studies that have documented negative effects associated with earlier warming and break-up and reduced snow cover (Hammill and Smith 1989, p. 131; Harwood et al. 2000, p. 11; Smith et al. 1991; Stirling and Smith 2004, p. 63; Ferguson et al. 2005, p. 131), in comparison to any apparent benefits of reduced ice thickness further support this conclusion.

Snow depth on the sea ice, in addition to the timing of ice break-up, appears to be important in affecting the survival of ringed seal pups. Ferguson et al. (2005, pp. 130–131) attributed decreased snow depth in April and May with low ringed seal recruitment in western Hudson Bay. Reduced snowfall results in less snow drift accumulation on the leeward side of pressure ridges; pups in lairs with thin snow roofs are more vulnerable to predation than pups in lairs with thick roofs (Hammill and Smith 1989, p.131; Ferguson et al. 2005, p. 131). Access to birth lairs for thermoregulation is also considered to be crucial to the survival of nursing pups when air temperatures fall below 0 degrees C (Stirling and Smith 2004, p. 65). Warming temperatures that melt snow-covered birth lairs can result in pups being exposed to ambient conditions and suffering from hypothermia (Stirling and Smith 2004, p. 63). Others have noted that when lack of snow cover has forced birthing to occur in the open, nearly 100 percent of pups died from predation (Kumlien 1879; Lydersen et al. 1987; Lydersen and Smith 1989, p. 489; Smith and Lydersen 1991; Smith et al. 1991, all cited in Kelly 2001, p. 49). More recently, Kelly et al. (2006, p. 11) found that ringed seal emergence from lairs was related to structural failure of the snow pack, and PM satellite measurements indicating liquid moisture in snow. These studies suggest that warmer temperatures have and will continue to have negative effects on ringed seal pup survival, particularly in areas such as western Hudson Bay (Ferguson et al. 2005, p. 121).

Similar to earlier spring break-up or reduced snow cover, increased rain-on-snow events during the late winter also negatively impact ringed seal recruitment by damaging or eliminating snow-covered pupping lairs, increasing exposure and the risk of hypothermia, and facilitating predation by polar bears and Arctic foxes (*Alopex lagopus*) (Stirling and Smith 2004, p. 65). Stirling and Smith (2004, p. 64) document the collapse of snow roofs of ringed seal birth lairs associated with rain events near southeastern Baffin Island and the resultant exposure of adult seals and pups to hypothermia. Predation of pups by polar bears was observed, and the researchers suspect that most of the pups in these areas were eventually killed by polar bears (Stirling and Archibald 1977, p. 1,127), Arctic foxes (Smith 1976, p. 1,610) or possibly gulls (Lydersen and Smith 1989). Stirling and Smith (2004, p. 66) postulated that should early season rain become regular and widespread in the future, mortality of ringed seal pups will increase, especially in more southerly parts of their range. Any significant decline in ringed seal numbers, especially in the production of young, could negatively affect reproduction and survival of polar bears (Stirling and Smith 2004, p. 66).

Changes in snow and ice conditions can also have impacts on polar bear prey other than ringed seals (Born 2005a, p. 152). These species include harbor seals (*Phoca vitulina*), spotted seals (*Phoca largha*), and ribbon seals (*Phoca fasciata*), and in the north Atlantic, harp seals (*Phoca greenlandica*) and hooded seals (*Crystophora cristata*). The absence of ice in southerly pupping areas or the relocation of pupping areas for other ice-dependent seal species to more northerly areas has been demonstrated to negatively affect seal production. For example, repeated years of little or no ice in the Gulf of St. Lawrence resulted in almost zero production of harp seal pups, compared to hundreds of thousands in good ice years (ACIA 2005, p. 510). Marginal ice conditions and early ice break-up during harp seal whelping (pupping) are believed to have resulted in increased juvenile mortality from starvation and cold stress and an overall reduction in this age class (Johnston et al. 2005, pp. 215–216). Northerly shifts of whelping areas for hooded seals were reported to occur during periods of warmer climate and diminished ice (Burns 2002, p. 42). In recent years, the location of a hooded seal whelping patch near Jan Mayen, in East Greenland, changed position apparently in response to decreased sea ice in this area. This change in distribution has corresponded with a decrease in seal numbers (T. Haug, pers. comm. 2005). Laidre et al. (in press) concluded that harp and hooded seals will be susceptible to negative effects associated with reduced sea ice because they whelp in large numbers at high density with a high degree of fidelity to traditional and critical whelping locations. Because polar bears prey primarily on seal species whose reproductive success is closely linked to the availability of stable, spring ice, the productivity of these species, and, therefore, prey availability for polar bears, is expected to decline in response to continued declines in the extent and duration of sea ice.

Reduced Prey Availability

Current evidence suggests that prey availability to polar bears will be altered due to reduced prey abundance, changes in prey distribution, and changes in sea ice availability as a platform for hunting seals (Derocher et al. 2004, pp. 167–169). Young, immature bears may be particularly vulnerable to changes in prey availability. Polar bears feed preferentially on blubber, and adult bears often leave much of a kill behind (Stirling and McEwan 1975, p. 1,021). Younger bears, which are not as efficient at taking seals, are known to utilize these kills to supplement their diet (Derocher et al. 2004, p. 168). Younger bears may be disproportionately impacted if there are fewer kills or greater consumption of kills by adults, resulting in less prey to scavenge (Derocher et al. 2004, pp. 167–168). Altered prey distribution would also likely lead to increased competition for prey between dominant and subordinate bears, resulting in subordinate or subadult bears having reduced access to prey (Derocher et al. 2004, p. 167). Thus, a decrease in prey abundance and availability would likely result in a concomitant effect to polar bears.

Reduction in food resources available to seals, in addition to the previously discussed effects on reproduction, could affect seal abundance and availability as a prey resource to polar bears. Ringed seals are generalist feeders but depend on Arctic cod (*Boreogadus saida*) as a major component of their diet (Lowry et al. 1980, p. 2,254; Bradstreet and Cross 1982, p. 3; Welch et al. 1997, p. 1,106; Weslawski et al. 1994, p. 109). Klumov (1937) regarded Arctic cod as the 'biological pivot' for many northern marine vertebrates, and as an important intermediary link in the food chain. Arctic cod are strongly associated with sea ice throughout their range and use the underside of the ice to escape from predators (Bradstreet and Cross 1982, p. 39; Craig et al. 1982, p. 395; Sekerak 1982, p. 75). While interrelated changes in the Arctic food web and effects to upper level consumers are difficult to predict, a decrease in seasonal ice cover could negatively affect Arctic cod (Tynan and DeMaster 1997, p. 314; Gaston et al. 2003, p. 231). Though decreased ice could improve the ability of ringed seals to access and prey upon Arctic cod in open water, this change would come at increased costs for pups that are forced into the water at an earlier age and at risk of predation and thermal challenges (Smith and Harwood 2001). For example, studies have shown that even in the presence of abundant prey, growth and condition of ringed seals continued to be negatively affected by earlier ice break-up (Harwood et al. 2000, p. 422). Ice seals, including the ringed seal, are vulnerable to habitat loss from changes in the extent or concentration of Arctic ice because they depend on pack-ice habitat for pupping, foraging, molting, and resting (Tynan and DeMaster 1997, p. 312; Derocher et al. 2004, p. 168).

Sea ice is an essential platform that allows polar bears to access their prey. The importance of sea ice to polar bear foraging is supported by documented relationships between the duration and extent of sea ice and polar bear condition, reproduction, and survival that are apparent across decades, despite likely fluctuations in ringed seal abundance (Stirling et al. 1999, p. 294; Regehr et al. 2007a; p. 2,673; Regehr et al. 2007b, p. 18; Rode et al. 2007, p. 6–8). Ferguson et al. (2000b, p. 770) reported that higher seal density in Baffin Bay in comparison to the Arctic Archipelago did not correspond with a higher density of polar bears as a result of the more variable ice conditions that occur there. These results emphasize the dependence of polar bears on sea ice as a means of accessing prey. Not only does ice have to be present over areas of abundant prey, but the physical characteristics of sea ice appear to also be important. Stirling et al. (2008, in press) noted that unusually rough and rafted sea ice in the southeastern Beaufort Sea from about Atkinson Point to the Alaska border during the springs of 2004–2006 resulted in reduced hunting success of polar bears seeking seals despite extensive searching for prey. Thus, transitory or localized increases in prey abundance will have no benefit for polar bears if these changes are accompanied by a reduction in ice habitat or changes in physical characteristics of ice habitat that negate its value for hunting or accessing seals. Observations-to-date and projections of future ice conditions support the conclusion that accessibility of prey to polar bears is likely to decline.

Adaptation

Animals can adapt to changing environmental conditions principally through behavioral plasticity or as a result of natural selection. Behavioral changes allow adaptation over shorter timeframes and can complement and be a precursor to the forces of natural selection that allow animals to evolve to better fit new or changed environmental patterns. Unlike behavioral plasticity, natural selection is a multi-generational response to changing conditions, and its speed is dependent upon the organism's degree of genetic variation and generation time and the rate of environmental change (Burger and Lynch 1995, p. 161). While some short-lived species have exhibited micro-evolutionary responses to climate change (e.g., red squirrels (Reale et al. 2003, p. 594)), the relatively long generation time (Amstrup 2003, pp. 599–600) and low genetic variation of polar bears (Amstrup 2003, p. 590) combined with the relatively rapid rate of predicted sea ice changes that are expected (Comiso 2006, p. 72; Serreze et al. 2007, p. 1,533–1,536; Stroeve et al. 2007, pp. 1–5; Hegerl et al. 2007, p. 716), suggest that adaptation through natural selection will be limited for polar bears (Stirling and Derocher 1990, p. 201). Furthermore, several recent reviews of species adaptation to changing climate suggest that rather than evolving, species appear to first alter their geographic distribution (Walther et al. 2002, p. 390; Parmesan 2006, p. 655). For example, evidence suggests that altered species distribution was the mechanism allowing many species to survive during the Pleistocene warming period (Parmesan 2006, p. 655). Because polar bears already occur in cold extreme climates, they are constrained from responding to climate change by significantly altering their distribution (Parmesan 2006, p. 653). Furthermore, a number of physiological and physical characteristics of polar bears constrain their ability to adapt behaviorally to rapid and extensive alteration of their sea-ice habitat.

Bears as a genus display a high degree of behavioral plasticity (Stirling and Derocher 1990, p. 189), opportunistic feeding strategies (Lunn and Stirling 1985, p. 2295; Schwartz et al. 2003, p. 568), and physiological mechanisms for energy conservation (Derocher et al. 1990, p. 196; McNab 2002, p. 385). However, polar bears evolved to be the largest of the bear species (Amstrup 2003, p. 588) by specializing on a calorically dense, carnivorous diet that differs from all other bear species. Their large size has the advantage of both increased fat storage capability (McNab 2002, p. 383) and reduced surface-area to volume ratios that minimize heat loss in the Arctic environment (McNab 2002, pp. 102–103). Because reproduction in polar bears and other bears is dependent upon achieving sufficient body mass (Atkinson and Ramsay 1995, p. 559; Derocher and Stirling 1996, p. 1,246; Derocher and Stirling 1998, p. 253), population density is directly linked to the availability of high-quality food and primary productivity (Hilderbrand et al. 1999, p. 135; Ferguson and McLoughlin 2000, p. 196). Thus, maintenance of a high caloric intake is facilitated by the high fat content of seals, which is required to maintain polar bears at the body size and in the numbers in which they exist today.

The most recent population estimates of ringed seals, the preferred prey of most polar bear populations, range to about 4 million or more, making them one of the most abundant seal species in the world (Kingsley 1990, p. 140). Rather than switching to alternative prey items when ringed seal populations decline as a result of environmental conditions, several studies demonstrated corresponding declines in polar bear abundance (Stirling and Øritsland 1995, p. 2,594; Stirling 2002, p. 68). For those polar bear populations that have been shown to utilize alternative prey species in response to changing availability, such shifts have been among other ice-dependent pinnipeds (Derocher et al. 2002, p. 448; Stirling 2002, p. 67; Iverson et al. 2006, pp. 110–112). For example, Stirling and Parkinson (2006, p. 270) and Iverson et al. (2006, p. 112) have shown that polar bears in the Davis Strait region have taken advantage of increases in availability of harp and hooded seals. See also the section ''Effects of Sea Ice Habitat Changes on Polar Bear Prey.'' However, harp and hooded seals have historically occurred in areas not frequented by polar bears, and are extremely vulnerable to polar bear predation and in Davis Strait survival of juveniles is believed to have declined in recent years due to significant and rapid reduction in sea ice in the spring (Stirling and Parkinson 2006, p. 270).

Changes in ringed seal distribution and abundance in response to changing ice conditions and the ability of polar bears to respond to those changes will likely be the most important factor determining effects on polar bear populations. Currently, access to ringed seals is seasonal for most polar bear populations, resulting in cycles of weight gain and weight loss. The most important foraging periods occur during the spring, early summer, and following the open-water period in the fall (Stirling et al. 1999, p. 303; Derocher et al. 2002, p. 449; Durner et al. 2004, pp. 18–19). Because observed and predicted changes in sea ice are most dramatic during the summer/fall period (Lemke et al. 2007, p. 351; Serreze et al. 2007, p. 1,533–1,536), this is the timeframe with the greatest potential for reduced access to ringed seals as prey. Most POLAR BEAR POPULATIONs forage minimally during the fall open-water period, but a reduction in sea ice can extend the time period in which bears have minimal or no access to prey (Stirling et al. 1999, p. 299). The effects of a lengthened ice-free season during this time period have been associated with declines in polar bear condition (Stirling et al. 1999, p. 304; Rode et al. 2007, p. 8), reproduction (Regehr et al. 2006; Rode et al. 2007, p. 8–9), survival (Regehr et al. 2007a, p. 2,677–2,678; Regehr et al 2007b, p. 13) and population size (Regehr et al. 2007a, p. 2,678–2,679;).

Marine mammal carcasses do not currently constitute a large portion of polar bear diets and are unlikely to contribute substantially to future diets of polar bears. Although marine mammal carcass availability occasionally is predictable where whales are harvested for subsistence by Native people (Miller et al. 2006, p. 1) or where walruses haul out on land and are killed in stampeding events (Kochnev 2006, p. 159), in most cases scavenging opportunities are unpredictable and not a substitute for normal foraging by polar bears. Even where their distribution is predictable, marine mammal carcasses are presently used by only a small proportion of most populations or contribute minimally to total diet (Bentzen 2006, p. 23; Iverson et al. 2006, p. 111), and do not appear to be a preferred substitute for the normal diet. For example, on the Alaskan Southern Beaufort Sea coast, from 2002–2004, on average less than 5 percent of the estimated population size of 1,500 polar bears visited subsistence-harvested whale carcasses (Miller et al. 2006, p. 9). A small fraction of collared pregnant adult females visited whale harvest sites (Fischbach et al. 2007, pp. 1,401–1,402). Quotas on subsistence whale harvest preclude the possibility that carcasses will be increasingly available in the future. Similarly, while walrus contributed up to 24 percent of diets of a few individual bears in Davis Strait, population wide, walruses composed a small fraction of the total diet (Iverson et al. 2006, p. 112). Less predictable sea-ice conditions could increase the frequency of future marine mammal strandings (Derocher et al. 2004, p. 89), and some polar bears may benefit from such increases in marine mammal mortality. However, if stranding events become frequent, they are likely to result in declines of source populations. Thus, the likelihood of polar bears relying heavily on stranded or harvested marine mammals as a food source is low.

The potential for polar bears to substitute terrestrial food resources in place of their current diet of marine mammals is limited by the low quality and availability of foods in most northern terrestrial environments. Although smaller bears can maintain their body weight consuming diets consisting largely of berries and vegetation, low digestibility (Pritchard and Robbins 1990, p. 1,645), physical constraints on intake rate, and in the case of berries, low protein content, prevent larger bears from similarly subsisting on vegetative resources (Stirling and Derocher 1990, p. 191; Rode and Robbins 2000, p. 1,640; Rode et al. 2001, p. 70; Welch et al. 1997, p. 1,105). While some meat sources are available in terrestrial Arctic habitats, such as caribou, muskox, and Arctic char, the relative scarcity of these resources results in these areas supporting some of the smallest grizzly bears in the world at some of the lowest densities of any bear populations (Hilderbrand et al. 1999, p. 135; Miller et al. 1997, p. 37). Lunn and Stirling (1985, p. 2,295) suggest that predation on terrestrially-based prey by polar bears may be rare due to the high energetic cost of locomotion in polar bears in comparison to grizzly bears (Best 1982, p. 63). Energy expended to pursue terrestrial prey could exceed the amount of energy obtained. Furthermore, terrestrial meat resources are primarily composed of protein and carbohydrates that provide approximately half as many calories per gram as fats (Robbins 1993, p. 10). Because the wet weight of ringed seals is composed of up to 50 percent fat (Stirling 2002, p. 67), they provide a substantially higher caloric value in comparison to terrestrial foods. Physiological and environmental limitations, therefore, preclude the possibility that terrestrial food sources alone or as a large portion of the diet would be an equivalent substitute for the high fat diet supporting the population densities and body size of present-day polar bear populations.

An alternative to maintaining caloric intake would be for polar bears to adopt behavioral strategies that reduce energy expenditure and requirements. Across populations, polar bears do appear to alter home range size and daily travel distances in response to varying levels of prey density (Ferguson et al. 2001, p. 51). Additionally, polar bears exhibit a variety of patterns of fasting and feeding throughout their range, including 3-to 8-month-long fasts, denning by pregnant females, and moving between a fasting and a feeding metabolism based on continuously changing food availability throughout the year (Derocher et al. 1990, p. 202). These physiological and behavioral strategies have occurred in response to regional variation in environmental conditions but have limitations relative to their application across all regions and habitats. Both the long fasts that occur in Western Hudson Bay and denning of females throughout polar bear ranges are dependent on prey availability that allows sufficient accumulation of body fat to survive fasting periods (Derocher and Stirling 1995, p. 535). The 3-to 8-month-long periods of food deprivation exhibited by bears in the southern reaches of their range are supported by a rich marine environment that allows spring weight gains sufficient to sustain extended summer fasts. In the southern Beaufort Sea, for example, the heaviest polar bears were observed during autumn (Durner and Amstrup 1996, p. 483). In the Beaufort Sea and other regions of the polar basin, the probability that polar bears could survive extended summer fasting periods appears to be low. The documented reduction in polar bear condition in Western Hudson Bay associated with the recent lengthening of the ice-free season (Stirling et al. 1999, p. 294) suggests that even in the productive Hudson Bay environment there are limits to the ability of polar bears to fast.

Any period of fasting, whether while denning or resting onshore, would require an increase in food availability during alternative, non-fasting periods for fat accumulation. Adequate food may not be available to support sex and age classes other than pregnant females to adopt a strategy of denning over extended periods of time during food shortage. Furthermore, the ability to take advantage of seasonally fluctuating food availability and avoid extended torpor and associated physiological costs (Humphries et al. 2003, p. 165) has allowed polar bears to maximize access to food resources and is an important factor contributing to their large size.

The known current physiological and physical characteristics of polar bears suggest that behavioral adaptation will be sufficiently constrained to cause a pronounced reduction in polar bear distribution, and abundance, as a result of declining sea ice. The pace at which ice conditions are changing and the long generation time of polar bears precludes adaptation of new physiological mechanisms and physical characteristics through natural selection. Current evidence opposes the likelihood that extended periods of torpor, consumption of terrestrial foods, or capture of seals in open water will be sufficient mechanisms to counter the loss of ice as a platform for hunting seals. Polar bear survival and maintenance at sustainable population sizes depends on large and accessible seal populations and vast areas of ice from which to hunt.

Open Water Habitat

While sea ice is considered essential habitat for polar bear life functions because of the importance for feeding, reproduction, or resting, open water is not. Vast areas of open water can present a barrier or hazard under certain circumstances for polar bears to access sea ice or land. Diminished sea ice cover will increase the energetic cost to polar bears for travel, and will increase the risk of drowning that may occur during long distance swimming or swimming under unfavorable weather conditions. In addition, diminished sea ice cover may result in hypothermia for young cubs that are forced to swim for longer periods than at present. Under diminishing sea ice projections (IPCC 2001, p. 489; ACIA 2005, p. 192; Serreze 2006), ice-dependent seals, the principal prey of polar bears, will also be affected through distribution changes and reductions in productivity that will ultimately translate into reductions in seal population size.

Reduced Hunting Success

Polar bears are capable of swimming great distances, but exhibit a strong preference for sea ice (Mauritzen et al. 2003b, pp. 119–120). However, polar bears will also quickly abandon sea ice for land once the sea ice concentration drops below 50 percent. This is likely due to reduced hunting success in broken ice with significant open water (Derocher et al. 2004, p. 167; Stirling et al. 1999, pp. 302–303). Bears have only rarely been reported to capture ringed seals in open water (Furnell and Oolooyuk 1980, p. 88), therefore, hunting in ice-free water would not compensate for the corresponding loss of sea ice and the access sea ice affords polar bears to hunt ringed seals (Stirling and Derocher 1993, p. 241; Derocher et al. 2004, p. 167).

Reduction in sea ice and corresponding increase in open water would likely result in a net reduction in ringed and bearded seals, and Pacific walrus abundance (ACIA 2005, p. 510), as well as a reduction in ribbon and spotted seals (Born 2005a). While harp and hooded seals may change their distribution and temporarily serve as alternative prey for polar bears, it appears that these species cannot successfully redistribute in a rapidly changing environment and reproduce and survive at former levels. Furthermore, a recent study suggests that these two species will be the most vulnerable to effects of changing ice conditions (Laidre et al. in press). Loss of southern pupping areas due to inadequate or highly variable ice conditions will, in the long run, also serve to reduce these species as a potential polar bear prey (Derocher et al. 2004, p. 168). That increased take of other species such as bearded seals, walrus, harbor seals, or harp and hooded seals, if they were available, would not likely compensate for reduced availability of ringed seals (Derocher et al. 2004, p. 168).

Open Water Swimming

Open water is considered to present a potential hazard to polar bears because it can result in long distances that must be crossed to access sea ice or land habitat. In September 2004, four polar bears drowned in open water while attempting to swim in an area between shore and distant ice (Monnett and Gleason 2006, p. 5). Seas during this period were rough, and extensive areas of open water persisted between pack ice and land. Because the survey area covered 11 percent of the study area, an extrapolation of the survey data to the entire study area suggests that a larger number of bears may have drowned during this event. Mortalities due to offshore swimming during years when sea ice formation nearshore is delayed (or mild) may also be an important and unaccounted source of natural mortality given energetic demands placed on individual bears engaged in long-distance swimming (Monnett and Gleason 2006, p. 6). This suggests that drowning related deaths of polar bears may increase in the future if the observed trend of recession of pack ice with longer open-water periods continues. However, this phenomenon may be shortlived if natural selection operates against the behavioral inclination to swim between ice and land and favors bears that remain on land or on ice.

Wave height (sea state) increases as a function of the amount of open water surface area. Thus ice reduction not only increases areas of open water across which polar bears must swim, but may have an influence on the size of wave action. Considered together, these may result in increases in bear mortality associated with swimming when there is little sea ice to buffer wave action (Monnett and Gleason 2006, p. 5). Evidence of such mortality was also reported east of Svalbard in 2006, where one exhausted and one apparently dead polar bear were stranded (J. Dowdeswell, Head of the Scott Polar Research Institute of England, pers. obs.).

Terrestrial Habitat

Although sea ice is the polar bear's principal habitat, terrestrial habitat serves a vital function seasonally for maternal denning. In addition, use of terrestrial habitat is seasonally important for resting and feeding in the absence of suitable sea ice. Due to retreating sea ice, polar bears may be forced to make increased use of land in future years. The following sections describe the effects or potential effects of climate change and other factors on polar bear use of terrestrial habitat. One section focuses on access to or changes in the quality of denning habitat, and one focuses on distribution changes and corresponding increases in polar bear-human interactions in coastal areas. Also discussed are the potential consequences of and potential concerns for development, primarily oil and gas exploration and production which occur in polar bear habitat (both marine and terrestrial).

Access to and Alteration of Denning Areas

Many female polar bears repeatedly return to specific denning areas on land (Harrington 1968, p. 11; Schweinsburg et al. 1984, p. 169; Garner et al. 1994, p. 401; Ramsay and Stirling 1990, p. 233; Amstrup and Gardner 1995, p. 8). For bears to access preferred denning areas, pack ice must drift close enough or must freeze sufficiently early in the fall to allow pregnant females to walk or swim to the area by late October or early November (Derocher et al. 2004, p. 166), although polar bears may den into early December (Amstrup 2003, p. 597). Stirling and Andriashek (1992, p. 364) found that the distribution of polar bear maternal dens on land was related to the proximity of persistent summer sea ice, or areas that develop sea ice early in the autumn.

Derocher et al. (2004, p. 166) predicted that under future climate change scenarios, pregnant female polar bears will likely be unable to reach many of the most important denning areas in the Svalbard Archipelago, Franz Josef Land, Novaya Zemlya, Wrangel Island, Hudson Bay, and the Arctic National Wildlife Refuge and north coast of the Beaufort Sea (see Figure 8). Under likely climate change scenarios, the distance between the edge of the pack ice and land will increase (ACIA 2005, pp. 456–459). As distance increases between the southern edge of the pack ice and coastal denning areas, it will become increasingly difficult for females to access preferred denning locations. In addition to suitable access and availability of den sites, body condition is an important prerequisite for cub survival, and recruitment into the population as pregnant bears with low lipid stores are less likely to leave the den with healthy young in the spring (Atkinson and Ramsay 1995, pp. 565–566). Messier et al. (1994) postulated that pregnant bears may reduce activity levels up to 2 months prior to denning to conserve energy.

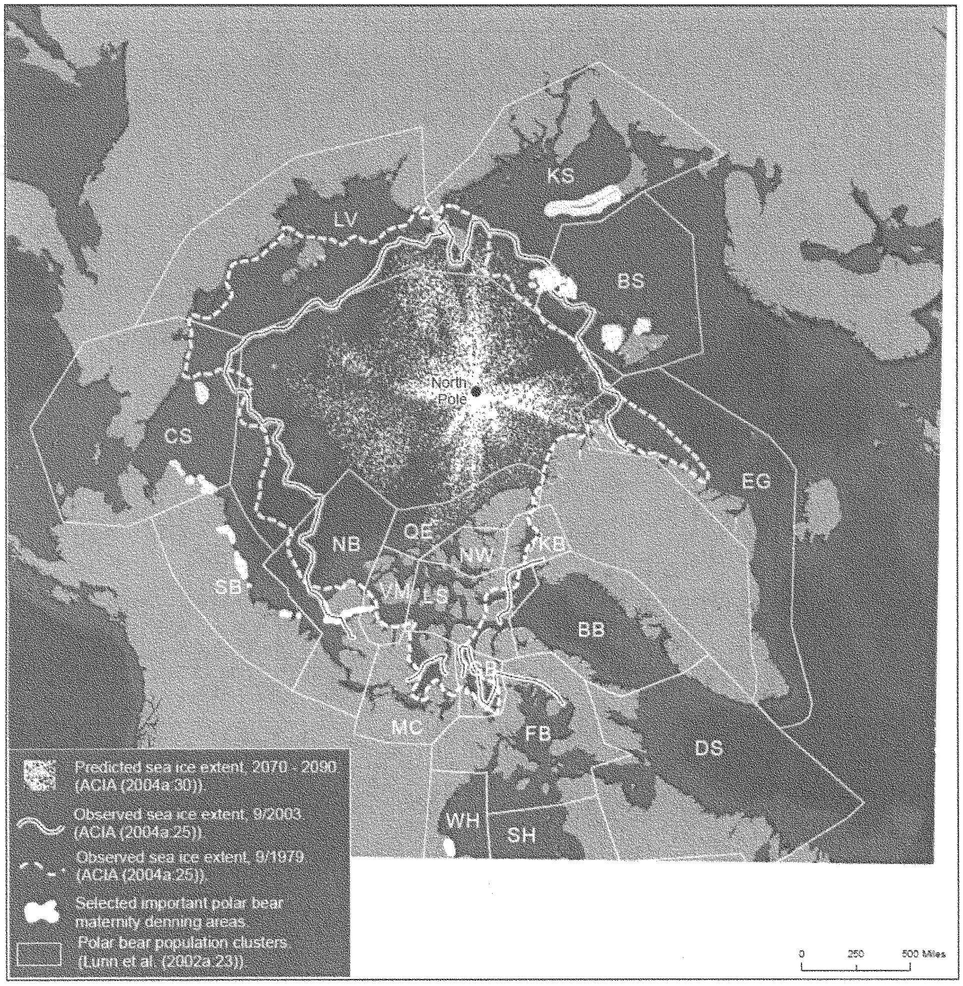


Figure 8. Circumpolar map of higher density polar bear terrestrial denning areas compared to past, present, and projected future extents of summer sea ice. Source: Adapted from Lunn et al. (2002a, p. 23) and ACIA (2005, pp. 25, 30).

Polar Bear Population Abbreviations. CS = Chukchi Sea; SB = Southern Beaufort Sea; NB = Northern Beaufort Sea; QE = Queen Elizabeth Islands; VM = Viscount Melville Sound; NW = Norwegian Bay; LS = Lancaster Sound; MC = M'Clintock Channel; GB = Gulf of Boothia; FB = Foxe Basin; WH = Western Hudson Bay; SH = Southern Hudson Bay; KB = Kane Basin; BB = Baffin Bay; DS = Davis Strait; EG = East Greenland; BS = Barents Sea; KS = Kara Sea; LV = Laptev Sea; Arctic Basin is the unlabelled area centered on the North Pole.

Bergen et al. (2007, p. 2) hypothesized that denning success is inversely related to the distance a pregnant polar bear must travel to reach denning habitat. These authors developed an approach using observed sea ice distributions (1979–2006) and GCM-derived sea ice projections (1975–2060) to estimate minimum distances that pregnant polar bears would have to travel between summer sea ice habitats and a terrestrial den location in northeast Alaska (Bergen et al. 2007, p. 2–3). In this pilot assessment, calculations were made with and without the constraint of least cost movement paths, which required bears to optimally follow high-quality sea ice habitats. Although variation was evident and considerable among the five GCMs analyzed, the smoothed multi-model average distances aligned well with those derived from the observational record. The authors found that between 1979 and 2006, the minimum distance polar bears traveled to denning habitats in northeast Alaska increased at an average linear rate of 6–8 km per year (3.7–5.0 mi per year), and almost doubled after 1992. They projected that travel would increase threefold by 2060 (Bergen et al. 2007, p. 2–3).

Based on projected retraction of sea ice in the future, Bergen et al. (2007, p. 2) states, ''thus, pregnant polar bears will likely incur greater energetic expense in reaching traditional denning regions if sea ice loss continues along the projected trajectory.'' Increased travel distances could negatively affect individual fitness, denning success, and ultimately populations of polar bears (Aars et al. 2006). While the Bergen et al. (2007, p. 2) study focused on polar bears using denning habitat in northern Alaska, other denning regions in the Arctic, particularly within the polar basin region, are much farther from areas where summer ice is predicted to persist in the future. Polar bears returning to other denning locales, such as Wrangel Island or the Chukotka Peninsula, will likely have to travel greater distances than those reported here. Most high-density denning areas are located at more southerly latitudes (see Figure 8). For populations that den at high latitudes in the Canadian archipelago islands, access to, and availability of, suitable den sites may not currently be a problem. However, access to historically-used den sites in the future may become more problematic in the northern areas. The degree to which polar bears may use nontraditional denning habitats at higher latitudes in the future, through facultative adaptation, is largely unknown but is possible.

Climate change could also impact populations where females den in snow (Derocher et al. 2004). Insufficient snow would prevent den construction or result in use of poor sites where the roof could collapse (Derocher et al. 2004). Too much snow could necessitate the reconfiguration of the den by the female throughout the winter (Derocher et al. 2004). Changes in amount and timing of snowfall could also impact the thermal properties of the dens (Derocher et al. 2004). Since polar bear cubs are born helpless and need to nurse for three months before emerging from the den, major changes in the thermal properties of dens could negatively impact cub survival (Derocher et al. 2004). Finally, unusual rain events are projected to increase throughout the Arctic in winter (ACIA 2005), and increased rain in late winter and early spring could cause den collapse (Stirling and Smith 2004). Den collapse following a warming period was observed in the Beaufort Sea and resulted in the death of a mother and her two young cubs (Clarkson and Irish 1991). After March 1990 brought unseasonable rain south of Churchill, Manitoba, Canada, researchers observed large snow banks along creeks and rivers used for denning that had collapsed because of the weight of the wet snow, and noted that had there been maternity dens in this area the bears likely would have been crushed (Stirling and Derocher 1993).

Oil and Gas Exploration, Development, and Production

Each of the Parties to the 1973 Polar Bear Agreement (see International Agreements and Oversight section below) has developed detailed regulations pertaining to the extraction of oil and gas within their countries. The greatest level of oil and gas activity within polar bear habitat is currently occurring in the United States (Alaska). Exploration and production activities are also actively underway in Russia, Canada, Norway, and Denmark (Greenland). In the United States, all such leasing and production activities are evaluated as specified by the National Environmental Policy Act (42 U.S.C. 4321 et seq.) (NEPA), Outer Continental Shelf Lands Act (43 U.S.C. 1331 et seq.) (OCSLA), and numerous other statutes, that evaluate and guide exploration, development, and production in order to minimize possible environmental impacts. In Alaska, the majority of oil and gas development is on land; however, some offshore production sites have been developed, and others are planned.

Historically, oil and gas activities have resulted in little direct mortality to polar bears, and that mortality which has occurred has been associated with human-bear interactions as opposed to a spill event. However, oil and gas activities are increasing as development continues to expand throughout the U.S. Arctic and internationally, including in polar bear terrestrial and marine habitats. The greatest concern for future oil and gas development is the effect of an oil spill or discharges in the marine environment impacting polar bears or their habitat. Disturbance from activities associated with oil and gas activities can result in direct or indirect effects on polar bear use of habitat. Direct disturbances include displacement of bears or their primary prey (ringed and bearded seals) due to the movement of equipment, personnel, and ships through polar bear habitat. Female polar bears tend to select secluded areas for denning, presumably to minimize disturbance during the critical period of cub development. Direct disturbance may cause abandonment of established dens before their cubs are ready to leave. For example, expansion of the network of roads, pipelines, well pads, and infrastructure associated with oil and gas activities may force pregnant females into marginal denning locations (Lentfer and Hensel 1980, p. 106; Amstrup et al. 1986, p. 242). The potential effects of human activities are much greater in areas where there is a high concentration of dens such as Wrangel Island. Although bear behavior is highly variable among individuals and the sample size was small, Amstrup (1993, pp. 247–249) found that in some instances denning bears were fairly tolerant to some levels of activity. Increased shipping may increase the amount of open water, cause disturbance to polar bears and their prey, and increase the potential for additional oil spills (Granier et al. 2006 p. 4). Much of the North Slope of Alaska contains habitat suitable for polar bear denning (Durner et al. 2001, p. 119). Furthermore, in northern Alaska and Chukotka, Russia, polar bears appear to be using land areas with greater frequency during the season of minimum sea ice. Some of these areas coincide with areas that have traditionally been used for oil and gas production and exploration. These events increase the potential for interactions with humans (Durner et al. 2001, p. 115; National Research Council (NRC) 2003, p. 168); however, current regulations minimize these interactions by establishing buffer zones around active den sites.

The National Research Council (NRC 2003, p. 169) evaluated the cumulative effects of oil and gas development in Alaska and concluded the following related to polar bears and ringed seals:

- ''Industrial activity in the marine waters of the Beaufort Sea has been limited and sporadic and likely has not caused serious cumulative effects to ringed seals or polar bears.
- Careful mitigation can help to reduce the effects of oil and gas development and their accumulation, especially if there are no major oil spills. However, the effects of full-scale industrial development of waters off the North Slope would accumulate through the displacement of polar bears and ringed seals from their habitats, increased mortality, and decreased reproductive success.
- A major Beaufort Sea oil spill would have major effects on polar bears and ringed seals.
- Climatic warming at predicted rates in the Beaufort Sea region is likely to have serious consequences for ringed seals and polar bears, and those effects will accumulate with the effects of oil and gas activities in the region.
- Unless studies to address the potential accumulation of effects on North Slope polar bears or ringed seals are designed, funded, and conducted over long periods of time, it will be impossible to verify whether such effects occur, to measure them, or to explain their causes.''

Some alteration of polar bear habitat has occurred from oil and gas development, seismic exploration, or other activities in denning areas, and potential oil spills in the marine environment and expanded activities increase the potential for additional alteration. Any such impacts would be additive to other factors already or potentially affecting polar bears and their habitat. However, mitigative regulations that have been instituted, and will be modified as necessary, have proven to be highly successful in providing for polar bear conservation in Alaska.

Oil and gas exploration, development, and production activities do not threaten the species throughout all or a significant portion of its range based on: (1) mitigation measures in place now and likely to be used in the future; (2) historical information on the level of oil and gas development activities occurring within polar bear habitat within the Arctic; (3) the lack of direct quantifiable impacts to polar bear habitat from these activities noted to date in Alaska; (4) the current availability of suitable alternative habitat; and (5) the limited and localized nature of the development activities, or possible events, such as oil spills.

Documented direct impacts on polar bears by the oil and gas industry during the past 30 years are minimal. Polar bears spend a limited amount of time on land, particularly in the southern Beaufort Sea, coming ashore to feed, den, or move to other areas. At times, fall storms deposit bears along the coastline where bears remain until the ice returns. For this reason, polar bears have mainly been encountered at or near most coastal and offshore production facilities, or along the roads and causeways that link these facilities to the mainland. During those periods, the likelihood of incidental interactions between polar bears and industry activities increases. As discussed under our Factor D analysis below, the MMPA has specific provisions for such incidental take, including specific findings that must be made by the Service and the provision of mitigation actions, which serve to minimize the likelihood of impacts upon polar bears. We have found that the polar bear interaction planning and training requirements set forth in the incidental take regulations and required through the letters of authorization (LOA) process, and the overall review of the regulations every one to five years has increased polar bear awareness and minimized these encounters in the United States. The LOA requirements have also increased our knowledge of polar bear activity in the developed areas.

Prior to issuance of regulations, lethal takes by industry were rare. Since 1968, there have been two documented cases of lethal take of polar bears associated with oil and gas activities. In both instances, the lethal take was reported to be in defense of human life. In the winter of 1968–1969, an industry employee shot and killed a polar bear (Brooks et al. 1971, p. 15). In 1990, a female polar bear was killed at a drill site on the west side of Camden Bay (USFWS internal correspondence, 1990). In contrast, 33 polar bears were killed in the Canadian Northwest Territories from 1976 to 1986 due to encounters with industry (Stenhouse et al. 1988, p. 276). Since the beginning of the incidental take program, which includes requirements for monitoring, project design, and hazing of bears presenting a safety problem, no polar bears have been killed due to encounters associated with the current industry activities on the North Slope of Alaska.

Observed Demographic Effects of Sea Ice Changes on Polar Bear

The potential demographic effects of sea ice changes on polar bear reproductive and survival rates (vital rates) and ultimately on population size are difficult to quantify due to the need for extensive time series of data. This is especially true for a long-lived and widely dispersed species like the polar bear. Recent research by Stirling et al. (2006), Regehr et al. (2007a, b), Hunter et al. (2007), and Rode et al. (2007), however, evaluates these important relationships and adds significantly to our understanding of how and to what extent environmental changes influence essential life history parameters. The key demographic factors for polar bears are physical condition, reproduction, and survival. Alteration of these characteristics has been associated with elevated risks of extinction for other species (McKinney 1997, p. 496; Beissinger 2000, p. 11,688; Owens and Bennett 2000, p. 12,145).

Physical condition of polar bears determines the welfare of individuals, and, ultimately, through their reproduction and survival, the welfare of populations (Stirling et al. 1999, p. 304; Regehr et al. 2007a, p. 13; Regehr et al 2007b, pp. 2,677–2,680; Hunter et al. 2007, pp. 8–13). In general, Derocher et al. (2004, p. 170) predict that declines in the physical condition will initially affect female reproductive rates and juvenile survival and then under more severe conditions adult female survival rates. Adult females represent the most important sex and age class within the population regarding population status (Taylor et al. 1987, p. 811).

Declines in fat reserves during critical times in the polar bear life cycle detrimentally affect populations through delay in the age of first reproduction, decrease in denning success, decline in litter sizes with more single cub litters and fewer cubs, and lower cub body weights and lower survival rates (Atkinson and Ramsay 1995, pp. 565–566; Derocher et al. 2004, p. 170). Derocher and Stirling (1998, pp. 255–256) demonstrated that body mass of adult females is correlated with cub mass at den emergence, with heavier females producing heavier cubs and lighter females producing lighter cubs. Heavier cubs have a higher rate of survival (Derocher and Stirling 1996, p. 1,249). A higher proportion of females in poor condition do not initiate denning or are likely to abandon their den and cub(s) mid-winter (Derocher et al. 2004, p. 170). Females with insufficient fat stores or in poor hunting condition in the early spring after den emergence could lead to increased cub mortality (Derocher et al. 2004, p. 170). In addition, sea ice conditions that include broken or more fragmented ice may require young cubs to enter water more frequently and for more prolonged periods of time, thus increasing mortality from hypothermia. Blix and Lenter (1979, p. 72) and Larsen (1985, p. 325) indicate that cubs are unable to survive immersion in icy water for more than approximately 10 minutes. This is due to cubs having little insulating fat, their fur losing its insulating ability when wet (though the fur of adults sheds water and recovers its insulating properties quickly), and the core body temperature dropping rapidly when they are immersed in icy water (Blix and Lentfer 1979, p. 72).

Reductions in sea ice, as discussed in previous sections, will alter ringed seal distribution, abundance, and availability for polar bears. Such reductions will, in turn, decrease polar bear body condition (Derocher et al. 2004, p. 165). Derocher et al. (2004, p. 165) projected that most females in the Western Hudson Bay population may be unable to reach the minimum 189 kg (417 lbs) body mass required to successfully reproduce by the year 2012. Stirling (Canadian Wildlife Service, pers comm. 2006) indicates, based on the decline in weights of lone and suspected pregnant females in the fall (Stirling and Parkinson 2006), that the 2012 date is likely premature. However, Stirling (Canadian Wildlife Service, pers comm. 2006) found that the trend of continuing weight loss by adult female polar bears in the fall is clear and continuing, and, therefore, Stirling believed that the production of cubs in these areas will probably be negligible within the next 15–25 years.

Furthermore, with the extent of sea ice projected to be substantially reduced in the future (e.g., Stroeve et al. 2007, pp. 1–5), opportunities for increased feeding to recover fat stores during the season of minimum ice may be limited

(Durner et al. 2007, p. 12). It should be noted that the models project decreased ice cover in all months in the Arctic, but that (as has been observed) the projected changes in the 21st century are largest in summer (Holland et al. 2006, pp. 1–5; Stroeve et al. 2007, pp. 1–5; Durner et al. 2007, p. 12; DeWeaver 2007, p. 2; IPCC 2007). Mortality of polar bears is thought to be the highest in winter when fat stores are low and energetic demands are greatest. Pregnant females are in dens during this period using fat reserves and not feeding. The availability and accessibility of seals to polar bears, which often hunt at the breathing holes, is likely to decrease with increasing amounts of open water or fragmented ice (Derocher et al. 2004, p. 167).

Demographic Effects on Polar Bear Populations with Long-term Data Sets

This section summarizes demographic effects on polar bear populations for which long-term data sets are available. These populations are: Western Hudson Bay, Southern Hudson Bay, Southern Beaufort Sea, Northern Beaufort Sea, and, to a lesser extent, Foxe Basin, Baffin Bay, Davis Strait, and Eastern Hudson Bay.

Western Hudson Bay

The Western Hudson Bay polar bear population occurs near the southern limit of the species' range and is relatively discrete from adjacent populations (Derocher and Stirling 1990, p. 1,390; Stirling et al. 2004, p. 16). In winter and spring, polar bears of the Western Hudson Bay population disperse over the ice-covered Bay to hunt seals (Iverson et al. 2006, p. 98). In summer and autumn, when Hudson Bay is ice-free, the population is confined to a restricted area of land on the western coast of the Bay. There, nonpregnant polar bears are cut off from their seal prey and must rely on fat reserves until freeze-up, a period of approximately 4 months. Pregnant bears going into dens may be food deprived for up to an additional 4 months (a total of 8 months).

In the past 50 years, spring air temperatures in western Hudson Bay have increased by 2–3 degrees C (Skinner et al. 1998; Gagnon and Gough 2005, p. 289). Consequently, the sea ice on the Bay now breaks up approximately 3 weeks earlier than it did 30 years ago (Stirling and Parkinson 2006, p. 265). This forces the Western Hudson Bay polar bears off the sea ice earlier, shortening the spring foraging period when seals are most available, and reducing the polar bears' ability to accumulate the fat reserves needed to survive while stranded onshore. Previous studies have shown a correlation between rising air temperatures, earlier sea ice break-up, and declining recruitment and body condition for polar bears in western Hudson Bay (Derocher and Stirling 1996, p. 1,250; Stirling et al. 1999, p. 294; Stirling and Parkinson 2006, p. 266). Based on GCM projections of continued warming and progressively earlier sea ice break-up (Zhang and Walsh 2006), Stirling and Parkinson (2006, p. 271–272) predicted that conditions will become increasingly difficult for the Western Hudson Bay population.

Regehr et al. (2007a, p. 2,673) used capture-recapture models to estimate population size and survival for polar bears captured from 1984 to 2004 along the western coast of Hudson Bay. During this period the Western Hudson Bay population experienced a statistically significant decline of 22 percent, from 1,194 bears in 1987 to 935 bears in 2004. Regehr et al. (2007a, p. 2,673) notes that while survival of adult female and male bears was stable, survival of juvenile, subadult, and senescent (nonreproductive) bears was negatively correlated with the spring sea ice break-up date—a date that occurred approximately 3 weeks earlier in 2004 than in 1984. Long-term observations suggest that the Western Hudson Bay population continues to exhibit a high degree of fidelity to the study area during the early part of the sea ice-free season (Stirling et al. 1977, p. 1,126; Stirling et al. 1999, p. 301; Taylor and Lee 1995, p. 147), which precludes permanent emigration as a cause for the population decline. The authors (Regehr et al. 2007a, p. 2,673) attribute the decline of the Western Hudson Bay population to increased natural mortality associated with earlier sea ice break-up, and the continued harvest of approximately 40 polar bears per year (Lunn et al. 2002, p. 104). No support for alternative explanations was found.

Southern Hudson Bay

Evidence of declining body condition for polar bears in the Western Hudson Bay population suggests that there should be evidence of parallel declines in adjacent polar bear populations experiencing similar environmental conditions. In an effort to evaluate an adjacent population, Obbard et al. (2006, p. 2) conducted an analysis of polar bear condition in the Southern Hudson Bay population by comparing body condition for two time periods, 1984–1986 and 2000–2005. The authors found that the average body condition for all age and reproductive classes combined was significantly poorer for Southern Hudson Bay bears captured from 2000–2005 than for bears captured from 1984–1986 (Obbard et al. 2006, p. 4). The results indicate a declining trend in condition for all age and reproductive classes of polar bears since the mid-1980s. The results further reveal that the decline has been greatest for pregnant females and subadult bears—trends that will likely have an impact on future reproductive output and subadult survival (Obbard et al. 2006, p. 1).

Obbard et al (2006, p. 4) evaluated inter-annual variability in body condition in relation to the timing of ice melt and to duration of ice cover in the previous winter and found no significant relationship despite strong evidence of a significant trend towards both later freeze-up and earlier break-up (Gough et al. 2004, p. 298; Gagnon and Gough 2005, p. 293). While southern Hudson Bay loses its sea ice cover later in the year than western Hudson Bay, the authors believe that other factors or combinations of factors (that likely also include later freeze-up and earlier break-up) are operating to affect body condition in southern Hudson Bay polar bears. These factors may include unusual spring rain events that occur during March or April when ringed seals are giving birth to pups in on-ice birthing lairs (Stirling and Smith 2004, pp. 60–63), depth of snow accumulation and roughness of the ice that vary over time and also affect polar bear hunting success (Stirling and Smith 2004, p. 60–62; Ferguson et al. 2005, p. 131), changes in the abundance and distribution of ringed seals, and reduced pregnancy rates and of reduced pup survival in ringed seals from western Hudson Bay during the 1990s (Ferguson et al. 2005, p. 132; Stirling 2005, p. 381).

A more recent status assessment using open population capture-recapture models was conducted to evaluate population trend in the Southern Hudson Bay population (Obbard et al. 2007, pp. 3–9). The authors found that the population and survival estimates for subadult female and male polar bears were not significantly different between 1984–1986 and 1999–2005 respectively. There was weak evidence of lower survival of cubs, yearlings, and senescent adults in the recent time period (Obbard et al. 2007, pp. 10–11). As previously reported, no association was apparent between survival and cub-of-the-year body condition, average body condition for the age class, or extent of ice cover. The authors indicate that lack of association could be real or attributable to various factors—the coarse scale of average body condition measure, or to limited sample size, or limited years of intensive sampling (Obbard et al. 2007, pp. 11–12).

The decline in survival estimates, although not statistically significantly, combined with the evidence of significant declines in body condition for all age and sex classes, suggest that the Southern Hudson Bay population may be under increased stress at this time (Obbard et al. 2007, p. 14). The authors also indicated that if the trend in earlier ice break-up and later freeze-up continues in this area, it is likely that the population will exhibit changes similar to the Western Hudson Bay population even though no current significant relationships exist between extent of ice cover and the survival estimates and the average body condition for each age class (Obbard et al. 2007, p. 14).

Southern Beaufort Sea

The Southern Beaufort Sea population has also been subject to dramatic changes in the sea ice environment, beginning in the winter of 1989–1990 (Regehr et al. 2006, p. 2). These changes were linked initially through direct observation of distribution changes during the fall open-water period. With the exception of the Western Hudson Bay population, the Southern Beaufort Sea population has the most complete and extensive time series of life history data, dating back to the late 1960s. A 5-year coordinated capture-recapture study of this population to evaluate changes in the health and status of polar bears and life history parameters such as reproduction, survival, and abundance was completed in 2006. Results of this study indicate that the estimated population size has gone from 1,800 polar bears (Amstrup et al. 1986, p. 244; Amstrup 2000, p. 146) to 1,526 polar bears in 2006 (Regehr et al. 2006, p. 16). The precision of the earlier estimate (1,800 polar bears) was low, and consequently there is not a statistically significant difference between the two point estimates. Amstrup et al. (2001, p. 230) provided a population estimate of as many as 2,500 bears for this population in the late 1980s, but the statistical variance of this estimate could not be calculated and thus precludes the comparative value of the estimate.

Survival rates, weights, and skull sizes were compared for two periods of time, 1967–1989 and 1990–2006. In the later period, estimates of cub survival declined significantly, from 0.65 to 0.43 (Regehr et al. 2006, p. 11). Cub weights also decreased slightly. The authors believed that poor survival of new cubs may have been related to declining physical condition of females entering dens and consequently of cubs born during recent years, as reflected by smaller skull measurements. In addition, body weights for adult males decreased significantly, and skull measurements were reduced since 1990 (Regehr et al. 2006, p 1). Because male polar bears continue to grow into their teen years (Derocher et al. 2005, p. 898), if nutritional intake was similar since 1990, the size of males should have increased (Regehr et al. 2006, p. 18). The observed changes reflect a trend toward smaller size adult male bears. Although a number of the indices of population status were not independently significant, nearly all of the indices illustrated a declining trend. In the case of the Western Hudson Bay population, declines in cub survival and physical stature were recorded for a number of years (Stirling et al. 1999, p. 300; Derocher et al. 2004, p. 165) before a statistically significant decline in the population size was confirmed (Regehr et al. 2007, p. 2,673).

In further support of the interaction of environmental factors, nutritional stress, and their effect on polar bears, several unusual mortality events have been documented in the southern Beaufort Sea. During the winter and early spring of 2004, three observations of polar bear cannibalism were recorded (Amstrup et al. 2006b, p. 1). Similar observations had not been recorded in that region despite studies extending back for decades. In the fall of 2004, four polar bears were observed to have drowned while attempting to swim between shore and distant pack ice in the Beaufort Sea. Despite offshore surveys extending back to 1987, similar observations had not previously been recorded (Monnett and Gleason 2006, p. 3). In spring of 2006, three adult female polar bears and one yearling were found dead. Two of these females and the yearling had no fat stores and apparently starved to death, while the third adult female was too heavily scavenged to determine a cause of death. This mortality is suspicious because prime age females have had very high survival rates in the past (Amstrup and Durner 1995, p. 1,315). Similarly, the yearling that was found starved was the offspring of another radio-collared prime age female whose collar had failed prior to her yearling being found dead. Annual survival of yearlings, given survival of their mother, was previously estimated to be 0.86 (Amstrup and Durner 1995, p. 1,316). The probability, therefore, that this yearling died while its mother was still alive was only approximately 14 percent. Regehr et al. (2006, p. 27) indicate that these anecdotal observations, in combination with changes in survival of young and declines in size and weights reported above, suggest mechanisms by which a changing sea ice environment can affect polar bear demographics and population status.

The work by Regehr et al. (2006, pp. 1, 5) described above suggested that the physical stature (as measured by skull size and body weight data) of some sex and age classes of bears in the Southern Beaufort Sea population had changed between early and latter portions of this study, but trends in or causes of those changes were not investigated. Rode et al. (2007, pp. 1–28), using sea ice and polar bear capture data from 1982 to 2006, investigated whether these measurements changed over time or in relation to sea ice extent. Annual variation in sea ice habitat important to polar bear foraging was quantified as the percent of days between April to November when mean sea ice concentration over the continental shelf was greater than or equal to 50 percent. The 50 percent concentration threshold was used because bears make little use of areas where sea ice concentration is lower (Durner et al. 2004, p. 19). The April to November period was used because it is believed to be the primary foraging period for polar bears in the southern Beaufort Sea (Amstrup et al. 2000b, p. 963). The frequency of capture events for individual bears was evaluated to determine if this factor had an effect on bear size, mass, or condition. Rode et al. (2007, pp. 5–8) found that mass, length, skull size, and body condition indices (BCI) of growing males (aged 3–10), mass and skull size of cubs-of-the year, and the number of yearlings per female in the spring and fall were all positively and significantly related to the percent of days in which sea ice covered the continental shelf. Unlike Regehr et al. (2006, p. 1), Rode et al. (2007, p. 8) did not document a declining trend in skull size or body size of cubs-of-the-year when the date of capture was considered. Condition of adult males 11 years and older and of adult females did not decline. There was some evidence, based on capture dates, that females with cubs have been emerging from dens earlier in recent years. Thus, though cubs were smaller in recent years, they also were captured earlier in the year. Why females may be emerging from dens earlier than they used to is not certain and warrants additional research.

Skull sizes and/or lengths of adult and subadult males and females decreased over time during the study (Rode et al. 2007, p. 1). Adult body mass was not related to sea ice cover and did not show a trend with time. The condition of adult females exhibited a positive trend over time, reflecting a decline in length without a parallel trend in mass. Though cub production increased over time, the number of cubs-of-the-year per female in the fall and yearlings per female in the spring declined (Rode et al. 2007, p. 1), corroborating the reduced cub survival, as noted previously by Regehr et al. (2006, p. 1). Males exhibited a stronger relationship with sea ice conditions and more pronounced declines over time than females. The mean body mass of males of ages 3–10 years (63 percent of all males captured over the age of 3) declined by 2.2 kg (4.9 lbs) per year, consistent with Regehr et al. (2006, p. 1), and was positively related to the percent of days with greater than or equal to 50 percent mean ice concentration over the continental shelf (Rode et al. 2007, p. 10). Because declines were not apparent in older, fully grown males, but were apparent in younger, fully grown males, the authors suggest that nutritional limitations may have occurred only in more recent years after the time when older males in the population were fully grown. Bears with prior capture history were either larger or similar in stature and mass to bears captured for the first time, indicating that research activities did not influence trends in the data.

The effect of sea ice conditions on the mass and size of subadult males suggests that, if sea ice conditions changed over time, this factor could be associated with the observed declines in these measures. While the sea ice metric used in Rode et al. (2007, p. 3) was meaningful to the foraging success of polar bears, recent habitat analyses have resulted in improvements in the understanding of preferred sea ice conditions of bears in the Southern Beaufort Sea population. Durner et al. (2007, pp. 6, 9) recently identified optimal polar bear habitat based on bathymetry (water depth), proximity to land, sea ice concentration, and distance to sea ice edges using resource selection functions. The sum of the monthly extent of this optimal habitat for each year within the range of the Southern Beaufort Sea population (Amstrup et al. 2004, p. 670) was strongly correlated with the Rode et al. (2007, p. 10) sea ice metric for the 1982–2006 period. This suggests that the Rode et al. (2007, p. 10) sea ice metric effectively quantified important habitat value. While the Rode et al. (2007, p. 10) sea ice metric did not exhibit a significantly negative trend over time, the optimal habitat available to bears in the southern Beaufort Sea as identified by Durner et al. (2007, pp. 5–6) did significantly decline between 1982 and 2006. This further supports the observation that the declining trend in bear size and condition over time were associated with a declining trend in availability of foraging habitat, particularly for subadult males whose mass and stature were related to sea ice conditions.

Rode et al. (2007, p. 12) concludes that the declines in mass and body condition index of subadult males, declines in growth of males and females, and declines in cub recruitment and survival suggest that polar bears of the Southern Beaufort Sea population have experienced a declining trend in nutritional status. The significant relationship between several of these measurements and sea ice cover over the continental shelf suggests that nutritional limitations may be associated with changing sea ice conditions.

Regehr et al. (2007b, p. 3) used multistate capture-recapture models that classified individual polar bears by sex, age, and reproductive category to evaluate the effects of declines in the extent and duration of sea ice on survival and breeding probabilities for polar bears in the Southern Beaufort Sea population. The study incorporated data collected from 2001–2006. Key elements of the models were the dependence of survival on the duration of the ice-free period over the continental shelf in the southern Beaufort Sea region, and variation in breeding probabilities over time. Other factors considered included harvest mortality, uneven capture probability, and temporary emigrations from the study area. Results of Regehr et al. (2007b, p. 1) reveal that in 2001 and 2002, the ice-free period was relatively short (mean 92 days) and survival of adult female polar bears was high (approximately 0.99). In 2004 and 2005, the ice-free period was long (mean 135 days) and survival of adult female polar bears was lower (approximately 0.77). Breeding and cub-of-the-year litter survival also declined from high rates in early years to lower rates in latter years of the study. The short duration of the study (5 years) introduced uncertainty associated with the logistic relationship between the sea ice covariate and survival. However, the most supported noncovariate models (i.e., that excluded ice as a covariate) also estimated declines in survival and breeding from 2001 to 2005 that were in close agreement to the declines estimated by the full model set.

Although the precision of vital rates estimated by Regehr et al. (2007b, pp. 17–18) was low, subsequent analyses (Hunter et al. 2007, p. 6) indicated that the declines in vital rates associated with longer ice-free periods have ramifications for the trend of the Southern Beaufort Sea population (i.e., result in a declining population trend). The Southern Beaufort Sea population occupies habitats similar to four other populations (Chukchi, Laptev, Kara, and Barents Seas) which represent over one-third of the world's polar bears. These areas have experienced sea ice declines in recent years that have been more severe than those experienced in the southern Beaufort Sea (Durner et al. 2007, pp. 32–33), and declining trends in status for these populations are projected to be similar to or greater than those projected for the Southern Beaufort Sea population (Amstrup et al. 2007, pp 7–8, 32).

Northern Beaufort Sea

The Northern Beaufort Sea population, unlike the Southern Beaufort Sea and Western Hudson Bay populations, is located in a region where sea ice converges on shorelines throughout most of the year. Stirling et al. (2007, pp. 1–6) used open population capture-recapture models of data collected from 1971–2006 to assess the relationship between polar bear survival and sex, age, time period, and a number of environmental covariates in order to assess population trends. Three covariates, two related to sea ice habitat and yearly seal productivity, were used to assess the recapture probability for estimates of long-term trends in the size of the Northern Beaufort Sea population (Stirling et al. 2007, pp. 4–8). Associations between survival estimates and the three covariates (sea ice habitat variables and seal abundance) were not, in general, supported by the data. Population estimates (model averaged) from 2004–2006 (980) were not significantly different from estimates for the periods of 1972–1975 (745) and 1985–1987 (867). The abundance during the three sampling periods, 1972–1975, 1985–1987, and 2004–2006 may be slightly low because (1) some bears residing in the extreme northern portions of the population may not have been equally available for capture and (2) the number of polar bears around Prince Patrick Island was not large relative to the rest of the population. Stirling et al. (2007, p. 10) concluded that currently the Northern Beaufort Sea population appears to be stable, probably because ice conditions remain suitable for feeding through much of the summer and fall in most years and harvest has not exceeded sustainable levels.

Other Populations

As noted earlier in the ''Distribution and Movement'' and the ''Polar Bear Seasonal Distribution Patterns Within Annual Activity Areas'' sections of this final rule, Stirling and Parkinson (2006, pp. 261–275) investigated ice break-up relative to distribution changes in five other polar bear populations in Canada: Foxe Basin, Baffin Bay, Davis Strait, Western Hudson Bay, and Eastern Hudson Bay. They found that sea-ice break-up in Foxe Basin has been occurring about 6 days earlier each decade; ice break-up in Baffin Bay has been occurring 6 to 7 days earlier per decade; and ice break-up in Western Hudson Bay has been occurring 7 to 8 days earlier per decade. Although long-term results from Davis Strait were not conclusive, particularly because the maximum percentage of ice cover in Davis Strait varies considerably more between years than in western Hudson Bay, Foxe Basin, or Baffin Bay, Stirling and Parkinson (2006, p. 269) did document a negative shortterm trend from 1991 to 2004 in Davis Strait. In eastern Hudson Bay, there was not a statistically significant trend toward earlier sea-ice break-up.

In four populations, Western Hudson Bay, Foxe Basin, Baffin Bay, and Davis Strait, residents of coastal settlements have reported seeing more polar bears and having more problem bear encounters during the open-water season, particularly in the fall. In those areas, the increased numbers of sightings, as well as an increase in the number of problem bears handled at Churchill, Manitoba, have been interpreted as indicative of an increase in population size. As discussed earlier, the declines in population size, condition, and survival of young bears in the Western Hudson Bay population as a consequence of earlier sea ice break-up brought about by climate warming have all been well documented (Stirling et al. 1999, p. 294; Gagnon and Gough 2005; Regehr et al. 2007a, p. 2,680). In Baffin Bay, the available data suggest that the population is being overharvested, so the reason for seeing more polar bears is unlikely to be an increase in population size. Ongoing research in Davis Strait (Peacock et al. 2007, pp. 6–7) indicates that this population may be larger than previously believed, which may at first seem inconsistent with the Stirling and Parkinson (2006, pp. 269–270) hypothesis of declining populations over time. This observation, however, is not equilavent to an indication of population growth. The quality of previous population estimates for this region, and the lack of complete coverage of sampling used to derive the previous estimates, preclude establishment of a trend in numbers. Although the timing and location of availability of sea ice in Davis Strait may have been declining (Amstrup et al. 2007, p. 25), changes in numbers and distribution of harp seals at this time may support large numbers of polar bears even if ringed seals are less available (Stirling and Parkinson 2006, p. 270; Iverson et al. 2006, p. 110). As stated previously, continuing loss of sea ice ultimately will have negative effects on this population and other populations in the Seasonal Ice ecoregion.

Polar Bear Populations without Long-term Data Sets

The remaining circumpolar polar bear populations either do not have data sets of sufficiently long time series or do not have data sets of comparable information that would allow the analysis of population trends or relationships to various environmental factors and other variables over time.

Projected Effects of Sea Ice Changes on Polar Bears

This section reviews a study by Durner et al. (2007) that evaluated polar bear habitat features and future habitat distribution and seasonal availability into the future. Studies by Amstrup et al. (2007) and Hunter et al. (2007) are also reviewed which included new analyses and approaches to examine trends and relationships for populations or groups of populations based on commonly understood relationships with habitat features and environmental conditions.

Habitat loss has been implicated as the greatest threat to the survival for most species (Wilcove et al. 1998, p. 614). Extinction theory suggests that the most vulnerable species are those that are specialized (Davis et al. 2004), long-lived with long generation times and low reproductive output (Bodmer et al. 1997), and carnivorous with large geographic extents and low population densities (Viranta 2003, p. 1,275). Because of their specialized habitats and life history constraints (Amstrup 2003, p. 605), polar bears have many qualities that make their populations susceptible to the potential negative impacts of sea ice loss resulting from climate change.

As discussed in detail in the ''Sea Ice Habitat'' section of this final rule, contemporary observations and state-of-the-art models point to a warming global climate, with some of the most accelerated changes in Arctic regions. In the past 30 years, average world surface temperatures have increased 0.2 degrees C per decade, but parts of the Arctic have experienced warming at a rate of 10 times the world average (Hansen et al. 2006). Since the late 1970s there have been major reductions in summer (multi-year) sea ice extent (Meier et al. 2007, pp. 428–434) (see detailed discussion in section entitled ''Summer Sea Ice''); decreases in ice age (Rigor and Wallace 2004; Belchansky et al. 2005) and thickness (Rothrock et al. 1999; Tucker et al. 2001) (see detailed discussion in section entitled ''Sea Ice Thickness''); and increases in length of the summer melt period (Belchansky et al. 2004; Stroeve et al. 2005) (see detailed discussion in section entitled ''Length of the Melt Period''). Recent observations further indicate that winter ice extent is declining (Comiso 2006) (see detailed discussion in section entitled ''Winter Sea Ice''). Empirical evidence therefore establishes that the environment on which polar bears depend for their survival has already changed substantially.

Without sea ice, polar bears lack the platform that allows them to access prey. Longer melt seasons and reduced summer ice extent will force polar bears into habitats where their hunting success will be compromised (Derocher et al. 2004, p. 167; Stirling and Parkinson 2006, pp. 271–272). Increases in the duration of the summer season, when polar bears are restricted to land or forced over relatively unproductive Arctic waters, may reduce individual survival and ultimately population size (Derocher et al. 2004, pp. 165–170). Ice seals typically occur in open-water during summer and therefore are inaccessible to polar bears during this time (Harwood and Stirling 1992, p. 897). Thus, increases in the length of the summer melt season have the potential to reduce annual availability of prey. In addition, unusual movements, such as long distance swims to reach pack ice or land, place polar bears at risk and may affect mortality (Monnett and Gleason 2006, pp. 4–6). Because of the importance of sea ice to polar bears, projecting patterns of ice habitat availability has direct implications on their future status. This section reports on recent studies that project the effects of sea ice change on polar bears.

Polar Bear Habitat

Durner et al. (2007, pp. 4–10) developed resource selection functions (RSFs) to identify ice habitat characteristics selected by polar bears and used these selection criteria as a basis for projecting the future availability of optimal polar bear habitat throughout the 21st century. Location data from satellite-collared polar bears and environmental data (e.g., sea ice concentration, bathymetry, etc.) were used to develop RSFs (Manly et al. 2002), which are considered to be a quantitative measure of habitat selection by polar bears. Important habitat features identified in the RSF models were then used to determine the availability of optimal polar bear habitat in GCM projections of 21st century sea ice distribution. The following information has been excerpted or extracted from Durner et al. (2007).

Durner et al. (2007, p. 5) used the outputs from 10 GCMs from the IPCC 4AR report as inputs into RSFs models to forecast future distribution and quantities of preferred polar bear habitat. The 10 GCMs were selected based on their ability to accurately simulate actual ice extent derived from passive microwave satellite observations (as described in DeWeaver 2007). The area of the assessment was the pelagic ecoregion of the Arctic polar basin comprised of the Divergent and Convergent ecoregions described by Amstrup et al. (2007, pp. 5–7) as described previously in introductory materials contained in the ‘‘Polar Bear Ecoregions’’ section of this final rule. Predictions of the amount and rate of change in polar bear habitat varied among GCMs, but all predicted net losses in the polar basin during the 21st century. Projected losses in optimal habitat were greatest in the peripheral seas of the polar basin (Divergent ecoregion) and projected to be greatest in the Southern Beaufort, Chukchi, and Barents Seas. Observed losses of sea ice in the Southern Beaufort, Chukchi, and Barents Seas are occurring more rapidly than projected and suggest that trajectories may vary at regional scales. Losses were least in high-latitude regions where the RSF models predicted an initial increase in optimal habitat followed by a modest decline. Optimal habitat changes in the Queen Elizabeth and Arctic Basin units of the Canada-Greenland group (Convergent ecoregion) were projected to be negligible if not increasing. Very little optimal habitat was observed or predicted to occur in the deep water regions of the central Arctic basin.

Durner et al. (2007, p. 13) found that the largest seasonal reductions in habitat were predicted for spring and summer. Based on the multi-model mean of 10 GCMs, the average area of optimal polar bear habitat during summer in the polar basin declined from an observed 1.0 million sq km (0.39 million sq mi) in 1985–1995 (baseline) to a projected multi-model average of 0.58 million sq km (0.23 million sq mi) in 2045–2054 (42 percent decline), 0.36 million sq km (0.14 million sq mi) in 2070–2079 (64 percent decline), and 0.32 million sq km (0.12 million sq mi) in 2090–2099 (68 percent decline). After summer melt, most regions of the polar basin were projected to refreeze throughout the 21st century. Therefore, winter losses of polar bear habitat were more modest, from 1.7 million sq km (0.54 million sq mi) in 1985–1995 to 1.4 million sq km (0.55 million sq mi) in 2090–2099 (17 percent decline). Simulated and projected rates of habitat loss during the late 20th and early 21st centuries by many GCMs tend to be less than observed rates of loss during the past two decades; therefore, habitat losses based on GCM multi-model averages were considered to be conservative.

Large declines in optimal habitat are projected to occur in the Alaska-Eurasia region (Divergent ecoregion) where 60–80 percent of the polar bear’s historical area of spring and summer habitat may disappear by the end of the century (Durner et al. 2007). The Canada-Greenland region (Convergent ecoregion) has historically contained less total optimal habitat area, since it is geographically smaller than the Alaska-Eurasia region. In the Queen Elizabeth region, while there is a similar seasonal pattern to the projected loss of optimal habitat, the magnitude of habitat loss was much less because of the predicted stability of ice in this region (Durner et al. 2007, p. 13). The projected rates of habitat loss over the 21st century were not constant over time (Durner et al. 2007). Rates of loss tended to be greatest during the second and third quarters of the century and then diminish during the last quarter.

Losses in optimal habitat between 1985–1995 and 1996–2006 established an observed trajectory of change that was consistent with the GCM projections; however, the observed rate of change (established over a 10-year period), when extrapolated over the first half of the 21st century, resulted in more habitat lost than that projected by the GCM ensemble average (i.e., faster than projected) (Durner et al. 2007, p. 13).

The recent findings regarding the record minimum summer sea ice conditions for 2007 reported by the NSIDC in Boulder, Colorado, were not considered in the analysis of sea ice conditions reported by Durner et al. (2007) because the full 2007 data were not yet available when the analyses in Durner et al. (2007) were conducted. In 2007, sea ice losses in the Canadian Archipelago and the polar basin Convergent ecoregions were the largest observed to date; these areas had previously been observed to be relatively stable (Durner et al. 2007).

Durner et al. (2007, pp. 18–19) indicated that less available habitat will likely result in reduced polar bear populations, although the precise relationship between habitat loss and population demographics remains unknown. Other authors (Stirling and Parkinson 2006, pp. 271–272; Regehr et al. 2007, pp. 14–18; Hunter et al. 2007, pp. 14–18; Rode et al. 2007, pp. 5–8; Amstrup et al. 2007, pp. 19–31) present detailed information regarding demographic effects of loss of sea ice habitat. Durner et al. (2007, pp. 19–20) does hypothesize that density effects may become more important as polar bears make long distance annual migrations from traditional winter areas to remnant high-latitude summer areas already occupied by polar bears. Further, Durner et al. (2007, p. 19) indicate that declines and large seasonal swings in habitat availability and distribution may impose greater impacts on pregnant females seeking denning habitat or leaving dens with cubs than on males and other age groups. Durner et al. (2007, p. 19) found that although most winter habitats would be replenished annually, long distance retreat of summer habitat may ultimately preclude bears from seasonally returning to their traditional winter ranges. Please also see the section in this final rule entitled ‘‘Access to and Alteration of Denning Areas.’’

Polar Bear Population Projections—Southern Beaufort Sea

Recent demographic analyses and modeling of the Southern Beaufort Sea population have provided insight about the current and future status of this population (Hunter et al. 2007; Regehr et al. 2007b). This population occupies habitats similar to four other populations in the Divergent ecoregion (Barents, Chukchi, Kara and Laptev Seas), which together represent over one-third of the current worldwide polar bear population. Because these other populations have experienced more severe sea ice changes than the southern Beaufort Sea, this assessment may understate the severity of the demographic impact that polar bear populations face in the Divergent ecoregion.

Hunter et al. (2007, pp. 2–6) conducted a demographic analysis of the Southern Beaufort Sea population using a life-cycle model parameterized with vital rates estimated from capture-recapture data collected between 2001 and 2006 (Regehr et al. 2007b, pp. 12–

14). Population growth rates and resultant population sizes were projected both deterministically (i.e., assuming that environmental conditions remained constant over time) and stochastically (i.e., allowing for environmental conditions to vary over time).

The deterministic model produced positive point estimates of population growth rate under the conditions in 2001–2003, ranging from 1.02 to 1.08 (i.e., 2 to 8 percent growth per year), and negative point estimates of population growth rate under the conditions in 2004–2005 when the region was ice-free for much longer, ranging from 0.77 to 0.90 (i.e., 23 to 10 percent decline per year) (Hunter et al. 2007, p. 8). The overall growth rate estimate for the study period was about 0.997, i.e., a 0.3 percent decline per year. Population growth rate was most affected by adult female survival, with secondary effects from reduced breeding probability (Hunter et al. 2007, p. 8). A main finding of this analysis was that when there are more than 125 ice-free days over the continental shelf of the broad southern Beaufort Sea region, population growth rate declines precipitously.

The stochastic model incorporated environmental variability by partitioning observed data into ''good'' years (2001–2003, short ice-free period) and ''bad'' years (2004–2005, long ice-free period), and evaluating the effect of the frequency of bad years on population growth rate (Hunter et al. 2007, p. 6). Stochastic projections were made in two ways: (1) Assuming a variable environment with the probability of bad years equal to what has been observed recently (1979–2006); and (2) assuming a variable environment described by projections of sea ice conditions in outputs of 10 selected general circulation models, as described by DeWeaver (2007). In the first analysis, Hunter et al. (2007, pp. 12–13) found that the stochastic growth rate declined with an increase in frequency of bad years, and that if the frequency of bad years exceeded 17 percent the result would be population decline. The observed frequency of bad years since 1979 indicated a decline of about 1 percent per year for the Southern Beaufort Sea population. The average frequency of bad ice years from 1979–2006 was approximately 21 percent and from 2001–2005 was approximately 40 percent. In the second analysis, using outputs from 10 GCMs to determine the frequency of bad years, Hunter et al. (2007, p. 13) estimated a 55 percent probability of decline to 1 percent of current population size in 45 years using the non-covariate model set, and a 40 percent probability of decline to 0.1 percent of current population size in 45 years, also using the non-covariate model set. Under sea ice conditions predicted by each of the 10 GCMs, the Southern Beaufort Sea population was projected to experience a significant decline within the next century. The demographic analyses of Hunter et al. (2007, pp. 3–9) incorporated uncertainty arising from demographic parameter estimation, the short time-series of capture-recapture data, the form of the population model, environmental variation, and climate projections. Support for the conclusions come from the agreement of results from different statistical model sets, deterministic and stochastic models, and models with and without climate forcing.

Polar Bear Population Projections—Range-wide

Amstrup et al. (2007, pp. 5–6) used two modeling approaches to estimate the future status of polar bears in the 4 ecoregions they delineated (see section entitled ''Polar Bear Ecoregions'' and Figure 2 above). First, they used a deterministic Carrying Capacity Model (CM) that applied current polar bear densities to future GCM sea ice projections to estimate potential future numbers of polar bears in each of the 4 ecoregions. The second approach, a Bayesian Network Model (BM), included the same annual measure of sea ice area as well as measures of the spatial and temporal availability of sea ice. In addition, the BM incorporated numerous other stressors that might affect polar bear populations that were not incorporated in the carrying capacity model. The CM ''provided estimates of the maximum potential sizes of polar bear populations based on climate modeling projections of the quantity of their habitat—but in the absence of effects of any additional stressors * * *'' while the BM ''provided estimates of how the presence of multiple stressors * * * may affect polar bears'' (Amstrup et al. 2007, p. 5).

For both modeling approaches, the 19 polar bear populations were grouped into 4 ecoregions, which are defined by the authors on the basis of observed temporal and spatial patterns of ice formation and ablation (melting or evaporation), observations of how polar bears respond to these patterns, and projected future sea ice patterns (see ''Current Population Status and Trends'' section). The four ecoregions are: (1) the Seasonal Ice ecoregion (which occurs mainly at the southern extreme of the polar bear range); (2) the Archipelago ecoregion of the central Canadian Arctic; (3) the polar basin Divergent ecoregion; and (4) the polar Basin Convergent ecoregion (see Figure 2 above). The ecoregions group polar bear populations that share similar environmental conditions and are, therefore, likely to respond in a similar fashion to projected future conditions.

Carrying Capacity Model (CM)

The deterministic Carrying Capacity Model (CM) developed by Amstrup et al. (2007) was used to estimate present-day polar bear density in each ecoregion based on estimates of the number of polar bears and amount of sea ice in each ecoregion. These density estimates were defined as ''carrying capacities'' and applied to projected future sea ice availability scenarios using the assumption that current ''carrying capacities'' will apply to available habitat in the future. This density and habitat index, therefore, allows a straightforward comparison between the numbers of bears that are present now and the number of bears which might be present in the future.

Amstrup et al. (2007, p. 8) defined total available sea ice habitat in the Divergent and Convergent ecoregions as the 12-month sum of sea ice cover (in km2) over the continental shelves of the 2 polar basin ecoregions; in the Archipelago and Seasonal Ice ecoregions, all sea ice-covered areas were considered shelf areas and defined as available habitat (Amstrup et al. 2007, p. 9). In the Divergent and Convergent ecoregions, available sea ice habitat was further defined as either optimal (according to the definition of Durner et al. 2007, p. 9) or nonoptimal; this further subdivision was not applied in the Archipelago and Seasonal Ice ecoregions, which used the one measure of total available sea ice habitat. Projections of future sea ice availability for each ecoregion were derived from 10 General Circulation Models (GCMs) selected by DeWeaver (2007, p. 21). Projections of polar bear status based on habitat availability were determined for each of the four ecoregions for 4 time periods: the present (year 0); 45 years from the present (the decade of 2045–2055); 75 years from the present (2070–2080); and 100 years (2090–2100) from the present. For added perspective, the authors also looked at 10 years in the past (1985–1995). Three sea ice habitat availability estimates were derived for each time period, based on the minimum, mean, and maximum sea ice projections from the 10-model GCM ensemble. Changes in habitat were defined in terms of direction (contracting, stable or expanding) and magnitude (slow or none, moderate, or fast), while changes in carrying capacity were defined in terms of direction (decreasing, stable or increasing) and magnitude (low to none, moderate, or high) (Amstrup et al. 2007, pp. 10–12). ''Outcomes of habitat change and carrying capacity change were categorized into 4 composite summary categories to describe the status of polar bear populations: enhanced, maintained, decreased, or toward extirpation'' (Amstrup et al. 2007, p. 12).

The range of projected carrying capacities (numbers of bears potentially remaining assuming historic densities were maintained) varied by ecoregion and to whether maximum or minimum ice values were used. Table 1 below presents the range of projected change in carrying capacity of sea ice habitats for polar bears by ecoregion based on sea ice projections from GCMs. The range of percentages represents minimum and maximum projected changes in carrying capacity based on minimum and maximum projected changes in the total area of sea ice habitat at various times.

Table 1. Projected maximum and minimum percent changes in polar bear carrying capacity based on maximum and minimum projected changes in the total area of sea ice habitat at various times. Negative values indicate percent decrease in carrying capacity and positive values indicate percent increase in carrying capacity.

	Percent change in carrying capacity of sea ice habitats		
Ecoregion	Year 45	Year 75	Year 100
Seasonal Ice	-7 to -10	-21 to -32	-22 to -32
Archipelago	-3 to -14	-18 to -21	-21 to -24
Divergent Ice	-19 to -35	-29 to -43	-23 to -48
Convergent Ice	+4 to -24	-8 to -11	-3 to -25
Global	-10 to -22	-22 to -32	-20 to -37

All CM runs projected declines in polar bear carrying capacity in all four ecoregions (Amstrup et al. 2007, Figure 9). Some CM model runs project that polar bear carrying capacity will be trending ''toward extirpation'' (the term ''toward extirpation'' is defined as one of three combinations of habitat change and carrying capacity change (i.e., contracting moderate habitat change, decreasing fast carrying capacity change; contracting fast, decreasing moderate; contracting fast, decreasing high)) in some ecoregions at certain times, but that less severe carrying capacity changes will occur in other ecoregions (see Tables 2 and 6, and Figure 9 in Amstrup et al. 2007). Using the 4 composite summary categories of Amstrup et al. (2007, p. 12), the minimum sea ice extent model results project that a trend toward extirpation of polar bears will appear in the polar basin Divergent ecoregion by year 45 and in the Seasonal Ice ecoregion by year 75. Mean sea ice extent model results project that a trend toward extirpation of bears will appear in the polar basin Divergent ecoregion by year 75 and in the polar basin Convergent ecoregion by year 100. None of the model results project that a trend toward extirpation will appear in the Archipelago region by year 100. Likewise, none of the model results project that polar bear carrying capacity will increase or remain stable in any ecoregion beyond 45 years. Although the pattern of projected carrying capacity varied greatly among regions, the summary finding was for a range-wide decline in polar bear carrying capacity of between 10 and 22 percent by year 45 and between 22 and 32 percent by year 75 (Amstrup et al. 2007, p. 20). CM results provide a conservative view of the potential magnitude of change in bear carrying capacity over time and area, because these results are based solely on the area of sea ice present at a given point in time and do not consider the effects of other population stressors.

Bayesian Network Model (BM)

To address other variables in addition to sea ice habitat that may affect polar bears, Amstrup et al. (2007, pp. 5–6) developed a prototype Bayesian Network Model (BM). The BM incorporated empirical data and GCM projections of annual and seasonal sea ice availability, numerous other stressors, and expert judgment regarding known relationships between these stressors and polar bear demographics to obtain probabilistic estimates of future polar bear distributions and relative numbers. Anthropogenic stressors included human activities that could affect distribution or abundance of polar bears, such as hunting, oil and gas development, shipping, and direct bear-human interactions. Natural stressors included changes in the availability of primary and alternate prey and foraging areas, and occurrence of parasites, disease, and predation. Environmental factors included projected changes in total ice and optimal habitat, changes in the distance that ice retreats from traditional autumn or winter foraging areas, and changes in the number of months per year that ice is absent in the continental shelf regions. Habitat changes, natural and anthropogenic stressors, and environmental factors were evaluated for their potential effects on the density and distribution of polar bears and survival throughout their range. BM outcomes were defined according to their collective influence on polar bear population distribution and relative numbers with respect to current conditions (e.g., larger than now, the same as now, smaller than now, rare, or extinct) (Amstrup et al. 2007).

As a caveat to their results, the authors note that, because a BM combines expert judgment and interpretation with quantitative and qualitative empirical information, inputs from multiple experts are usually incorporated into the structure and parameterization of a ''final'' BM. Because the BM in Amstrup et al. (2007) incorporates the input of a single polar bear expert, the model should be viewed as an ''alpha'' level prototype (Marcot et al. 2006, cited in Amstrup et al. 2007, p.27) that would benefit from additional development and refinement. Given this caveat, it is extremely important, while interpreting model outcomes, to focus on the general direction and magnitude of the probabilities of projected outcomes rather than the actual numerical probabilities associated with each outcome. For example, situations with high probability of a particular outcome (e.g., of extinction) or consistent directional effect across sea ice scenarios suggest a higher likelihood of that outcome as opposed to situations where the probability is evenly spread across outcomes or where there is large disagreement among different sea ice scenarios. These considerations were central to the authors' interpretation of BM results (Amstrup et al. 2007).

The overall outcomes from the BM indicate that in each of the four ecoregions polar bear populations in the future are very likely to be smaller and have a higher likelihood of experiencing multiple stressors in comparison to the past or present. In the future, multiple natural and anthropogenic stressors will likely become important, and negative effects on all polar bear populations will be apparent by year 45 with generally increased effects through year 100.

In the Seasonal Ice ecoregion the dominant outcome of the BM was ''extinct'' at all future time periods under all three GCM scenarios used in the analysis, with low probabilities associated with alternative outcomes, except for the minimum GCM scenario at year 45 (when the probability of alternative outcomes was around 44 percent). The small probabilities for outcomes other than extinct suggest a trend in this ecoregion toward probable extirpation by the mid-21st century. In the polar basin Divergent ecoregion, ''extinct'' was also the predominant outcome, with very low probabilities associated with alternative outcomes (i.e., less then 15 percent probability of not becoming extinct). The small probabilities for outcomes other than extinct also suggest a trend in this ecoregion toward probable extirpation by the mid-21st century. In the polar basin Convergent ecoregion, population persistence at ''smaller in numbers'' or ''rare'' was the predominant outcome at year 45, but the probability of extinction came to predominate (i.e., was greater than 60 percent) at year 75 and year 100. In the Archipelago ecoregion, a smaller population was the most probable outcome at year 45 under all GCM scenarios. By year 75, the most probable outcome for this ecoregion (as in the other ecoregions) across all GCM ice scenarios was population persistence, albeit in lower numbers. Even late in the century, however, the probability of a smaller than present population in the Archipelago Ecoregion was relatively high. Therefore, Amstrup et al. (2007) concluded that polar bears, in reduced numbers, could occur in the Archipelago Ecoregion through the end of the century. The authors note that the projected changes in sea ice conditions could result in loss of approximately two-thirds of the world's current polar bear population by the mid-21st century. They further note that, because the observed trajectory of Arctic sea ice decline appears to be underestimated by currently available models, these projections may be conservative.

As part of the BM, Amstrup et al. (2007, pp. 29–31) conducted a sensitivity analysis to determine the influence of model inputs and found that the overall projected population outcome was greatly influenced by changes in sea ice habitat. The Bayesian sensitivity analysis found that 91 percent of the variation in the overall predicted population outcome was determined by six variables. Four of these six were sea ice related, including patterns of seasonal and spatial distribution. The fifth variable among these top six was the ecoregion being considered. Outcomes varied for ecoregions as a result of differences in their sea ice characteristics. The sixth ranked variable, with regard to overall population outcome, was the level of intentional takes or harvest (overutilization). The stressors that related to bear-human interactions, parasites and disease and predation, and other natural or man-made factors provided a nominal influence of less than 9 percent contribution to the status outcome.

Amstrup et al. (2007, pp. 22–24) characterize the types and implications of uncertainty inherent to the carrying capacity and BM modeling in their report. Analyses in this report contain three main categories of uncertainty: (1) uncertainty in our understandings of the biological, ecological, and climatological systems; (2) uncertainty in the representation of those understandings in models and statistical descriptions; and (3) uncertainty in model predictions. In addition, Amstrup et al. (2007) discussed potential consequences of and efforts to evaluate and minimize uncertainty in the analyses. We reiterate the caveat that a BM combines expert judgment and interpretation with quantitative and qualitative empirical information, therefore necessitating inputs from multiple experts (if available) before it can be considered final. We note again that because the BM presented in Amstrup et al. (2007) incorporates the input of a single polar bear expert, it should be viewed as a first-generation prototype (Marcot et al. 2006, cited in Amstrup et al. 2007, p.27) that would benefit from additional development.

Because the BM includes numerous qualitative inputs (including expert assessment) and requires additional development (Amstrup et al. 2007, p. 27), we are more confident in the general direction and magnitude of the projected outcomes rather than the actual numerical probabilities associated with each outcome, and we are also more confident in outcomes within the 45-year foreseeable future than in outcomes over longer timeframes (e.g., year 75 and year 100 in Amstrup et al. (2007)). We conclude that the outcomes of the BM are consistent with ''the increasing volume of data confirming negative relationships between polar bear welfare and sea ice decline'' (Amstrup et al. 2007, p. 31), and parallel other assessments of both the demographic parameter changes as well as trends in various factors that threaten polar bears as described by Derocher et al. (2004), and in the proposed rule to list polar bears as a threatened species (72 FR 1064). However, because of the preliminary nature of the BM and levels of uncertainty associated with the initial Bayesian Modeling efforts, we do not find that the projected outcomes derived from the BM to be as reliable as the data derived from the ensemble of climate models used by the Service to gauge the loss of sea ice habitat over the next 45 years. Both the proposed rule and the status assessment (*Range Wide Status Review of the Polar Bear* (*Ursus maritimus*), Schliebe et al. 2006a), underwent extensive peer review by impartial experts within the disciplines of polar bear ecology, climatology, toxicology, seal ecology, and traditional ecological knowledge, and thereby represent a consensus on the conclusions in these documents. The more recent projections from the BM exercise conducted by Amstrup et al. (2007) are consistent with conclusions reached in the earlier assessments that polar bear populations will continue to decline in the future.

Polar Bear Mortality

As changes in habitat become more severe and seasonal rates of change more rapid, catastrophic mortality events that have yet to be realized on a large scale are expected to occur. Observations of drownings and starved animals may be a prelude to such events. Populations experiencing compromised physical condition will be increasingly prone to sudden die-offs. While no information currently exists to evaluate such events, the possibility of other forms of unanticipated mortality are mentioned here because they have been observed in other species (e.g., canine distemper in Caspian seals (*Phoca caspica*) (Kuiken et al. 2006, p. 321) and phocine distemper virus in harbor seals (Heide-Jorgensen et al. 1992, cited in Goodman 1998).

Conclusion Regarding Current and Projected Demographic Effects of Habitat Changes on Polar Bears

Polar bears have evolved in a sea ice environment that serves as an essential platform from which they meet life functions. Polar bears currently are exposed to a rapidly changing sea ice platform, and in many regions of the Arctic already are being affected by these changes. Sea ice changes are projected to continue and positive feedbacks are expected to amplify changes in the arctic which will hasten sea ice retreat. These factors will likely negatively impact polar bears by increasing energetic demands of seeking prey. Remaining members of many populations will be redistributed, at least seasonally, into terrestrial or offshore habitats with marginal values for feeding, and increasing levels of negative bear-human interactions. Increasing nutritional stress will coincide with exposure to numerous other potential stressors. Polar bears in some regions already are demonstrating reduced physical condition, reduced reproductive success, and increased mortality. As changes in habitat become more severe and seasonal rates of change more rapid, catastrophic mortality events that have yet to be realized on a large scale are expected to occur. Observations of drownings and starved animals may be a prelude to such events. These changes will in time occur throughout the world-wide range of polar bears. Ultimately, these inter-related factors will result in range-wide population declines. Populations in different ecoregions will experience different rates of change and timing of impacts. Within the foreseeable future, however, all ecoregions will be affected.

Conclusion for Factor A

Rationale

Polar bears evolved over thousands of years to life in a sea ice environment. They depend on the sea ice-dominated ecosystem to support essential life functions. Sea ice provides a platform for hunting and feeding, for seeking mates and breeding, for movement to terrestrial maternity denning areas and occasionally for maternity denning, for resting, and for long-distance movements. The sea ice ecosystem supports ringed seals, primary prey for polar bears, and other marine mammals that are also part of their prey base.

Sea ice is rapidly diminishing throughout the Arctic. Patterns of increased temperatures, earlier onset of and longer melting periods, later onset of freeze-up, increased rain-on-snow events, and potential reductions in snowfall are occurring. In addition, positive feedback systems (i.e., the sea-ice albedo feedback mechanism) and naturally occurring events, such as warm water intrusion into the Arctic and changing atmospheric wind patterns, can operate to amplify the effects of these phenomena. As a result, there is fragmentation of sea ice, a dramatic increase in the extent of open water areas seasonally, reduction in the extent and area of sea ice in all seasons, retraction of sea ice away from productive continental shelf areas throughout the polar basin, reduction of the amount of heavier and more stable multi-year ice, and declining thickness and quality of shore-fast ice. Such events are interrelated and combine to decrease the extent and quality of sea ice as polar bear habitat during all seasons and particularly during the spring-summer period. Arctic sea ice will continue to be affected by climate change. Due to the long persistence time of certain GHGs in the atmosphere, the current and projected patterns of GHG emissions over the next few decades, and interactions among climate processes, climate changes for the next 40–50 years are already largely set (IPCC 2007, p. 749; J. Overland, NOAA, in litt. to the Service, 2007). Climate change effects on sea ice and polar bears will continue through this timeframe and very likely further into the future.

Changes in sea ice negatively impact polar bears by increasing the energetic demands of movement in seeking prey, causing seasonal redistribution of substantial portions of populations into marginal ice or terrestrial habitats with limited values for feeding, and increasing the susceptibility of bears to other stressors, some of which follow. As the sea ice edge retracts to deeper, less productive polar basin waters, polar bears will face increased competition for limited food resources, increased open water swimming with increased risk of drowning, increasing interaction with humans with negative consequences, and declining numbers that may be unable to sustain ongoing harvests.

Changes in sea ice will reduce productivity of most ice seal species, result in changes in composition of seal species indigenous to some areas, and eventually result in a decrease in seal abundance. These changes will decrease availability or timing of availability of seals as food for polar bears. Ringed seals will likely remain distributed in shallower, more productive southerly areas that are losing their seasonal sea ice and becoming characterized by vast expanses of open water in the spring-summer-fall period. As a result, the seals will remain unavailable as prey to polar bears during critical times of the year. These factors will, in turn, result in a steady decline in the physical condition of polar bears, which has proven to lead to population-level demographic declines in reproduction and survival.

The ultimate net effect of these inter-related factors will be that polar bear populations will decline or continue to decline. Not all populations will be affected evenly in the level, rate, and timing of effects, but we have determined that, within the foreseeable future, all polar bear populations will be negatively affected. This determination is broadly supported by results of the USGS studies, and within the professional community, including a majority of polar bear experts who peer reviewed the proposed rule. The PBSG evaluated potential impacts to the polar bear, and determined that the observed and projected changes in sea ice habitat would negatively affect the species (Aars et al. 2006, p. 47). The IUCN, based on the PBSG assessment, reclassified polar bears as ''vulnerable.'' Similarly, their justification for the classification was the projected change in sea ice, effect of climate change on polar bear condition, and corresponding effect on reproduction and survival, which have been associated with a steady and persistent decline in abundance.

A series of analyses of the best available scientific information on the ecology and demography of polar bears were recently undertaken by the USGS at the request of the Secretary of the Interior. These include additional analyses of some specific populations (Southern Beaufort Sea, Northern Beaufort Sea, Southern Husdon Bay), analysis of optimal polar bear habitat and projections of optimal habitat through the 21st century, projections of the status of populations into the future, and information from a pilot study regarding the increase in travel distance for pregnant females to reach denning areas on the North Slope of Alaska with insights to potential consequences. Results of the analyses are detailed within this final rule. This significant effort enhanced and reaffirmed our understanding of the interrelationships of ecological factors and the future status of polar bear populations.

The USGS report by Amstrup et al. (2007) synthesized historical and recent scientific information and conducted two modeling exercises to provide a range-wide assessment of the current and projected future status of polar bears occupying four ecoregions. In this effort, using two approaches and validation processes, the authors described four ''ecoregions'' based on current and projected sea ice conditions and developed a suite of population projections by ecoregion. This assessment helps inform us on the future fate of polar bear populations subject to a rapidly changing sea ice environment. In summary, polar bear populations within all ecoregions were not uniformly impacted, but all populations within ecoregions declined, with the severity of declines depending on the sea ice projections (minimal, mean, maximum), season of the year, and area. Amstrup et al. (2007, p. 36) forecasts the extirpation of populations in the Seasonal Ice, and polar basin Divergent ecoregions by the mid-21st century. Because the BM presented in the report be viewed as a first-generation prototype (Marcot et al. 2006, cited in Amstrup et al. 2007, p.27) that would benefit from additional development, and because the BM includes numerous qualitative inputs (including expert assessment), we are more confident in the general direction and magnitude of the projected outcomes rather than the actual numerical probabilities associated with each outcome, and we are also more confident in outcomes within the 45-year foreseeable future.

In the southerly populations (Seasonal Ice ecoregion) of Western Hudson Bay, Southern Hudson Bay, Foxe Basin, Davis Strait, and Baffin Bay, polar bears already experience stress from seasonal fasting due to early sea ice retreat, and have or will be affected earliest (Stirling and Parkinson 2006, p. 272; Obbard et al. 2006, pp. 6–7; Obbard et al. 2007, p. 14). Populations in the Divergent ecoregion, including the Chukchi Sea, Barents Sea, Southern Beaufort Sea, Kara Sea, and Laptev Sea will, or are currently, experiencing initial effects of changes in sea ice (Rode et al. 2007, p. 12; Regehr et al. 2007b, pp. 18–19; Hunter et al. 2007, p. 19; Amstrup et al. 2007, p. 36). These populations are vulnerable to large-scale dramatic seasonal fluctuations in ice movements, decreased abundance and access to prey, and increased energetic costs of hunting. Polar bear populations inhabiting the central island archipelago of Canada (Archipelago ecoregion) will also be affected but to lesser degrees and later in time. These more northerly populations (Norwegian Bay, Lancaster Sound, M'Clintock Channel, Viscount Melville Sound, Kane Basin, and the Gulf of Boothia) are expected to be affected last due to the buffering effects of the island archipelago complex, which lessens effects of oceanic currents and seasonal retractions of ice and retains a higher proportion of heavy, more stable, multi-year sea ice. A caution in this evaluation is that historical record minimum summer ice conditions in September 2007 resulted in vast ice-free areas that encroached into the area of permanent polar sea ice in the central Arctic Basin, and the Northwest Passage was open for the first time in recorded history. The record low sea ice conditions of 2007 are an extension of an accelerating trend of minimum sea ice conditions and further support the concern that current sea ice models may be conservative and underestimate the rate and level of change expected in the future.

Although climate change may improve conditions for polar bears in some high latitude areas where harsh conditions currently prevail, these improvements will only be transitory. Continued warming will lead to reduced numbers and reduced distribution of polar bears range-wide (Regehr et al. 2007b, p. 18; Derocher et al. 2004, p. 19; Hunter et al. 2007, p. 14; Amstrup et al. 2007, p. 36). Projected declines in the sea ice for most parts of the Arctic are long-term, severe, and occurring at a pace that is unprecedented (Comiso 2003; ACIA 2004; Holland et al. 2006, pp. 1–5); therefore, the most northerly polar bear populations will experience declines in demographic parameters similar to those observed in the Western Hudson Bay population, along with changes in distribution and other currently unknown ecological responses (Derocher et al. 2004, p. 171; Aars et al. 2006, p. 47). Ultimately, all polar bear populations will be affected within the foreseeable future, and the species will likely become in danger of extinction throughout all of its range.

It is possible, even with the total loss of summer sea ice, that a small number of polar bears could survive, provided there is adequate seasonal ice cover to serve as a platform for hunting opportunities, and that sea ice is present for a period of time adequate for replenishment of body fat stores and condition. However, this possibility is difficult to evaluate. As a species, polar bears have survived at least two warming periods, the Last Interglacial (140,000—115,000 years Before Present (BP)), and the Holocene Thermal maximum (ca 12,000—4,000 BP) (Dansgaard et al. 1993, p. 218; Dahl-Jensen et al. 1998, p. 268). Greenland ice cores revealed that the climate was much more variable in the past, and some of the historical shifts between the warm and cold periods were rapid, suggesting that the recent relative climate stability seen during the Holocene may be an exception (Dansgaard et al. 1993, p. 218). While the precise impacts of these warming periods on polar bears and the Arctic sea ice habitat are unknown, the ability of polar bears to adapt to alternative food sources seems extremely limited given the caloric requirements of adult polar bears and the documented effects of nutritional stress on reproductive success.

In addition to the effects of climate change on sea ice, we have also evaluated changes to habitat in the Arctic as a result of increased pressure from human activities. Increased human activities include a larger footprint from the number of people resident to the area, increased levels of oil and gas exploration and development and expanding areas of interest, and potential increases in shipping. Cumulatively, these activities may result in alteration of polar bear habitat. Any potential impact from these activities would be additive to other factors already or potentially affecting polar bears and their habitat. We acknowledge that the sum total of documented direct impacts from these activities in the past have been minimal. We also acknowledge, as discussed further under the Factor D analysis in this final rule, that national and local concerns for these activities has resulted in the development and implementation of multi-layered regulatory programs to monitor and eliminate or minimize potential effects. Regarding potential shipping activities within the Arctic, increased future monitoring is necessary to enhance the understanding of potential effects from this activity.

Determination for Factor A

We have evaluated the best available scientific and commercial information on polar bear habitat and the current and projected effects of various factors (including climate change) on the quantity and distribution of polar bear habitat, and have determined that the polar bear is threatened throughout its entire range by ongoing and projected changes in sea ice habitat (i.e., the species is likely to become endangered throughout all of its range within the foreseeable future due to habitat loss).

Factor B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Use of polar bears for commercial, recreational, scientific, and educational purposes is generally low, with the exception of harvest. Use for nonlethal scientific purposes is highly regulated and does not pose a threat to populations. Similarly, the regulated, low-level use for educational purposes through placement of cubs or orphaned animals into zoos or public display facilities or through public viewing is not a threat to populations. Sport harvest of polar bears in Canada is discussed in the harvest section below. For purposes of population assessment, no distinction is made between harvest uses for sport or subsistence. Take associated with defense of life, scientific research, illegal take, and other forms of take are generally included in harvest management statistics, so this section also addresses all forms of take, including bear-human interactions.

Overview of Harvest

Polar bears historically have been, and continue to be, an important renewable resource for coastal communities throughout the Arctic (Lentfer 1976, p. 209; Amstrup and DeMaster 1988, p. 41; Servheen et al. 1999, p. 257, Table 14.1; Schliebe et al. 2006a, p. 72). Polar bears and polar bear hunting remain an important part of indigenous peoples' culture, and polar bear hunting is a source of pride, prestige, and accomplishment. Polar bears provide a source of meat and raw materials for handicrafts, including functional clothing such as mittens, boots (mukluks), parka ruffs, and pants (Nageak et al. 1991, p. 6).

Prior to the 1950s, most hunting was by indigenous people for subsistence purposes. Increased sport hunting in the 1950s and 1960s resulted in population declines (Prestrud and Stirling 1994, p. 113). International concern about the status of polar bears resulted in biologists from the five polar bear range nations forming the Polar Bear Specialist Group (PBSG) within the IUCN SSC (Servheen et al. 1999, p. 262). The PBSG was largely responsible for the development and ratification of the 1973 International Agreement on the Conservation of Polar Bears (1973 Polar Bear Agreement) (Prestrud and Stirling 1994, p. 114) (see detailed discussion under Factor D, ''Inadequacy of Existing Regulatory Mechanisms'' below). The 1973 Polar Bear Agreement and the actions of the member nations are credited with the recovery of polar bears following the previous period of overexploitation.

Harvest Management by Nation

Canada

Canada manages or shares management responsibility for 13 of the world's 19 polar bear populations (Kane Basin, Baffin Bay, Davis Strait, Foxe Basin, Western Hudson Bay, Southern Hudson Bay, Gulf of Boothia, Lancaster Sound, Norwegian Bay, M'Clintock Channel, Viscount Melville Sound, Northern Beaufort Sea, and Southern Beaufort Sea). Wildlife management is a shared responsibility of the Provincial and Territorial governments. The Federal government (Canadian Wildlife Service) has an ongoing research program and is involved in management of wildlife populations shared with other jurisdictions, especially ones with other nations (e.g., where a polar bear stock ranges across an international boundary). To facilitate and coordinate management of polar bears, Canada has formed the Federal Provincial Technical Committee for Polar Bear Research and Management (PBTC) and the Federal Provincial Administrative Committee for Polar Bear Research and Management (PBAC). These committees include Provincial, Territorial, and Federal representatives who meet annually to review research and management activities.

Polar bears are harvested in Canada by native residents and by sport hunters employing native guides. All human-caused mortality (i.e., hunting, defense of life, and incidental kills) is included in a total allowable harvest. Inuit people from communities in Nunavut, Northwest Territories (NWT), Manitoba, Labrador, Newfoundland, and Quebec conduct hunting. In Ontario, the Cree and the Inuit can harvest polar bears. In Nunavut and NWT, each community obtains an annual harvest quota that is based on the best available scientific information and monitored through distribution of harvest tags to local hunter groups, who work with scientists to set quotas. Native hunters may use their harvest tags to guide sport hunts. The majority of sport hunters in Canada are U.S. citizens. In 1994 the MMPA was amended to allow these hunters to import their trophies into the United States if the bears had been taken in a legal manner from sustainably managed populations.

The Canadian system places tight controls on the size and design of harvest limits and harvest reporting. Quotas are reduced in response to population declines (Aars et al. 2006, p. 11). In 2004, existing polar bear harvest practices caused concern when Nunavut identified quota increases for 8 populations, 5 of which are shared with other jurisdictions (Lunn et al. 2005, p. 3). Quota increases were largely based on indigenous knowledge (the Nunavut equivalent of traditional ecological knowledge) and the perception that some populations were increasing from historic levels. Nunavut did not coordinate these changes with adjacent jurisdictions that share management responsibility. This action resulted in an increase in the quota of allowable harvest from 398 bears in 2003–2004 to 507 bears in 2004–2005 (Lunn et al. 2005, p. 14, Table 6). Discussions between jurisdictions, designed to finalize cooperative agreements regarding the shared quotas, continue.

Greenland

The management of polar bear harvest in Greenland is through a system introduced in 1993 that allows only full-time hunters living a subsistence lifestyle to hunt polar bears. Licenses are issued annually for a small fee contingent upon reporting harvest during the prior 12 months. Until 2006, no quotas were in place, but harvest statistics were collected through Piniarneq, a local reporting program (Born and Sonne 2005, p. 137). In January 2006, a new harvest monitoring and quota system was implemented (Lønstrup 2005, p. 133). Annual quotas are determined in consideration of international agreements, biological advice, user knowledge, and consultation with the Hunting Council. However, for the Baffin Bay and Kane Basin populations, which are shared with Canada, evaluation of quota levels, harvest levels for shared populations occurring in other jurisdictions, and best available estimates of population numbers indicate that the quotas and combined jurisdictions harvest levels are not sustainable and the enforcement of harvest quotas may not be effective

(Aars et al. 2006). These populations are thought to be reduced and the trend is thought to be declining. Greenland is considering the allocation of part of the quota for sport hunting (Lønstrup 2005, p. 133).

Norway

Norway and Russia share jurisdiction over the Barents Sea population of polar bears. Management in Norway is the responsibility of the Ministry of the Environment (Wiig et al. 1995, p. 110). The commercial, subsistence, or sport hunting of polar bears in Norway is prohibited (Wiig et al. 1995, p. 110). Bears may only be killed in self-defense or protection of property, and all kills, including ''mercy'' kills, must be reported and recorded (Gjertz and Scheie 1998, p. 337).

Russia

The commercial, subsistence, or sport hunting of polar bears in Russia is prohibited. Some bears are killed in defense of life, and a small number of cubs (1 or 2 per year) have been taken in the past for zoos. Despite the 1956 ban on hunting polar bears, illegal harvest is occurring in the Chukchi Sea region and elsewhere where there is limited monitoring or enforcement (Aars et al. 2007, p. 9; Belikov et al. 2005, p. 153). The level of illegal harvest in Russian populations is unknown. There is a significant interest in reopening subsistence hunting by indigenous people. The combined ongoing illegal hunting in Russia and legal subsistence harvest in Alaska is a concern for the Chukchi Sea population, which may be in decline (USFWS 2003, p. 1). This mutual concern resulted in the United States and Russia signing the ''Agreement between the United States of America and the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population'' (Bilateral Agreement) on October 16, 2000. On January 12, 2007, the President of the United States signed into law the ''Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006.'' This Act added Title V to the MMPA, which implements the Bilateral Agreement. On September 22, 2007, the governments of the United States and Russian Federation exchanged instruments of ratification. Full implementation of the Bilateral Agreement is intended to address overharvest, but implementation has not yet occurred (Schliebe et al. 2005, p. 75). In the United States, Presidential appointment of Commissioners necessary to implement the Bilateral Agreement is pending. Accordingly, we have not relied on implementation of the Bilateral Agreement in our assessment of the threat of overutilization of polar bears (see ''International Agreements and Oversight'' section under Factor D below).

United States

Polar bear subsistence hunting by coastal Alaska Natives has occurred for centuries (Lentfer 1976, p. 209). Polar bear hunting and the commercial sale of skins took on increasing economic importance to Alaskan Natives when whaling began in the 1850s, and a market for pelts emerged (Lentfer 1976, p. 209). Trophy hunting using aircraft began in the late 1940s. In the 1960s, State of Alaska hunting regulations became more restrictive, and in 1972 aircraft-assisted hunting was stopped altogether (Lentfer 1976, p. 209). Between 1954 and 1972, an average of 222 polar bears was harvested annually, resulting in a population decline (Amstrup et al. 1986, p. 246).

Passage of the MMPA in 1972 established a moratorium on the sport or commercial hunting of polar bears in Alaska. However, the MMPA exempts harvest, conducted in a nonwasteful manner, of polar bears by coastal dwelling Alaska Natives for subsistence and handicraft purposes. The MMPA and its implementing regulations also prohibit the commercial sale of any marine mammal parts or products except those that qualify as authentic articles of handicrafts or clothing created by Alaska Natives. The Service cooperates with the Alaska Nanuuq Commission, an Alaska Native organization that represents Native villages in North and Northwest Alaska on matters concerning the conservation and sustainable subsistence use of the polar bear, to address polar bear subsistence harvest issues. In addition, for the Southern Beaufort Sea population, hunting is regulated voluntarily and effectively through an agreement between the Inuvialuit of Canada and the Inupiat of Alaska (Brower et al. 2002, p. 371) (see ''International Agreements and Oversight'' section under Factor D below). The harvest is monitored by the Service's marking and tagging program. Illegal take or trade is monitored by the Service's law enforcement program.

The MMPA was amended in 1994 to allow for the import into the United States of sport-hunted polar bear trophies legally taken by the importer in Canada. Prior to issuing a permit for import of such trophies, the Service must have found that Canada has a monitored and enforced sport-hunting program consistent with the purposes of the 1973 Polar Bear Agreement, and that the program is based on scientifically sound quotas ensuring the maintenance of the population at a sustainable level. Six populations were approved for import of polar bear trophies (62 FR 7302, 64 FR 1529, 66 FR 50843) under regulations implementing section 104(c)(5) of the MMPA (50 CFR 18.30). However, as of the effective date of the threatened listing, authorization for the import of sport hunted polar bear trophies is no longer available under section 104(c)(5) of the MMPA.

Harvest Summary

A thorough review and evaluation of past and current harvest, including other forms of removal, for all populations has been described in the *Polar Bear Status Review* (Schliebe *et al.* 2006a, pp. 108–127). The Status Review is available on our Marine Mammal website (*http://alaska.fws.gov/fisheries/mmm/polarbear/issues.htm*). Table 2 of the Status Review provides a summary of harvest statistics from the populations and is included herein as a reference. The total harvest and other forms of removal were considered in the summary analysis.

Five populations (including four that are hunted) have no estimate of potential risk from overharvest, since adequate demographic information necessary to conduct a population viability analysis and risk assessment are not available (see Table 1 below). For one of the populations, Chukchi Sea, severe overharvest is suspected to have occurred during the past 10–15 years, and anecdotal information suggests the population is in decline (Aars et al. 2006, pp. 34–35). The Chukchi Sea, Baffin Bay, Kane Basin, and Western Hudson Bay populations may be overharvested (Aars et al. 2006, pp. 40, 44–46). In other populations, including East Greenland and Davis Strait, substantial harvest occurs annually in the absence of scientifically derived population estimates (Aars et al. 2006, pp. 39, 46). Considerable debate has occurred regarding the recent changes in population estimates based on indigenous or local knowledge (Aars et al. 2006, p. 57) and subsequent quota increases for some populations in Nunavut (Lunn et al. 2005, p. 20). The PBSG (Aars et al. 2006, p. 57), by resolution, recommended that ''polar bear harvest can be increased on the basis of local and traditional knowledge only if supported by scientifically collected information.'' Increased polar bear observations along the coast may be attributed to changes in bear distribution due to lack of suitable ice habitat rather than to increased population size (Stirling and Parkinson 2006, p. 266). Additional data are needed to reconcile these differing interpretations.

As discussed in Factor A, Amstrup et al. (2007, p.30) used a first-generation BM model to forecast the range-wide status of polar bears during the 21st century, factoring in a number of stressors, including intentional take or harvest. The authors conducted a sensitivity analysis to determine the importance and influence of the stressors on the population forecast. Their analysis indicated that intentional take was the 4th ranked .potential stressor, and could exacerbate the effects of habitat loss in the future. Because of the preliminary nature of the BM results, we are more confident in the general direction and magnitude of the projected outcomes rather than the actual numerical probabilities associated with each outcome. Nonetheless, the relatively high ranking for this stressor indicates that effective management of hunting and evaluation of sustainable harvest levels will continue to be important to minimize effects for populations experiencing increased stress.

Table 2. Polar Bear Harvest Statistics, adapted from the PBTC status table

	Aerial Survey/M-R Analysis		5 yr mean kill		3 yr mean kill		1 yr mean kill					
Population	Number (year of estimate)	±2 SE	Actual removals	Likelihood of decline (next 10 years)[a]	Actual removals	Likelihood of decline (next 10 years)[a]	Actual removals	Likelihood of decline (next 10 years)[a]	Identified Permitted Harvest[b]	Estimated Maximum Sustainable Yield[c]	Observed or Predicted Trend[d]	Status[e]
Southern Beaufort Sea	1500 (2006)	1000 - 2000	57 8	No Estimate	59 3	No Estimate	44	No Estimate	81	84	Decline	Reduced
Northern Beaufort Sea	980 (2007)	825-1135	36 2	No Estimate	38	No Estimate	36	No Estimate	65	56	Stable	Not reduced
Viscount Melville	161 (1992)	121 - 201	4 4	5 6%	4 7	6 5%	5	6 8%	7	10	Increase	Severely reduced
Norwegian Bay	190 (1998)	102 - 278	2 6	70 5%	2 7	73 1%	4	84 4%	4	9	Decline	Not reduced
Lancaster Sound	2541 (1998)	1759 - 3323	74	67 0%	79	74 0%	87	80 6%	85	119	Stable	Not reduced
M'Clintock Channel	284 (2000)	166 - 402	3	2 5%	1	1 0%	2	1 8%	3	13	Increase	Severely reduced
Gulf of Boothia	1528 (2000)	953 - 2093	45 8	3 3%	48 3	4 3%	66	12 9%	74	72	Increase	Not reduced
Foxe Basin	2197 (1994)	1677 - 2717	97 2	14 0%	96	12 1%	97	13 1%	106 + Quebec	108	Stable	Not reduced
Western Hudson Bay	935 (2004)	791 - 1079	44 8	99 9%	46 3	99 9%	43	99.9%	62	44	Decline	Reduced
Southern Hudson Bay	681 (2007)	784 - 1216	36 6	0 1%	36.7	0 1%	27	0 1%	25 + Ontario, Quebec	47	Stable	Not reduced
Kane Basin	164 (1998)	94 -234	10 8	99 9%	10 3	99 9%	11	99 9%	5 + Greenland	8	Decline	Reduced
Baffin Bay	2074 (1988)	1544 - 2604	216 8	99 9%	251 7	99 9%	252	99 9%	105 + Greenland	72	Decline	Reduced
Davis Strait			64 8	12 9%	67.3	17 1%	70	18 9%	46 + Greenland, Quebec,	77	Stable	Not reduced
East Greenland	Unknown		70	No Estimate					50	No Estimate	Data Deficient	Data Deficient
Barents Sea	3000 (2004)										Data Deficient	Data Deficient
Kara Sea											Data Deficient	Data Deficient
Laptev Sea	800-1200 (1993)										Data Deficient	Data Deficient
Chukchi Sea	2000 (1993)		43- AK Unk # in Chukotka	No Estimate	Unknown	No Estimate	43++	No Estimate	Unknown	Unknown	Data Deficient	Data Deficient

[a] Presented is the proportion of simulation runs using the RISKMAN model and vital rates presented in natural survival and recruitment tables resulting in any decline after 10 years of simulation, assuming minimum 2M 1F in the harvest. One-minus this value represents the proportion of simulations resulting in population increase after 10 years

[b] The identified permitted harvest includes the maximum harvest that is presently allowed by jurisdictions with an identified quota.

[c] The estimated maximum sustainable yield (MSY) is based on a meta-analysis of the 1990s that assumed mean reproduction and survival for polar bears across their range in Canada (given information available at the time) MSY = N * 0 0156/Pr[F], where N = total population number, 0 0156 is a constant derived from a meta-analysis to estimate survival and recruitment rates for Canadian polar bears,

[d] Observed or predicted status as suggested by PVA results and, where vital rates are not sufficient for analysis, anectodatal information

[e] Current status relative to probable historic numbers

Bear-Human Interactions

Polar bears come into conflict with humans when they scavenge for food at sites of human habitation, and also because they occasionally prey or attempt to prey upon humans (Stirling 1988, p. 182). ''Problem bears,'' the bears most associated with human conflicts, are most often subadult bears that are inexperienced hunters and, therefore, that scavenge more frequently than adult bears (Stirling 1988, p. 182). Following subadults, females with cubs are most likely to interact with humans, because females with cubs are likely to be thinner and hungrier than single adult bears, and starving bears are more likely to interact with humans in their pursuit of food (Stirling 1988, p. 182). For example, in Churchill, Manitoba, Canada, an area of high polar bear use, the occurrence of females with cubs feeding at the town's garbage dump in the fall increased during years when bears came ashore in poorer condition (Stirling 1988, p. 182). Other factors that may influence bear-human encounters include increased land use activities, increased human populations in areas of high polar bear activity, increased polar bear concentrations on land, and earlier polar bear departure from ice habitat to terrestrial habitats.

Increased bear-human interactions and defense-of-life kills may occur under predicted climate change scenarios where more bears are on land and in contact with human settlements (Derocher et al. 2004, p. 169). Direct interactions between people and bears in Alaska have increased markedly in recent years, and this trend is expected to continue (Amstrup 2000, p. 153). Since the late 1990s, the timing of complete ice formation in the fall has occurred later in November or early December than it formerly did (September and October), resulting in an increased amount of time polar bears spend on land. This consequently increases the probability of bear-human interactions occurring in coastal villages. Adaptive management programs that focus on the development of community or ecotourism based polar bear-human interaction plans (that include polar bear patrols, deterrent and hazing programs, efforts to manage and minimize sources of attraction, and education about polar bear behavior and ecology) are ongoing in a number of Alaska North Slope communities and should be expanded or further developed for other communities in the future. In four Canadian populations-Western Hudson Bay, Foxe Basin, Baffin Bay, and Davis Strait-Inuit hunters reported seeing more bears in recent years around settlements, hunting camps, and sometimes locations where they had not (or only rarely) been seen before, resulting in an increase in threats to human life and damage to property (Stirling and Parkinson 2006, p. 262).

As discussed in Factor A, Amstrup et al. (2007, p.30) used a first-generation BM model to forecast the range-wide status of polar bears during the 21st century, factoring in a number of stressors, including bear-human interactions. The authors conducted a sensitivity analysis to determine the importance and influence of the stressors on the population forecast. Their analysis indicated that bear-human interactions ranked 7th of potential stressors. Because of the preliminary nature of the BM results, we are more confident in the general direction and magnitude of the projected outcomes rather than the actual numerical probabilities associated with each outcome. Although this factor's singular contribution to a declining population trend was relatively small, it could operate with other mortality factors (such as harvest) in the future to exacerbate the effects of habitat loss. Thus, bear-human interactions should be monitored, and may require additional management actions in the future.

Conclusion for Factor B

Rationale

Polar bears are harvested in Canada, Alaska, Greenland, and Russia. Active harvest management or reporting programs are in place for populations in Canada, Greenland, and Alaska. Principles of sustainable yield are instituted through harvest quotas or guidelines for a number of Canadian populations. Other forms of removal, such as defense-of-life take are considered through management actions by the responsible jurisdictions. Hunting or killing polar bears is illegal in Russia, although an unknown level of harvest occurs, and harvest impacts on Russian populations are generally unknown. While overharvest is occurring for some populations, laws and regulations for most management programs have been instituted and are flexible enough to allow adjustments in order to ensure that harvests are sustainable. These actions are largely viewed as having succeeded in reversing widespread overharvests by many jurisdictions that resulted in population depletion during the period prior to signing of the multilateral 1973 Polar Bear Agreement (Prestrud and Stirling 1994) see additional discussion under Factor D below). For the internationally-shared populations in the Chukchi Sea, Baffin Bay, Kane Basin, and Davis Strait, conservation agreements have been developed (United States-Russia) or are in development (Canada-Greenland), but in making our finding we have not relied on agreements that have not been implemented.

We realize that management agencies will be challenged in the future with managing populations that are declining and under stress from loss of sea ice. We also note that the sensitivity anlaysis conducted by Amstrup et al. (2007, pp. 35, 58) suggests that, for some populations, the effects of habitat and environmental changes will far outweigh the effects of harvest, and consequently, that harvest regulation may have little effect on the ultimate population outcome. For other populations affected to a lesser degree by environmental changes and habitat impacts, effective implementation of existing regulatory mechanisms is necessary to address issues related to overutilization.

Determination for Factor B

We have evaluated the best available scientific and commercial information on the utilization of polar bears for commercial, recreational, scientific, or educational purposes. Harvest, increased bear-human interaction levels, defense-of-life take, illegal take, and take associated with scientific research live-capture programs are occurring for several populations. We have determined that harvest is likely exacerbating the effects of habitat loss in several populations. In addition, polar bear mortality from harvest and negative bear-human interactions may in the future approach unsustainable levels for several populations, especially those experiencing nutritional stress or declining population numbers as a consequence of habitat change. The PBSG (Aars et al. 2006, p. 57), through resolution, urged that a precautionary approach be instituted when setting harvest limits in a warming Arctic environment. Continued efforts are necessary to ensure that harvest or other forms of removal do not exceed sustainable levels. We find, however, that overutilization does not currently threaten the polar bear throughout all or a significant portion of its range.

Factor C. Disease and Predation

Disease

The occurrence of diseases and parasites in polar bears is rare compared to other bears, with the exception of the presence of *Trichinella* larvae, *Trichinella* has been documented in polar bears throughout their range, and, although infestations can be quite high, they are normally not fatal (Rausch 1970, p. 360; Dick and Belosevic 1978, p. 1,143; Larsen and Kjos-Hanssen 1983, p. 95; Taylor et al. 1985, p. 303; Forbes 2000, p. 321). Although rabies is commonly found in Arctic foxes, there has been only one documented case in polar bears (Taylor et al. 1991, p. 337). Morbillivirus has been documented in polar bears from Alaska and Russia (Garner et al. 2000, p. 477; C. Kirk, University of Alaska, Fairbanks, pers. comm. 2006). Antibodies to the protozoan parasite, *Toxoplasma gondii,* were found in Alaskan polar bears; whether this is a health concern for polar bears is unknown (C. Kirk, University of Alaska, Fairbanks, pers. comm. 2006).

Whether polar bears are more susceptible to new pathogens due to their lack of previous exposure to diseases and parasites is also unknown. Many different pathogens and viruses have been found in seal species that are polar bear prey (Duignan et al. 1997, p. 7; Measures and Olson 1999, p. 779; Dubey et al. 2003, p. 278; Hughes-Hanks et al. 2005, p. 1,226), so the potential exists for transmission of these diseases to polar bears. . As polar bears become more nutritionally stressed, they may eat more of the intestines and internal organs of their prey than they presently do, thus increasing potential exposure to parasites and viruses (Derocher et al. 2004, p. 170; Amstrup et al. 2006b, p. 3). In addition, new pathogens may expand their range northward from more southerly areas under projected climate change scenarios (Harvell et al. 2002, p. 60). A warming climate has been associated with increases in pathogens in other marine organisms (Kuiken et al. 2006, p. 322).

Amstrup et al. (2007, p. 87) considered a host of potential stressors, including diseases and parasites, in their status evaluation of polar bears. The influence of parasites and disease agents evaluated in the sensitivity analysis ranked 8th, and made very minor contributions to the projected population status. The authors note, however, that the potential effect of disease and parasites on polar bears would likely increase if the climate continues to warm (Amstrup et al. 2007, p. 21). Parasitic agents that have developmental stages outside the bodies of warm-blooded hosts (e.g., nematodes) will likely benefit from the warmer and wetter weather projected for the Arctic (Macdonald et al. 2005). Significant impacts from such parasites on some Arctic ungulates have been noted. Improved conditions for such parasites already have had significant impacts on some terrestrial mammals (Kutz et al. 2001, p. 771; Kutz et al. 2004). Bacterial parasites also are likely to benefit from a warmer and wetter Arctic. Although increases in disease and parasite agents have not yet been reported in polar bears, they are anticipated, if temperatures continue to warm as projected. Amstrup et al. (2007, p. 31) also indicated that diseases and parasites could operate to exacerbate the effects of habitat loss. Continued monitoring of pathogens and parasites in polar bears is appropriate.

Intraspecific Predation

Intraspecific killing has been reported among all North American bear species (Derocher and Wiig 1999, p. 307; Amstrup et al. 2006b, p. 1). Reasons for intraspecific predation in bear species are poorly understood but thought to include nutrition, and enhanced breeding opportunities in the case of predation on cubs. Although occurrences of infanticide by male polar bears have been well documented (Hansson and Thomassen 1983, p. 248; Larsen 1985, p. 325; Taylor et al. 1985, p. 304; Derocher and Wiig 1999, p. 307), this activity accounts for a small percentage of the cub mortality.

Cannibalism has also been documented in polar bears (Derocher and Wiig 1999, p. 307; Amstrup et al. 2006b, p. 1). Amstrup et al. (2006b, p. 1) observed three instances of cannibalism in the southern Beaufort Sea during the spring of 2004; two involved adult females (one an unusual mortality of a female in a den) and third involved a yearling. This is notable because, throughout a combined 58 years of research, there are no similar observations recorded. Active stalking or hunting preceded the attacks, and all three of the killed bears were wholly or partly consumed. Adult males were believed to be the predator in both attacks. Amstrup et al. (2006b, p. 43) indicated that in general a greater proportion of polar bears in the area where the predation events occurred were in poorer physical condition compared to bears captured in other areas. The authors hypothesized that large adult males may be the first to show effects of nutritional stress which is expected to occur first in more southerly areas, due to significant ice retreat (Skinner et al. 1988, p. 3; Comiso and Parkinson 2004, p. 43; Stroeve et al. 2005, p. 1) . Adult males may be the first to show the effects of nutritional stress because they feed little during the spring mating season and enter the summer in poorer condition than other sex/age classes. Derocher and Wiig (1999, p. 308) documented a similar intraspecific killing and consumption of another polar bear in Svalbard, Norway, which was attributed to relatively high population densities and food shortages. Taylor et al. (1985, p. 304) documented that a malnourished female killed and consumed her own cubs, and Lunn and Stenhouse (1985, p. 1,516) found an emaciated male consuming an adult female polar bear. The potential importance of cannibalism and infanticide for polar bear population regulation is unknown. However, given our current knowledge of disease and predation, we do not believe that these factors are currently having population-level effects.

Another form of intraspecific stress is cross-breeding, or hybridization. The first documented instance of cross-breeding in the wild was reported in the spring of 2006. Rhymer and Simberloff (1996, pp. 83–84) express concerns for cross-breeding in the wild, noting that habitat modification contributing to cross breeding may cause the break-down of reproductive isolation between native species, leading to mixing of gene pools and potential loss of genotypically distinct populations. The authors generally viewed hybridization through introgression (defined as gene flow between populations through hybridization when hybrids cross back to one of the parental populations) as a threat to plant and animal taxa, particularly for morphologically well-defined and evolutionarily isolated taxa. Cross-breeding in the wild is thought to be extremely rare, but cross-breeding may pose additional concerns for population and species viability in the future should the rate of occurrence increase.

Conclusion for Factor C

Rationale

Disease pathogen titers are present in polar bears; however, no epizootic outbreaks have been detected. In addition, forms of intraspecific stress and cannibalism are known to be present with bear species and within polar bears. For polar bears, there is no indication that these stressors have operated to influence population levels in the past. Cannibalism is an indication of intraspecific stress, however we do not believe it has resulted in population level effects.

Determination for Factor C

We have evaluated the best available scientific information on disease and predation, and have determined that disease and predation (including intraspecific predation) do not threaten the species throughout all or any significant portion of its range. Potential for disease outbreaks, an increased possibility of pathogen exposure from changed diet or the occurrence of new pathogens that have moved northward with a warming environment, and increased mortality from cannibalism all warrant continued monitoring and may become more significant threat factors in the future for polar bear populations experiencing nutritional stress or declining population numbers.

Factor D. Inadequacy of Existing Regulatory Mechanisms

Regulatory mechanisms directed specifically at managing many of the threats to polar bears, such as overharvest or disturbance, exist in all of the countries states where the species occurs, as well as between (bilateral and multilateral) range countries.

IUCN/SSC Polar Bear Specialist Group

The Polar Bear Specialist Group (PBSG) is not a regulatory authority nor do they provide any regulatory mechanisms. However, the PBSG contributed significantly to the negotiation and development of the International Agreement on the Conservation of Polar Bears (1973 Polar Bear Agreement), and has been instrumental in monitoring the worldwide status of polar bear populations. Therefore, we believe a discussion of the PBSG is relevant to a current understanding of the status of polar bears worldwide. We did not rely on the PBSG or any actions of the PBSG for determining the status of the polar bear under the Act.

The PBSG operates under the IUCN Species Survival Commission (SSC), and was formed in 1968. The PBSG meets periodically at 3-to 5-year intervals in compliance with Article VII of the 1973 Polar Bear Agreement; said article instructs member parties to conduct national research programs on polar bears, particularly research relating to the conservation and management of the species and, as appropriate, coordinate such research with the research carried out by other parties, consult with other parties on management of migrating polar bear populations, and exchange information on research and management programs, research results, and data on bears taken. The PBSG first evaluated the status of all polar bear populations in 1980. In 1993, 1997, and 2001, the PBSG conducted circumpolar status assessments of polar bear populations, and the results of those assessments were published as part of the proceedings of the relevant PBSG meeting. The PBSG conducted its fifth polar bear status assessment in June 2005.

The PBSG also evaluates the status of polar bears under the IUCN Red List criteria. Previously, polar bears were classified under the IUCN Red List program as: ‘‘Less rare but believed to be threatened/requires watching’’ (1965); ‘‘Vulnerable’’ (1982, 1986, 1988, 1990, 1994); and ‘‘Lower Risk/Conservation Dependent’’ (1996). During the 2005 PBSG working group meeting, the PBSG re-evaluated the status of polar bears and unanimously agreed that a status designation of ‘‘Vulnerable’’ was warranted.

International Agreements and Oversight

International Agreement on the Conservation of Polar Bears

Canada, Denmark (on behalf of Greenland), Norway, the Russian Federation, and the United States are parties to the Agreement on the Conservation of Polar Bears (1973 Polar Bear Agreement) signed in 1973; by 1976, the Agreement was ratified by all parties. The 1973 Polar Bear Agreement requires the parties to take appropriate action to protect the ecosystem of which polar bears are a part, with special attention to habitat components such as denning and feeding sites and migration patterns, and to manage polar bear populations in accordance with sound conservation practices based on the best available scientific data. The 1973 Polar Bear Agreement relies on the efforts of each party to implement conservation programs and does not preclude a party from establishing additional controls (Lentfer 1974, p. 1).

The 1973 Polar Bear Agreement is viewed as a success in that polar bear populations recovered from excessive harvests and severe population reductions in many areas (Prestrud and Stirling 1994). At the same time, implementation of the terms of the 1973 Polar Bear Agreement varies across the member parties. Efforts are needed to improve current harvest management practices, such as restricting harvest of females and cubs, establishing sustainable harvest limits, and controlling illegal harvests (Derocher et al. 1998, pp. 47–48). In addition, a lack of protection of key habitats by member parties, with few notable exceptions for some denning areas, is a weakness (Prestrud and Stirling 1994, p. 118).

Inupiat-Inuvialuit Agreement for the Management of Polar Bears of the Southern Beaufort Sea

In January 1988, the Inuvialuit of Canada and the Inupiat of Alaska, groups that both harvest polar bears for cultural and subsistence purposes, signed a management agreement for polar bears of the southern Beaufort Sea. This agreement, based on the understanding that the two groups harvested animals from a single population shared across the international boundary, provides a joint responsibility for conservation and harvest practices (Treseder and Carpenter 1989, p. 4; Nageak et al. 1991, p. 341). Provisions of the agreement include: annual quotas (which may include problem kills); hunting seasons; protection of bears in dens or while constructing dens, and protection of females accompanied by cubs and yearlings; collection of specimens from killed bears to facilitate monitoring of the sex and age composition of the harvest; agreement to meet annually to exchange information on research and management and to set priorities; agreement on quotas for the coming year; and prohibition of hunting with aircraft or large motorized vessels and of trade in products taken in violation of the agreement. In Canada, recommendations and decisions from the Commissioners are then implemented through Community Polar Bear Management Agreements, Inuvialuit Settlement Region Community Bylaws, and NWT Big Game Regulations. In the United States, this agreement is implemented at the local level. Adherence to the agreement’s terms in Alaska is voluntary, and levels of compliance may vary. There are no Federal, State, or local regulations that limit the number or type (male, female, cub) of polar bear that may be taken. Brower et al. (2002) analyzed the effectiveness of the Inupiat-Inuvialuit Agreement, and found that it had been successful in maintaining the total harvest and the proportion of females in the harvest within sustainable levels. The authors noted the need to improve harvest monitoring in Alaska and increase awareness of the need to prevent overharvest of females for both countries.

Agreement between the United States of America and the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population

On October 16, 2000, the United States and the Russian Federation signed a bilateral agreement for the conservation and management of polar bear populations shared between the two countries. The Agreement between the United States of America and the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population (Bilateral Agreement) expands upon the progress made through the multilateral 1973 Polar Bear Agreement by implementing a unified conservation program for this shared population. The Bilateral Agreement reiterates requirements of the 1973 Polar Bear Agreement and includes restrictions on harvesting denning bears, females with cubs or cubs less than 1 year old, and prohibitions on the use of aircraft, large motorized vessels, and snares or poison for hunting polar bears. The Bilateral Agreement does not allow hunting for commercial purposes or commercial uses of polar bears or their parts. It also commits the parties to the conservation of ecosystems and important habitats, with a focus on conserving polar bear habitats such as feeding, congregating, and denning areas. The Russian government indicates that it is prepared to implement the Bilateral Agreement. On December 9, 2006, the Congress of the United States passed the ''United States—Russia Polar Bear Conservation and Management Act of 2006.'' This Act provides the necessary authority to regulate and manage the harvest of polar bears from the Chukchi Sea population, an essential conservation measure. Ratification documents have been exchanged between the countries, but the United States has yet to designate representatives to the Commission, and we did not rely on this treaty in our assessment as it is not formally implemented. Implementation of the Act will provide numerous conservation benefits for this population, however it does not provide authority or mechanisms to address ongoing loss of sea ice.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a treaty aimed at protecting species at risk from international trade. The CITES regulates international trade in animals and plants by listing species in one of its three appendices. The level of monitoring and regulation to which an animal or plant species is subject depends on the appendix in which the species is listed. Appendix I includes species threatened with extinction that are or may be affected by trade; trade of Appendix I species is only allowed in exceptional circumstances. Appendix II includes species not necessarily now threatened with extinction, but for which trade must be regulated in order to avoid utilization incompatible with their survival. Appendix III includes species that are subject to regulation in at least one country, and for which that country has asked other CITES Party countries for assistance in controlling and monitoring international trade in that species.

Polar bears were listed in Appendix II of CITES on July 7, 1975. As such, CITES parties must determine, among other things, that any polar bear, polar bear part, or product made from polar bear was legally obtained and that the export will not be detrimental to the survival of the species, prior to issuing a permit authorizing the export of the animal, part, or product. The CITES does not itself regulate take or domestic trade of polar bears; however, through its process of monitoring trade in wildlife species and requisite findings prior to allowing international movement of listed species and monitoring programs, the CITES is effective in ensuring that the international movement of listed species does not contribute to the detriment of wildlife populations. All polar bear range states are members to the CITES and have in place the CITES-required Scientific and Management Authorities. The Service therefore has determined that the CITES is effective in regulating the international trade in polar bear, or polar bear parts or products, and provides conservation measures to minimize those potential threats to the species.

Domestic Regulatory Mechanisms

United States

Marine Mammal Protection Act of 1972, as amended

The Marine Mammal Protection Act of 1972, as amended (16 U.S.C. 1361 et seq.) (MMPA) was enacted to protect and conserve marine mammals so that they continue to be significant functioning elements of the ecosystem of which they are a part. The MMPA set forth a national policy to prevent marine mammal species or population stocks from diminishing to the point where they are no longer a significant functioning element of the ecosystems.

The MMPA places an emphasis on habitat and ecosystem protection. The habitat and ecosystem goals set forth in the MMPA include: (1) Management of marine mammals (including of polar bears) to ensure they do not cease to be a significant element of the ecosystem to which they are a part; (2) protection of essential habitats, including rookeries, mating grounds, and areas of similar significance ''from the adverse effects of man's action''; (3) recognition that marine mammals ''affect the balance of marine ecosystems in a manner that is important to other animals and animal products,'' and that marine mammals and their habitats should therefore be protected and conserved; and (4) direction that the primary objective of marine mammal management is to maintain ''the health and stability of the marine ecosystem.'' Congressional intent to protect marine mammal habitat is also reflected in the definitions section of the MMPA. The terms ''conservation'' and ''management'' of marine mammals are specifically defined to include habitat acquisition and improvement.

The MMPA established a general moratorium on the taking and importing of marine mammals and a number of prohibitions, which are subject to a number of exceptions. Some of these exceptions include take for scientific purposes, for purposes of public display, for subsistence use by Alaska Natives, and unintentional incidental take coincident with conducting otherwise lawful activities. The Service, prior to issuing a permit authorizing the taking or importing of a polar bear, or a polar bear part or product, for scientific or public display purposes submits each request to a rigorous review, including an opportunity for public comment and consultation with the U.S. Marine Mammal Commision (MMC), as described at 50 CFR 18.31. In addition, in 1994, Congress amended the MMPA to allow for the import of polar bear trophies taken in Canada for personal use providing certain requirements are met. Import permits may only be issued to hunters that are citizens of the United States for trophies they have legally taken from those Canadian polar bear populations the Service has approved as meeting the MMPA requirements, as described at 50 CFR 18.30. The Service has determined that there is sufficient rigor under the regulations at 50 CFR 18.30 and 18.31 to ensure that any activities so authorized are consistent with the conservation of this species and are not a threat to the species.

Take is defined in the MMPA to include the ''harassment'' of marine mammals. ''Harassment'' includes any act of pursuit, torment, or annoyance that ''has the potential to injure a marine mammal or marine mammal stock in the wild'' (Level A harassment), or ''has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering'' (Level B harassment).

The Secretaries of Commerce and of the Interior have primary responsibility for implementing the MMPA. The Department of Commerce, through the National Oceanic and Atmospheric Administration (NOAA), has authority with respect to whales, porpoises, seals, and sea lions. The remaining marine mammals, including polar bears, walruses, sea otters, dugongs, and manatees are managed by the Department of the Interior through the U.S. Fish and Wildlife Service. Both agencies are ''* * * responsible for the promulgation of regulations, the issuance of permits, the conduct of scientific research, and enforcement as necessary to carry out the purposes of [the MMPA].''

Citizens of the United States who engage in a specified activity other than commercial fishing (which is specifically and separately addressed under the MMPA) within a specified geographical region may petition the Secretary of the Interior to authorize the incidental, but not intentional, taking of small numbers of marine mammals within that region for a period of not more than five consecutive years (16 U.S.C. 1371(a)(5)(A)). The Secretary ''shall allow'' the incidental taking if the Secretary finds that ''the total of such taking during each five-year (or less) period concerned will have no more than a negligible impact on such species or stock and will not have an unmitigable adverse impact on the availability of such species or stock for taking for subsistence uses.'' If the Secretary makes the required findings, the Secretary also prescribes regulations that specify (1) permissible methods of taking, (2) means of affecting the least practicable adverse impact on the species, their habitat, and their availability for subsistence uses, and (3) requirements for monitoring and reporting. The regulatory process does not authorize the activities themselves, but authorizes the incidental take of the marine mammals in conjunction with otherwise legal activities.

Similar to promulgation of incidental take regulations, the MMPA also established an expedited process by which citizens of the United States can apply for an authorization to incidentally take small numbers of marine mammals where the take will be limited to harassment (16 U.S.C. 1371(a)(5)(D)). These authorizations are limited to one year and as with incidental take regulations, the Secretary must find that the total of such taking during the period will have no more than a negligible impact on such species or stock and will not have an unmitigable adverse impact on the availability of such species or stock for taking for subsistence uses. The Service refers to these authorizations as Incidental Harassment Authorizations.

Examples and descriptions of how the Service has analyzed the effects of oil and gas activities and applied the general provisions of the MMPA described above to polar bear conservation programs in the Beaufort and Chukchi Seas are decribed in the *Range Wide Status Review of the Polar Bear* (*Ursus maritimus*) (Schliebe et al. 2006a). These regulations include an evaluation of the cumulative effects of oil and gas industry activities on polar bears from noise, physical obstructions, human encounters, and oil spills. The likelihood of an oil spill occurring and the risk to polar bears is modeled quantitatively and factored into the evaluation. The results of previous industry monitoring programs, and the effectiveness of past detection and deterrent programs that have a beneficial record of protecting polar bears, as well as providing for the safety of oil field workers, are also considered. Based on the low likelihood of an oil spill occurring and the effectiveness of industry mitigation measures within the Beaufort Sea region, the Service has found that oil and gas industry activities have not affected the rates of recruitment or survival for the polar bear populations over the period of the regulations.

General operating conditions in specific authorizations include the following: (1) Protection of pregnant polar bears during denning activities (den selection, birthing, and maturation of cubs) in known and confirmed denning areas; (2) restrictions on industrial activities, areas, time of year; and (3) development of a site-specific plan of operation and a site-specific polar bear interaction plan. Additional requirements may include: pre-activity surveys (e.g., aerial surveys, infra-red thermal aerial surveys, or polar bear scent-trained dogs) to determine the presence or absence of dens or denning activity and, in known denning areas, enhanced monitoring or flight restrictions, such as minimum flight elevations. These and other safeguards and coordination with industry have served to minimize industry effects on polar bears.

Outer Continental Shelf Lands Act

The Outer Continental Shelf Lands Act (43 U.S.C. 1331 et seq.) (OCSLA) established Federal jurisdiction over submerged lands on the Outer Continental Shelf (OCS) seaward of the State boundaries (3-mile limit) in order to expedite exploration and development of oil/gas resources on the OCS in a manner that minimizes impact to the living natural resources within the OCS. Implementation of OCSLA is delegated to the Minerals Management Service (MMS) of the Department of the Interior. The OCS projects that could adversely impact the Coastal Zone are subject to Federal consistency requirements under terms of the Coastal Zone Management Act, as noted below. The OCSLA also mandates that orderly development of OCS energy resources be balanced with protection of human, marine, and coastal environments. The OCSLA does not itself regulate the take of polar bears, although through consistency determinations it helps to ensure that OCS projects do not adversely impact polar bears or their habitats.

Oil Pollution Act of 1990

The Oil Pollution Act of 1990 (33 U.S.C. 2701) established new requirements and extensively amended the Federal Water Pollution Control Act (33 U.S.C. 1301 et. seq.) to provide enhanced capabilities for oil spill response and natural resource damage assessment by the Service. It requires us to consult on developing a fish and wildlife response plan for the National Contingency Plan, input to Area Contingency Plans, review of Facility and Tank Vessel Contingency Plans, and to conduct damage assessments associated with oil spills.

Coastal Zone Management Act

The Coastal Zone Management Act of 1972 (16 U.S.C. 1451 et seq.) (CZMA) was enacted to ''preserve, protect, develop, and where possible, to restore or enhance the resources of the Nation's coastal zone.'' The CZMA provides for the submission of a State program subject to Federal approval. The CZMA requires that Federal actions be conducted in a manner consistent with the State's CZM plan to the maximum extent practicable. Federal agencies planning or authorizing an activity that affects any land or water use or natural resource of the coastal zone must provide a consistency determination to the appropriate State agency. The CZMA applies to polar bear habitats of northern and western Alaska. The North Slope Borough and Alaska Coastal Management Programs assist in protection of polar bear habitat through the project review process. The CZMA does not itself regulate the take of polar bears, and, overall, is not determined to be effective at this time in addressing the threats identified in the five factor analysis.

Alaska National Interest Lands Conservation Act

The Alaska National Interest Lands Conservation Act of 1980 (16 U.S.C. 3101 et seq.) (ANILCA) created or expanded National Parks and National Wildlife Refuges in Alaska, including the expansion of the Arctic National Wildlife Refuge (NWR). One of the establishing purposes of the Arctic NWR is to conserve polar bears. Section 1003 of ANILCA prohibits production of oil and gas in the Arctic NWR, and no leasing or other development leading to production of oil and gas may take place unless authorized by an Act of Congress. Most of the Arctic NWR is a federally designated Wilderness, but the coastal plain of Arctic NWR, which provides important polar bear denning habitat, does not have Wilderness status. The ANILCA does not itself regulate the take of polar bears, although through its designations it has provided recognition of, and various levels of protection for, polar bear habitat. In the case of polar bear habitat, the Bureau of Land Management (BLM) is responsible for vast land areas on the North Slope, including the National Petroleum Reserve, Alaska (NPRA). Habitat suitable for polar bear denning and den sites have been identified within NPRA. The BLM considers fish and wildlife values under its multiple use mission in evaluating land use authorizations and prospective oil and gas leasing actions. Provisions of the MMPA regarding the incidental take of polar bears on land areas and waters within the jurisdiction of the United States continue to apply to activities conducted by the oil and gas industry on BLM lands.

Marine Protection, Research and Sanctuaries Act

The Marine Protection, Research and Sanctuaries Act (33 U.S.C. 1401 et seq.) (MPRSA) was enacted in part to ''prevent or strictly limit the dumping into ocean waters of any material that would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities.'' The MPRSA does not itself regulate the take of polar bears. There are no designated marine sanctuaries within the range of the polar bear.

Canada

Canada's constitutional arrangement specifies that the Provinces and Territories have the authority to manage terrestrial wildlife, including the polar bear, which is not defined as a marine mammal in Canada. The Canadian Federal Government is responsible for CITES-related programs and provides both technical (long-term demographic, ecosystem, and inventory research) and administrative (Federal-Provincial Polar Bear Technical Committee (PBTC), Federal-Provincial Polar Bear Administrative Committee (PBAC), and the National Database) support to the Provinces and Territories. The Provinces and Territories have the ultimate authority for management, although in several areas, the decision-making process is shared with aboriginal groups as part of the settlement of land claims. Regulated hunting by aboriginal people is permissible under Provincial and Territorial statutes (Derocher et al. 1998, p. 32) as described in Factor B.

In Manitoba, most denning areas have been protected by inclusion within the boundaries of Wapusk National Park. In Ontario, some denning habitat and coastal summer sanctuary habitat are included in Polar Bear Provincial Park. Some polar bear habitat is included in the National Parks and National Park Reserves and territorial parks in the Northwest Territories, Nunavut, and Yukon Territory (e.g., Herschel Island). While these parks and preserves provide some protection for terrestrial habitat, subsistence hunting activities are allowed in these areas. Additional habitat protection measures in Manitoba include restrictions on harassment and approaching dens and denning bears, and a land use permit review that considers potential impacts of land use activities on wildlife (Derocher et al. 1998, p. 35). The measures adopted by the Government of Manitoba have been effective on a site-specific basis. In addition, the Government of Manitoba has recently listed the polar bear as a threatened species in that province; however, we have no information on whether this designation provides any additional regulatory protection for the species.

Species at Risk Act

Canada's Species at Risk Act (SARA) became law on December 12, 2002, and went into effect on June 1, 2004 (Walton 2004, p. M1–17). Prior to SARA, Canada's oversight of species at risk was conducted through the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) which continues to function under SARA and through the Ministry of Environment. COSEWIC evaluates species status and provides recommendations to the Minister of the Environment, who makes final listing decisions and identifies species-specific management actions. The SARA provides a number of protections for wildlife species placed on the List of Wildlife Species at Risk, or ''Schedule 1'' (SARA Registry 2005). The listing criteria used by COSEWIC are based on the 2001 IUCN Red List assessment criteria (Appendix 3). Currently, under SARA the polar bear is designated as a Schedule 3 species, ''Species of Special Concern,'' awaiting re-assessment and public consultation for possible up-listing to Schedule 1 (Environment Canada 2005). A Schedule 3 listing under SARA does not include protection measures, whereas a Schedule 1 listing under SARA may include protection measures. We did not rely on this potential in our analysis as the action has not yet occurred.

Intra-jurisdiction Polar Bear Agreements Within Canada

Polar bears occur in the Northwest Territories (NWT), Nunavut, Yukon Territory, and in the Provinces of Manitoba, Ontario, Quebec, Newfoundland, and Labrador (see Figure 1 above). All 13 Canadian polar bear populations lie within or are shared with the NWT or Nunavut. The NWT and Nunavut geographical boundaries include all Canadian lands and marine environment north of the 60th parallel (except the Yukon Territory), and all islands and waters in Hudson Bay and Hudson Strait up to the low water mark of Manitoba, Ontario, and Quebec. The offshore marine areas along the coast of Newfoundland and Labrador are under Federal jurisdiction. Although Canada manages each of the 13 populations of polar bear as separate units, there is a complex sharing of responsibilities. While wildlife management has been delegated to the Provincial and Territorial Governments, the Federal Government (Environment Canada's Canadian Wildlife Service) has an active research program and is involved in management of wildlife populations shared with other jurisdictions, especially ones with other nations. In the NWT, Native Land Claims resulted in Co-management Boards for most of Canada's polar bear populations. Canada formed the PBTC and PBAC to ensure a coordinated management process consistent with internal and international management structures and the International Agreement. The committees meet annually to review research and management of polar bears in Canada and have representation from all Provincial and Territorial jurisdictions with polar bear populations and the Federal Government. Beginning in 1984, the Service and biologists from Norway and Denmark have, with varying degrees of frequency, participated in annual PBTC meetings. The annual meetings of the PBTC provide for continuing cooperation between jurisdictions and for recommending management actions to the PBAC (Calvert et al. 1995, p. 61).

The NWT Polar Bear Management Program (GNWT) manages polar bears in the Northwest Territories. A 1960 ''Order-in-Council'' granted authority to the Commissioner in Council (NWT) to pass ordinances to protect polar bears, including the establishment of a quota system. The Wildlife Act, 1988, and Big Game Hunting Regulations provide supporting legislation which addresses each polar bear population. The Inuvialuit and Nunavut Land Claim

Agreements supersede the Northwest Territories Act (Canada) and the Wildlife Act. The Government of Nunavut passed a new Wildlife Act in 2004 and has management and enforcement authority for polar bears in their jurisdiction. Under the umbrella of this authority, polar bears are now co-managed through wildlife management boards made up of Land Claim Beneficiaries and Territorial and Federal representatives. The Boards may develop Local Management Agreements (LMAs) between the communities that share a population of polar bears. Management agreements are in place for all Nunavut populations. The LMAs are signed between the communities, regional wildlife organizations, and the Government of Nunavut (Department of Environment) but can be over-ruled by the Nunavut Wildlife Management Board (NWMB).

In the case of populations that Nunavut shares with Quebec and Ontario, the management agreement is not binding upon residents of communities outside of Nunavut jurisdiction. Similarly, in the case of populations that Nunavut shares with Manitoba, or Newfoundland and Labrador, the management agreement is not binding upon residents of communities outside of Nunavut jurisdiction. Regulations implementing the LMAs specify who can hunt, season timing and length, age and sex classes that can be hunted, and the total allowable harvest for a given population. The Department of Environment in Nunavut and the Department of Environment and Natural Resources in the NWT have officers to enforce the regulations in most communities of the NWT. The officers investigate and prosecute incidents of violation of regulations, kills in defense of life, or exceeding a quota (USFWS 1997). Canada's inter-jurisdictional requirements for consultation and development of LMAs and oversight through the PBTC and PBAC have resulted in conservation benefits for polar bear populations. Although there are some localized instances where changes in management agreements may be necessary, these arrangements and provisions have operated to minimize the threats of overharvest to the species.

The Service analyzed the overall efficacy of Canada's management of polar bears in 1997 (62 FR 7302) and 1999 (64 FR 1529) and determined, at those times, that the species was managed by Canada using sound scientific principles and in such a manner that existing populations would be sustained. We continue to believe that, in general, Canada manages polar bears in an effective and sustainable manner. However, as discussed above (see ''Harvest Management by Nation''), the Territory of Nunavut has recently adopted changes to polar bear management, including some increased harvest quotas, that may place a greater significance on indigenous knowledge than on scientific data and analysis. Management improvements may be desirable for some Canadian populations. The Service will continue to monitor polar bear management in Canada and actions taken by the Nunavut Government. This is particularly important for populations that are currently in decline or may decline in the near future.

Russian Federation

Polar bears are listed in the second issue of the Red Data Book of the Russian Federation (2001). The Red Data Book establishes official policy for protection and restoration of rare and endangered species in Russia. Polar bear populations inhabiting the Barents Sea and part of the Kara Sea (Barents-Kara population) are designated as Category IV (uncertain status); polar bears in the eastern Kara Sea, Laptev Sea, and the western Eastern Siberian Sea (Laptev population) are listed as Category III (rare); and polar bears inhabiting the eastern part of the Eastern Siberian Sea, Chukchi Sea, and the northern portion of the Bering Sea (Chukchi population) are listed as Category V (restoring). The main government body responsible for management of species listed in the Red Data Book is the Ministry of Natural Resources of the Russian Federation. Russia Regional Committees of Natural Resources are responsible for managing polar bear populations consistent with Federal legislation (Belikov et al. 2002, p. 86).

Polar bear hunting has been totally prohibited in the Russian Arctic since 1956 (Belikov et al. 2002, p. 86). The only permitted take of polar bears is catching cubs for public zoos and circuses. There are no data on illegal trade of polar bears, and parts and products derived from them, although considerable concern persists for unquantified levels of illegal harvest that is occurring (Belikov et al. 2002, p. 87).

In the Russian Arctic, Natural Protected Areas (NPAs) have been established that protect marine and associated terrestrial ecosystems, including polar bear habitats. Wrangel and Herald Islands have high concentrations of maternity dens and polar bears, and were included in the Wrangel Island State Nature Reserve (zapovednik) in 1976. A 1997 decree by the Russian Federation Government established a 12-nautical mile (nm) (22.2 km) marine zone to the Wrangel Island State Nature Reserve; the marine zone was extended an additional 24-nm (44.4-km) to a total of 36-nm (66.7-km) by a decree from the Governor of Chukotsk Autonomous Okruga (Belikov et al. 2002, p. 87). The Franz Josef Land State Nature Refuge was established in 1994. In 1996, a federal nature reserve (zakaznik) was established on Severnaya Zemlya archipelago. In Chukotka, efforts are underway to establish new protected areas where polar bears aggregate seasonally; other special protected areas are proposed for the Russian High Arctic including the Novosibirsk Islands, Severnaya Zemlya, and Novaya Zemlya. However, because they have not yet been designated, protections that may be afforded the polar bear under these designations have not been considered in our evaluation of the adequacy of existing regulatory mechanisms. Within these protected areas, conservation and restoration of terrestrial and marine ecosystems, and plant and animal species (including the polar bear), are the main goals. In 2001, the Nenetskiy State Reserve, which covers 313,400 ha (774,428 ac), and includes the mouth of the Pechora River and adjacent waters of the Barents Sea, was established.

In May 2001, the Federal law ''Concerning territories of traditional use of nature by small indigenous peoples of North, Siberia, and Far East of the Russian Federation'' was passed. This law established areas for traditional use of nature (TTUN) within NPAs of Federal, regional, and local levels to support traditional life styles and traditional subsistence use of nature resources for indigenous peoples. This law and the law ''Concerning natural protected territories'' (1995) regulate protection of plants and animals on the TTUNs. The latter also regulates organization, protection and use of other types of NPAs: State Nature Reserves (including Biosphere Reserves), National Parks, Natural Parks, and State Nature Refuges. Special measures on protection of polar bears or other resources may be governed by specific regulations of certain NPAs.

Outside NPAs, protection and use of marine renewable natural resources are regulated by Federal legislation; Acts of the President of the Russian Federation; regulations of State Duma, Government, and Federal Senate of the Russian Federation; and regulations issued by appropriate governmental departments. The most important Federal laws for nature protection are: ''About environment protection'' (2002), ''About animal world'' (1995), ''About continental shelf of the Russian Federation'' (1995), ''About exclusive economical zone of the Russian Federation'' (1998), and ''About internal sea waters, territorial sea, and adjacent zone of the Russian Federation'' (1998) (Belikov et al. 2002, p. 87). The effectiveness of laws protecting marine and nearshore environments is unknown.

Norway

According to the Svalbard Treaty of February 9, 1920, Norway exercises full and unlimited sovereignty over the Svalbard Archipelago. Polar bears have complete protection from harvest under the Svalbard Treaty (Derocher et al. 2002b, p. 75), which is effectively implemented. The Svalbard Treaty applies to all the islands situated between 10 degree and 35 degrees East longitude and between 74 degrees and 81 degrees North latitude, and includes the waters up to 4 nm offshore. Beyond this zone, Norway claims an economic zone to the continental shelf areas to which Norwegian law applies. Under Norwegian Game Law, all game, including polar bears, are protected unless otherwise stated (Derocher et al. 2002b, p. 75). The main responsibility for the administration of Svalbard lies with the Norwegian Ministry of Justice. Norwegian civil and penal laws and various other regulations are applicable to Svalbard. The Ministry of Environment deals with matters concerning the environment and nature conservation. The Governor of Svalbard (Sysselmannen), who has management responsibilities for freshwater fish and wildlife, pollution and oil spill protection, and environmental monitoring, is the cultural and environmental protection authority in Svalbard (Derocher et al. 2002b, p. 75).

Approximately 65 percent of the land area of Svalbard is totally protected, including all major regions of denning by female bears; however, protection of habitat is only on land and to 4 nm offshore. Marine protection was increased in 2004, when the territorial border of the existing protected areas was increased to 12 nm (Aars et al. 2006, p. 145). Norway claims control of waters out to 200 nm and regards polar bears as protected within this area.

In 2001, the Norwegian Parliament passed a new Environmental Act for Svalbard which went into effect in July 2002. This Act was designed to ensure that wildlife, including polar bears, is protected, although hunting of some other species is allowed. The only permitted take of polar bears is for defense of life. The regulations included specific provisions on harvesting, motorized traffic, remote camps and camping, mandatory leashing of dogs, environmental pollutants, and environmental impact assessments in connection with planning development or activities in or near settlements. Some of these regulations were specific to the protection of polar bears, e.g., through enforcement of temporal and spatial restrictions on motorized traffic and through provisions on how and where to camp to ensure adequate bear security (Aars et al. 2006, p. 145).

In 2003, Svalbard designated six new protected areas, two nature reserves, three national parks and one ''biotope protection area.'' The new protected areas are mostly located around Isfjord, the most populated fjord on the west side of the archipelago. Another protected area, Hopen, is an important denning area (Aars et al. 2006, p. 145). Kong Karls Land is the main denning area and has the highest level of protection under the Norwegian land management system. These new protected areas cover 4,449 sq km (1,719 sq mi) which is 8 percent of the Archipelago's total area (*http://www.norway.org/News/archive/2003/200304svalbard.htm*), and increase the total area under protection to 65 percent of the total land area.

Denmark/Greenland

Under terms of the Greenland Home Rule (1979), the government of Greenland is responsible for management of all renewable resources, including polar bears. Greenland is also responsible for providing scientific data for sound management of polar bear populations and for compliance with terms of the 1973 Polar Bear Agreement. Regulations for the management and protection of polar bears in Greenland that were introduced in 1994 have been amended several times (Jensen 2002, p. 65). Hunting and reporting regulations include who can hunt polar bears (residents who live off the land), protection of family groups with cubs of the year, prohibition of trophy hunting, mandatory reporting requirements, and regulations on permissible firearms and means of transportation (Jensen 2002, p. 65). In addition, there are specific regulations that apply to traditional take within the National Park of North and East Greenland and the Melville Bay Nature Reserve. A large amount of polar bear habitat occurs within the National Park of North and East Greenland. One preliminary meeting between Greenland Home Rule Government and Canada (with the participation of the government of Nunavut) has occurred to discuss management of shared populations. Greenland introduced a quota system that took effect on January 1, 2006 (L°nstrup 2005, p. 133), although no scientifically supportable quotas have yet been developed. Some reconsideration to allow a limited sport hunt is under discussion within the Greenland governmental organizations. We have no information upon which to base a finding that Greenland is managing polar bear hunting activities in a manner that provides for sustainable populations.

Regulatory Mechanisms to Limit Sea Ice Loss

Although there are regulatory mechanisms for managing many of the threats to polar bears in all countries where the species occurs, as well as among range countries through bilateral and multilateral agreements, there are no known regulatory mechanisms that are directly and effectively addressing reductions in sea ice habitat at this time.

National and international regulatory mechanisms to comprehensively address the causes of climate change are continuing to be developed. International efforts to address climate change globally began with the United Nations Framework Convention on Climate Change (UNFCCC), adopted in May 1992. The stated objective of the UNFCCC is the stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The Kyoto Protocol, negotiated in 1997, became the first additional agreement added to the UNFCCC to set GHG emissions targets. The Kyoto Protocol entered into force in February 2005 for signatory countries.

Domestic U.S. efforts relative to climate change focus on implementation of the Clean Air Act, and continued studies programs, support for developing new technologies and use of incentives for supporting reductions in emissions.

The recent publication by Canadell et al. (2007) underscores the current deficiencies of regulatory mechanisms in addressing root causes of climate change. This paper, in the *Proceedings of the National Academy of Sciences,* indicates that the growth rate of atmospheric carbon dioxide (CO_2), the largest anthropogenic source of GHGs, is increasing rapidly. Increasing atmospheric CO_2 concentration is consistent with the results of climate-carbon cycle models, but the magnitude of the observed CO_2 concentration is larger than that estimated by models. The authors suggest that these changes ''characterize a carbon cycle that is generating stronger-than-expected and sooner-than-expected climate forcing'' (Canadell et al. 2007).

Conclusion for Factor D

Rationale

Our review of existing regulatory mechanisms at the national and international level has led us to determine that potential threats to polar bears from direct take, disturbance by humans, and incidental or harassment take are, for the most part, adequately addressed through international agreements, national, State, Provincial or Territorial legislation, and other regulatory mechanisms.

As described under Factor A, the primary threat to the survival of the polar bear is loss of sea ice habitat and its consequences to polar bear populations. Our review of existing regulatory mechanisms has led us to determine that, although there are some existing regulatory mechanisms to address anthropogenic causes of climate change, there are no known regulatory mechanisms in place at the national or international level that directly and effectively address the primary threat to polar bears-the rangewide loss of sea ice habitat.

Determination for Factor D

After evaluating the best available scientific information, we have determined that existing regulatory mechanisms at the national and international level are adequate to address actual and potential threats to polar bears from direct take, disturbance by humans, and incidental or harassment take.

We note that GHG loading in the atmosphere can have a considerable lag effect on climate, so that what has already been emitted will have impacts out to 2050 and beyond (IPCC 2007, p. 749; J. Overland, NOAA, in litt. to the Service, 2007)). This is reflected in the similarity of low, medium, and high SRES emissions scenarios out to about 2050 (see Figure 5). As noted above, the publication of Canadell et al. (2007) underscores the current deficiencies of regulatory mechanisms in addressing root causes of climate change. This paper indicates that the growth rate of atmospheric carbon dioxide (CO_2), the largest anthropogenic source of GHGs, is increasing rapidly. Increasing atmospheric CO_2 concentration is consistent with the results of climate-carbon cycle models, but the magnitude of the observed CO_2 concentration is larger than that estimated by models (Canadell et al. 2007). We have determined that there are no known regulatory mechanisms in place at the national or international level that directly and effectively address the primary threat to polar bears-the rangewide loss of sea ice habitat within the foreseeable future. We also acknowledge that there are some existing regulatory mechanisms to address anthropogenic causes of climate change, and these mechanisms are not expected to be effective in counteracting the worldwide growth of GHG emissions within the foreseeable future.

Factor E. Other Natural or Manmade Factors Affecting the Polar Bear's Continued Existence

Contaminants

Understanding the potential effects of contaminants on polar bears in the Arctic is confounded by the wide range of contaminants present, each with different chemical properties and biological effects, and the differing geographic, temporal, and ecological exposure regimes impacting each of the 19 polar bear populations. Further, contaminant concentrations in polar bear tissues differ with polar bears' age, sex, reproductive status, and other factors. Contaminant sources and transport; geographical, temporal patterns and trends; and biological effects are detailed in several recent Arctic Monitoring and Assessment Program (AMAP) publications (AMAP 1998; AMAP 2004a; AMAP 2004b; AMAP 2005). Three main groups of contaminants in the Arctic are thought to present the greatest potential threat to polar bears and other marine mammals: petroleum hydrocarbons, persistent organic pollutants (POPS), and heavy metals.

Petroleum Hydrocarbons

The principal petroleum hydrocarbons in the Arctic include crude oil, refined oil products, polynuclear aromatic hydrocarbons, and natural gas and condensates (AMAP 1998, p. 661). Petroleum hydrocarbons come from both natural and anthropogenic sources. The primary natural source is oil seeps. AMAP (2007, p. 18) notes that ''natural seeps are the major source of petroleum hydrocarbon contamination in the Arctic environment.'' Anthropogenic sources include activities associated with exploration, development, and production of oil (well blowouts, operational discharges), ship- and land-based transportation of oil (oil spills from pipelines, accidents, leaks, and ballast washings), discharges from refineries and municipal waste water, and combustion of wood and fossil fuels. In addition to direct contamination, petroleum hydrocarbons are transported from more southerly areas to the Arctic via long range atmospheric and oceanic transport, as well as by north-flowing rivers (AMAP 1998, p. 671).

Polar bears are particularly vulnerable to oil spills due to their inability to effectively thermoregulate when their fur is oiled, and to poisoning that may occur from ingestion of oil while from grooming or eating contaminated prey (St. Aubin 1990, p. 237). In addition, polar bears are curious and are likely to investigate oil spills and oil-contaminated wildlife. Under some circumstances polar bears are attracted to offshore drilling platforms (Stirling 1988, p. 6; Stirling 1990, p. 230). Whether healthy polar bears in their natural environment would avoid oil spills and contaminated seals is unknown; hungry polar bears are likely to scavenge contaminated seals, as they have shown no aversion to eating and ingesting oil (St. Aubin 1990, p. 237; Derocher and Stirling 1991, p. 56). Polar bears are generally known to be attracted to various refined hydrocarbon products such as anti-freeze, hydraulic fluids, etc., and may consume them, which in some instances has resulted in death (Amstrup et al. 1989).

The most direct exposure of polar bears to petroleum hydrocarbons would come from direct contact with and ingestion of oil from acute and chronic oil spills. Polar bears' range overlaps with many active and planned oil and gas operations within 40 km (25 mi) of the coast or offshore. In the past, no large volume major oil spills of more than 3,000 barrels have occurred in the marine environment within the range of polar bears. Oil spills associated with terrestrial pipelines have occurred in the vicinity of polar bear habitat, including denning areas (e.g., Russian Federation, Komi Republic, 1994 oil spill, *http://www.american.edu/ted/KOMI.HTM*). Despite numerous safeguards to prevent spills, smaller spills do occur. An average of 70 oil and 234 waste product spills per year occurred between 1977 and 1999 in the North Slope oil fields (71 FR 14456). Many spills are small (less than 50 barrels) by oil and gas industry standards, but larger spills (greater than or equal to 500 barrels) account for much of the annual volume. The largest oil spill to date on the North Slope oil fields in Alaska (estimated volume of approximately 4,786 barrels) occurred on land in March 2006, and resulted from an undetected leak in a corroded pipeline (see State of Alaska Prevention and Emergency Response web site (*http://www.dec.state.ak.us/spar/perp/*

response/sum_fy06/060302301/060302301_index.htm).

The MMS (2004, pp. 10, 127) estimated an 11 percent chance of a marine spill greater than 1,000 barrels in the Beaufort Sea from the Beaufort Sea Multiple Lease Sale in Alaska. The Minerals Management Service (MMS) prepared an EIS on the *Chukchi Sea Planning Area; Oil and Gas Lease Sale 193 and Seismic Surveying Activities in the Chukchi Sea;* they determined that polar bears could be affected by both routine activities and a large oil spill (MMS 2007, pp. ES 1–10). Regarding routine activities, the EIS determined that small numbers of polar bears could be affected by ''noise and other disturbance caused by exploration, development, and production activities'' (MMS 2007, p. ES–4). In addition, the EIS evaluated events that would be possible over the life of the hypothetical development and production that could follow the lease sale, and estimated that ''the chance of a large spill greater than or equal to 1,000 barrels occurring and entering offshore waters is within a range of 33 to 51 percent.'' If a large spill were to occur, the analysis conducted as part of the EIS process identified potentially significant impacts to polar bears occurring in the area affected by the spill; the evaluation was done without regard to the effect of mitigating measures (MMS 2007, p. ES–4).

Oil spills in the fall or spring during the formation or break-up of sea ice present a greater risk because of difficulties associated with clean up during these periods, and the presence of bears in the prime feeding areas over the continental shelf. Amstrup et al. (2000a, p. 5) concluded that the release of oil trapped under the ice from an underwater spill during the winter could be catastrophic during spring break-up if bears were present. During the autumn freeze-up and spring break-up periods, any oil spilled in the marine environment would likely concentrate and accumulate in open leads and polynyas, areas of high activity for both polar bears and seals (Neff 1990, p. 23). This would result in an oiling of both polar bears and seals (Neff 1990, pp. 23–24; Amstrup et al. 2000a, p. 3; Amstrup et al. 2006a, p. 9).

The MMS operating regulations require that Outer Continental Shelf (OCS) activities are carried out in a safe and environmentally sound manner to prevent harm, damage or waste of, any natural resources any life (including marine mammals such as the polar bear), property, or the marine, coastal, or human environment. Regulations for exploration, development, and production operations on the OCS are specified in 30 CFR part 250. These regulations provide measures for pollution prevention and control, including drilling procedures specific to individual wells, redundant safety and pollution prevention equipment, blowout preventers and subsurface safety valves, training of the drilling crews, and structural and safety system review of production facilities. Regulations related to oil-spill prevention and response are specified in 30 CFR part 254.

As previously discussed in the ''Oil and Gas Exploration, Development, and Production'' section, the actual history of oil and gas activities in the Beaufort and Chukchi Seas demonstrate that operations have been done safely and with a negligible effect on wildlife and the environment. On the Beaufort and Chukchi OCS, 35 exploratory wells have been drilled. During this drilling period, approximately 26.7 barrels of petroleum product have been spilled, and, of those 26.7 barrels, approximately 24 barrels were recovered or cleaned up. MMS and industry standards require strict protection measures during production of energy resources. For example, although it is located in State of Alaska waters, the shared State/Federal Northstar production facility used a specially-fabricated pipe that was buried 7–11 ft below the sea floor to prevent damage from ice keels, is pigged (the practice of using pipeline inspection gauges or 'pigs' to perform various operations on a pipeline without stopping the flow of the product in the pipeline), and has several different monitoring systems to detect spills.

In addition, NOAA and the Service require monitoring and avoidance measures for marine mammals during critical times during exploration and production. The Marine Mammal Observers (MMO) are required by NOAA and the Service to be on deck watching for animals. Depending on the activity and the particular circumstances, operations may be temporarily halted or modified. In some circumstances, hazing may be used to keep the polar bears away from operations. There are specific guidelines the MMO follow for observing and hazing. Hazing is only used to protect the safety of humans or the marine mammal.

Prior to any exploration, development, or production activities, companies must submit an Exploration Plan or a Development/Production Plan to MMS for review and approval. In Alaska, MMS provides a copy of all such plans to the Service for review. Prior to conducting drilling operations, the operator must also obtain approval for an Application for Permit to Drill (APD). The APD requires detailed information on the seafloor and shallow seafloor conditions for the drill site from shallow geophysical and, if necessary, archaeological and biological surveys. The APD requires detailed information about the drilling program to allow evaluation of operational safety and pollution-prevention measures. The lessee must use the best available and safest technology to minimize the potential for uncontrolled well flow, through the use of blowout preventers. For example, the operator also must identify procedures to curtail operations during critical ice or weather conditions.

In addition, the MMS identifies additional protection measures for the polar bear through the use of Information to Lessees (ITL). Lessees are advised that incidental take of marine mammals is prohibited unless authorization is received under the MMPA. For example, for Sale 193 in the Chukchi Sea, potential lessees were advised to obtain MMPA authorizations from FWS and to consult with the Service, local Native communities and the Alaska Nanuuq Commission during exploration, production and spill response planning, to assure adequate protection for the polar bear. Lessees are specifically advised to conduct their activities in a way that will limit potential encounters and interaction between lease operations and polar bears.

For production, the lessee must design, fabricate, install, use, inspect, and maintain all platforms and structures on the OCS to ensure their structural integrity for the safe conduct of operations at specific locations. All tubing installations open to hydrocarbon-bearing zones below the surface must be equipped with safety devices that will shut off the flow from the well in the event of an emergency, unless the well is incapable of flowing. All surface production facilities must be designed, installed, and maintained in a manner that provides for efficiency, safety of operations, and protection of the environment, including marine mammals.

Pipeline-permit applications to MMS include the pipeline location drawing, profile drawing, safety schematic drawing, pipe-design data to scale, a shallow-hazard-survey report, and an archaeological report. The MMS evaluates the design and fabrication of the pipeline. No pipeline route will be approved by MMS if any bottom-disturbing activities (from the pipeline itself or from the anchors of lay barges and support vessels) encroach on any biologically sensitive areas. The operators are required to monitor and inspect pipelines by methods prescribed by MMS for any indication of pipeline leakage.

MMS conducts onsite inspections to ensure compliance with plans and with the MMS pollution prevention regulations. It has been practice in Alaska to have an MMS inspector onboard drilling vessels during key drilling procedures.

In compliance with 30 CFR part 254, all owners and operators of oil-handling, oil-storage, or oil-transportation facilities located seaward of the coastline must submit an Oil Spill Response Plan to MMS for approval. Owners or operators of offshore pipelines are required to submit a plan for any pipeline that carries oil, condensate that has been injected into the pipeline, or gas and naturally occurring condensate.

Increases in circumpolar Arctic oil and gas development, coupled with increases in shipping and/or development of offshore and land-based pipelines, increase the potential for an oil spill to negatively affect polar bears and/or their habitat. Future declines in the Arctic sea ice may result in increased tanker traffic in high bear use areas (Frantzen and Bambulyak 2003, p. 4), which would increase the chances of an oil spill from a tanker accident, ballast discharge, or discharges during the loading and unloading of oil at the ports. Amstrup et al. (2007, p. 31) assumed that human activities related to oil and gas exploration and development are likely to increase with disappearance of sea ice from many northern areas. At the same time, less sea ice will facilitate an increase in offshore developments. More offshore development will increase the probability of hydrocarbon discharges into polar bear habitat (Stirling 1990, p. 228). The record of over 30 years of predominantly terrestrial oil and gas development in Alaska suggests that with proper management, potential negative effects of these activities on polar bears can be minimized (Amstrup 1993, p. 250; Amstrup 2000, pp. 150–154; Amstrup 2003, pp. 597, 604; Amstrup et al. 2004, p. 23) (for details see the ‘‘Oil and Gas Exploration, Development, and Production’’ section of this final rule). Increased industrial activities in the marine environment will require additional monitoring.

Amstrup et al. (2006) evaluated the potential effects of a hypothetical 5,912-barrel oil spill (the largest spill thought possible from a pipeline spill) on polar bears from the Northstar offshore oil production facility in the southern Beaufort Sea, and found that there is a low probability that a large number of bears (e.g., 25–60) might be affected by such a spill. For the purposes of this scenario, it was assumed that a polar bear would die if it came in contact with the oil. Amstrup et al. (2006a, p.21) found that 0–27 bears could potentially be oiled during the open water conditions in September, and from 0–74 bears in mixed ice conditions during October. If such a spill occurred, particularly during the broken ice period, the impact of the spill could be significant to the Southern Beaufort Sea polar bear population (Amstrup et al. 2006a, pp. 7, 22; 65 FR 16833). The sustainable harvest yield per year for the Southern Beaufort Sea population, based on a stable population size of 1,800 bears, was estimated to be 81.1 bears (1999–2000 to 2003–2004) (Lunn et al. 2005, p. 107). For the same time period, the average harvest was 58.2 bears, leaving an additional buffer of 23 bears that could have been removed from the population. Therefore, an oil spill that resulted in the death of greater than 23 bears, which was possible based on the range of oil spill-related mortalities from the previous analysis, could have had population level effects for polar bears in the southern Beaufort Sea. However, the harvest figure of 81 bears may no longer be sustainable for the Southern Beaufort Sea population, so, given the average harvest rate cited above, fewer than 23 oil spill-related mortalities could result in population-level effects.

The number of polar bears affected by an oil spill could be substantially higher if the spill spread to areas of seasonal polar bear concentrations, such as the area near Kaktovik, Alaska, in the fall, and could have a significant impact to the Southern Beaufort Sea polar bear population. It seems likely that an oil spill would affect ringed seals the same way the Exxon Valdez oil spill affected harbor seals (Frost et al. 1994a, pp. 108–110; Frost et al. 1994b, pp. 333–334, 343–344, 346–347; Lowry et al. 1994, pp. 221–222; Spraker et al. 1994, pp. 300–305). As with polar bears, the number of animals killed would vary depending upon the season and spill size (NRC 2003, pp. 168–169). Oil spills remain a concern for polar bears throughout their range. Increased industrial activities in the marine environment will require additional monitoring. Oil and gas exploration, development, and production effects on polar bears and their habitat are discussed under Factor A.

Persistent Organic Pollutants (POPs)

Contamination of the Arctic and sub-Arctic regions through long-range transport of persistent organic pollutants has been recognized for over 30 years (Bowes and Jonkel 1975, p. 2,111; de March et al. 1998, p. 184; Proshutinsky and Johnson 2001, p. 68; MacDonald et al. 2003, p. 38). These compounds are transported via large rivers, air, and ocean currents from the major industrial and agricultural centers located at more southerly latitudes (Barrie et al. 1992; Li et al. 1998, pp. 39–40; Proshutinsky and Johnson 2001, p. 68; Lie et al. 2003, p. 160). The presence and persistence of these contaminants within the Arctic is dependent on many factors, including transport routes, distance from source, and the quantity and chemical composition of the releases. Climate change may increase long-range marine and atmospheric transport of contaminants (Macdonald et al. 2003, p. 5; Macdonald et al 2005, p.15). For example, increased rainfall in northern regions has increased river discharges into the Arctic marine environment. Many north-flowing rivers originate in heavily industrialized regions and carry heavy contaminant burdens (Macdonald et al. 2005, p. 31).

The Arctic ecosystem is particularly sensitive to environmental contamination due to the slower rate of breakdown of persistent organic pollutants, including organochlorine (OC) compounds, the relatively simple food chains, and the presence of long-lived organisms with low rates of reproduction and high lipid levels. The persistence and tendency of OCs to reside and concentrate in fat tissues of organisms increases the potential for bioaccumulation and biomagnification at higher trophic levels (Fisk et al. 2001, pp. 225–226). Polar bears, because of their position at the top of the Arctic marine food chain, have some of the highest concentrations of OCs of any Arctic mammals (Braune et al. 2005, p. 23). Considering the potential for increases in both local and long-range transport of contaminants to the Arctic, with warmer climate and less sea ice, the influence these activities have on polar bears is likely to increase.

The most studied POPs in polar bears include polychlorinated biphenyls (PCBs), chlordanes (CHL), DDT and its metabolites, toxaphene, dieldrin, hexachloroabenzene (HCB), hexachlorocyclohexanes (HCHs), and chlorobenzenes (ClBz). Overall, the relative proportion of the more recalcitrant compounds, such as PCB 153 and β-HCH, appears to be increasing in polar bears (Braune et al. 2005, p. 50).

Although temporal trend information is lacking, newer compounds, such as polybrominated diphenyl ethers (PBDEs), polychlorinated naphthalenes (PCNs), perflouro-octane sulfonate (PFOsS), perfluoroalkyl acids (PFAs), and perflourocarboxylic acids (PFCAs), have been recently found in polar bears (Braune et al. 2005, p. 5). Of this relatively new suite of compounds, there is concern that both PFOsS, which are increasing rapidly, and PBDEs are a potential risk to polar bears (Ikonomou et al. 2002, p. 1,886; deWit 2002, p. 583; Martin et al. 2004, p. 373; Braune et al. 2005, p. 25; Smithwick et al. 2006, p. 1,139).

Currently, polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs) and dioxin-like PCBs are at relatively low concentrations in polar bears (Norstrom et al. 1990, p. 14). The highest PCB concentrations have been found in polar bears from the Russian Arctic (Franz Joseph Land and the Kara Sea), with decreasing concentrations to the east and west (Andersen et al. 2001, p. 231). Overall, there is evidence of declines in PCBs for most polar bear populations. The pattern of distribution for most other chlorinated hydrocarbons and metabolites generally follows that of PCBs, with the highest concentrations of DDT-related compounds and CHLs in Franz Joseph Land and the Kara Sea, followed by East Greenland, Svalbard, the eastern Canadian Arctic populations, the western Canadian populations, the Siberian Sea, and finally the lowest concentrations in Alaska populations (Bernhoft et al. 1997; Norstrom et al. 1998, p. 361; Andersen et al. 2001, p. 231; Kucklick et al. 2002, p. 9; Lie et al. 2003, p. 159; Verreault et al. 2005, pp. 369–370; Braune et al. 2005, p. 23).

The polybrominated diphenyl ethers (PBDEs) share similar physical and chemical properties with PCBs (Wania and Dugani 2003, p. 1,252; Muir et al. 2006, p. 449), and are thought to be transported to the Arctic by similar pathways. Muir et al. (2006, p. 450) analyzed archived samples from Dietz et al. (2004) and Verreault et al. (2005) for PBDE concentrations, finding the highest mean PBDE concentrations in female polar bear adipose tissue from East Greenland and Svalbard. Lower concentrations of PBDEs were found in adipose tissue from the Canadian and Alaskan populations (Muir et al. 2006, p. 449). Differences between the PBDE concentrations and composition in liver tissue between the Southern Beaufort Sea and the Chukchi Seas populations in Alaska suggest differences in the sources of PBDEs exposure (Kannan et al. 2005, p. 9057). Overall, the sum of the PBDE concentrations are much lower and less of a concern compared to PCBs, oxychlordane, and some of the more recently discovered perflouorinated compounds. PBDEs are metabolized to a high degree in polar bears and thus do not bioaccumulate as much as PCBs (Wolkers et al. 2004, p. 1,674).

Although baseline information on contaminant concentrations is available, determining the biological effects of these contaminants in polar bears is difficult. Field observations of reproductive impairment in females and males, lower survival of cubs, and increased mortality of females in Svalbard, Norway, however, suggest that high concentrations of PCBs may have contributed to population level effects in the past (Wiig 1998, p. 28; Wiig et al. 1998, p. 795; Skaare et al. 2000, p. 107; Haave et al. 2003, pp. 431, 435; Oskam et al. 2003, p. 2134; Derocher et al. 2003, p. 163). At present, however, PCB concentrations are not thought to be resulting population level effects on polar bears. Organochlorines may adversely affect the endocrine system as metabolites of these compounds are toxic and some have demonstrated endocrine disrupting activity (Letcher et al. 2000; Braune et al. 2005, p. 23). High concentrations of organochlorines may also affect the immune system, resulting in a decreased ability to produce antibodies (Lie et al. 2004, pp. 555–556).

Despite the regulatory steps taken to decrease the production or emissions of toxic chemicals, increases in some relatively new compounds are cause for concern. Some of these compounds have increased in the last decade (Ikonomou et al. 2002, p. 1,886; Muir et al. 2006, p. 453).

Metals

Numerous essential and non-essential elements have been reported on for polar bears and the most toxic or abundant elements in marine mammals are mercury, cadmium, selenium, and lead. Of these, mercury is of greatest concern because of its potential toxicity at relatively low concentrations, and its ability to biomagnify and bioaccumulate in the food web. Polar bears from the western Canadian Arctic and southwest Melville Island, Canada (Braune et al. 1991, p. 263; Norstrom et al. 1986, p. 195; AMAP 2005, pp. 42, 62, 134), and ringed seals from the western Canadian Arctic (Wagemann et al. 1996, p. 41; Deitz et al. 1998, p. 433; Dehn et al. 2005, p. 731; Riget et al. 2005, p. 312), have some of the highest known mercury concentrations. Wagemann et al. (1996, pp. 51, 60) observed an increase in mercury from eastern to western Canadian ringed seal populations and attributed this pattern to a geologic gradient in natural mercury deposits.

Although the contaminant concentrations of mercury found in marine mammals often exceed those found to cause effects in terrestrial mammals (Fisk et al. 2003, p. 107), most marine mammals appear to have evolved effective biochemical mechanisms to tolerate high concentrations of mercury (AMAP 2005, p.123). Polar bears are able to break down methylmercury and accumulate higher levels than their terrestrial counterparts without detrimental effects (AMAP 2005, p. 123). Evidence of mercury poisoning is rare in marine mammals, but Dietz et al. (1990, p. 49) noted that sick marine mammals often have higher concentrations of methylmercury, suggesting that these animals may no longer be able to detoxify methylmercury. Hepatic mercury concentrations are well below those expected to cause biological effects in most polar bear populations (AMAP 2005, p. 118). Only two polar bear populations have concentrations of mercury close to the biological threshold levels of 60 micrograms wet weight reported for marine mammals (AMAP 2005, p. 121): the Viscount Melville population (southwest Melville Sound), Canada, and the Southern Beaufort Sea population (eastern Beaufort Sea) (Dietz et al. 1998, p. 435, Figure 7–52).

Shipping and Transportation

Observations over the past 50 years show a decline in Arctic sea ice extent in all seasons, with the most prominent retreat in the summer. Climate models project an acceleration of this trend with periods of extensive melting in spring and autumn, thus opening new shipping routes and extending the period that shipping is practical (ACIA 2005, p. 1,002). Notably, the navigation season for the Northern Sea Route (across northern Eurasia) is projected to increase from 20–30 days per year to 90–100 days per year. Russian scientists cite increasing use of a Northern Sea Route for transit and regional development as a major source of disturbance to polar bears in the Russian Arctic (Wiig et al. 1996, pp. 23–24; Belikov and Boltunov 1998, p. 113; Ovsyanikov 2005, p. 171). Commercial navigation on the Northern Sea Route could disturb polar bear feeding and other behaviors, and would increase the risk of oil spills (Belikov et al. 2002, p. 87).

Increased shipping activity may disturb polar bears in the marine environment, adding additional energetic stresses. If ice-breaking activities occur, they may alter habitats used by polar bears, possibly creating ephemeral lead systems and concentrating ringed seals within the refreezing leads. This, in turn, may allow for easier access to ringed seals and may have some beneficial values. Conversely, this may cause polar bears to use areas that may have a higher likelihood of human encounters as well as increased likelihood of exposure to oil, waste products, or food wastes that are intentionally or accidentally released into the marine environment. If shipping involved the tanker transport of crude oil or oil products, there would be some increased likelihood of small to large volume spills and corresponding oiling of polar bears, as well as potential effects on seal prey species (AMAP 2005, pp. 91, 127).

The PBSG (Aars et al. 2006, pp. 22, 58, 171) recognized the potential for increased shipping and marine transportation in the Arctic with declining seasonal sea ice conditions. The PBSG recommended that the parties to the 1973 Polar Bear Agreement take appropriate measures to monitor, regulate, and mitigate ship traffic impacts on polar bear populations and habitats (Aars et al. 2006, p. 58).

Ecotourism

Properly regulated ecotourism will likely not have a negative effect on polar bear populations, although increasing levels of ecotourism and photography in polar bear viewing areas and natural habitats may lead to increased polar bear-human conflicts. Ecotourists and photographers may inadvertently displace bears from preferred habitats or alter natural behaviors (Lentfer 1990, p.19; Dyck and Baydack 2004, p. 344). Polar bears are inquisitive animals and often investigate novel odors or sights. This trait can lead to polar bears being killed at cabins and remote stations where they investigate food smells (Herrero and Herrero 1997, p. 11). Conversely, ecotourism has the effect of increasing the worldwide constituency of people with an interest in polar bears and their conservation.

Conclusion for Factor E

Rationale

Contaminant concentrations are not presently thought to have population level effects on most polar bear populations. However, increased exposure to contaminants has the potential to operate in concert with other factors, such nutritional stress from loss or degradation of the sea ice habitat or decreased prey availability and accessibility, to lower recruitment and survival rates that ultimately would have negative population level effects. Despite the regulatory steps taken to decrease the production or emissions of toxic chemicals, use of some relatively new compounds has increased recently in the last decade (Ikonomou et al. 2002, p. 1,886; Muir et al. 2006, p. 453). Several populations, such as the Svalbard, East Greenland, and Kara Sea populations, that currently have some of the highest contaminant concentrations may be affected, but we do not believe these effects will be significant within the foreseeable future. Increasing levels of ecotourism and shipping may lead to greater impacts on polar bears. The potential extent of impact is related to changing sea ice conditions and resulting changes to polar bear distribution.

Determination for Factor E

We have evaluated the best available scientific information on other natural or manmade factors that are affecting polar bears, and have determined that contaminants, ecotourism, and shipping do not threaten the polar bear throughout all or any significant portion of its range. Some of these, particularly contaminants and shipping, may become more significant threats in the future for polar bear populations experiencing declines related to nutritional stress brought on by sea ice and environmental changes.

Finding

We have carefully considered all available scientific and commercial information past, present, and future threats faced by the polar bear. We reviewed the petition, information available in our files, scientific journals and reports, and other published and unpublished information submitted to us during the public comment periods following our February 9, 2006 (71 FR 6745) 90-day petition finding, the January 9, 2007 (72 FR 1064), 12-month Finding and proposed rule, and during public hearings held in Washington, DC and Alaska. In addition, at the request of the Secretary of the Interior, the USGS analyzed and integrated a series of studies on polar bear population dynamics, range-wide habitat use and changing sea ice conditions in the Arctic, and provided the Service with nine scientific reports on the results of their studies. We carefully evaluated these new reports and other published and unpublished information submitted to us following the public comment period on these reports, initially opened for 15 days (September 20, 2007; 72 FR 53749), but then extended until October 22, 2007 (72 FR 56979).

In accordance with our policy published on July 1, 1994 (59 FR 34270), we solicited and received expert opinions on both the *Range Wide Status Review of the Polar Bear* (*Ursus maritimus*) (Schliebe et al. 2006a), and subsequently on the 12-month finding and proposed rule (72 FR 1064). We received reviews of the draft Status Review from 10 independent experts and on the proposed rule from 14 independent experts in the fields of polar bear ecology, contaminants and physiology, climatic science and physics, Arctic ecology, pinniped (seal) ecology, and traditional ecological knowledge (TEK). We also consulted with recognized polar bear experts and other Federal, State, and range country resource agencies.

In making this finding, we recognize that polar bears evolved in the ice-covered waters of the circumpolar Arctic, and are reliant on sea ice as a platform to hunt and feed on ice-seals, to seek mates and breed, to move to feeding sites and terrestrial maternity denning areas, and for long-distance movements. The rapid retreat of sea ice in the summer and overall diminishing sea ice throughout the year in the Arctic is unequivocal and extensively documented in scientific literature. Further extensive recession of sea ice is projected by the majority of state-of-the-art climate models, with a seasonally ice-free Arctic projected by the middle of the 21st century by many of those models. Sea ice habitat will be subjected to increased temperatures, earlier melt periods, increased rain-on-snow events, and shifts in atmospheric and marine circulation patterns.

Under Factor A (''Present or Threatened Destruction, Modification, or Curtailment of its habitat or range''), we have determined that ongoing and projected loss of the polar bear's crucial sea ice habitat threatens the species throughout all of its range. Productivity, abundance, and availability of ice seals, the polar bear's primary prey base, would be diminished by the projected loss of sea ice, and energetic requirements of polar bears for movement and obtaining food would increase. Access to traditional denning areas would be affected. In turn, these factors would cause declines in the condition of polar bears from nutritional stress and reduced productivity. As already evidenced in the Western Hudson Bay and Southern Beaufort Sea populations, polar bears would experience reductions in survival and recruitment rates. The eventual effect is that polar bear populations would decline. The rate and magnitude of decline would vary among populations, based on differences in the rate, timing, and magnitude of impacts. However, within the foreseeable future, all populations would be affected, and the species is likely to become in danger of extinction throughout all of its range due to declining sea ice habitat.

Under Factor B (''Overutilization for Commercial, Recreational, Scientific, or Educational Purposes'') we note that polar bears are harvested in Canada, Alaska, Greenland, and Russia, and we acknowledge that harvest is the consumptive use of greatest importance and potential effect to polar bear. Further we acknowledge that forms of removal other than harvest (such as defense-of-life take) have been considered in this analysis. While overharvest occurs for some populations, laws and regulations for most management programs have been instituted to provide sustainable harvests over the long term. As the status of populations declines, it may be necessary for management entitites to implement harvest reductions in order to limit the potential effect of harvest. This capability has a proven track record in Canada, and is adaptive to future needs. Further, bilateral agreements or conservation agreements have been developed to address issues of overharvest. Conservation benefits from agreements that are in development or have not yet been implemented are not considered in our evaluation. We also acknowledge that increased levels of bear-human encounters are expected in the future and that encounters may result in increased mortality to bears at some unknown level. Adaptive management programs, such as implementing polar bear patrols, hazing programs, and efforts to minimize attraction of bears to communities, to address future bear-human interaction issues, including on-the-land ecotourism activities, are anticipated.

Harvest is likely exacerbating the effects of habitat loss in several populations. In addition, continued harvest and increased mortality from bear-human encounters or other forms of mortality may become a more significant threat factor in the future, particularly for populations experiencing nutritional stress or declining population numbers as a consequence of habitat change. Although harvest, increased bear-human interaction levels, defense-of-life take, illegal take, and take associated with scientific research live-capture programs are occurring for several populations, we have determined that overutilization does not currently threaten the species throughout all or a significant portion of its range.

Under Factor C (''Disease and Predation'') we acknowledge that disease pathogens are present in polar bears; no epizootic outbreaks have been detected; and intra-specific stress through cannibalism may be increasing; however, population level effects have not been documented. Potential for disease outbreaks, an increased possibility of pathogen exposure from changed diet or the occurrence of new pathogens that have moved northward with a warming environment, and increased mortality from intraspecific predation (cannibalism) may become more significant threat factors in the future for polar bear populations experiencing nutritional stress or declining population numbers. We have determined that disease and predation (including intraspecific predation) do not threaten the species throughout all or a significant portion of its range.

Under Factor D (''Inadequacy of Existing Regulatory Mechanisms''), we have determined that existing regulatory mechanisms at the national and international level are generally adequate to address actual and potential threats to polar bears from direct take, disturbance by humans, and incidental or harassment take. We have determined that there are no known regulatory mechanisms in place at the national or international level that directly and effectively address the primary threat to polar bears—the rangewide loss of sea ice habitat within the foreseeable future.

We acknowledge that there are some existing regulatory mechanisms to address anthropogenic causes of climate change, and these mechanisms are not expected to be effective in counteracting the worldwide growth of GHG emissions in the foreseeable future.

Under Factor E (''Other Natural or Manmade Factors Affecting the Polar Bear's Continued Existence'') we reviewed contaminant concentrations and find that, in most populations, contaminants have not been found to have population level effects. We further evaluated increasing levels of ecotourism and shipping that may lead to greater impacts on polar bears. The extent of potential impact is related to changing ice conditions, polar bear distribution changes, and relative risk for a higher interaction between polar bears and ecotourism or shipping. Certain factors, particularly contaminants and shipping, may become more significant threats in the future for polar bear populations experiencing declines related to nutritional stress brought on by sea ice and environmental changes. We have determined, however, that contaminants, ecotourism, and shipping do not threaten the polar bear throughout all or a significant portion of its range.

On the basis of our thorough evaluation of the best available scientific and commercial information regarding present and future threats to the polar bear posed by the five listing factors under the Act, we have determined that the polar bear is threatened throughout its range by habitat loss (i.e., sea ice recession). We have determined that there are no known regulatory mechanisms in place at the national or international level that directly and effectively address the primary threat to polar bears—the rangewide loss of sea ice habitat. We have determined that overutilization does not currently threaten the species throughout all or a significant portion of its range, but is exacerbating the effects of habitat loss for several populations and may become a more significant threat factor within the foreseeable future. We have determined that disease and predation, in particular intraspecific predation, and contaminants do not currently threaten the species throughout all or a significant portion of its range, but may become more significant threat factors for polar bear populations, especially those experiencing nutritional stress or declining population levels, within the foreseeable future.

Distinct Population Segment (DPS) and Significant Portion of the Range (SPR) Evaluation

The Act defines an endangered species as a species in danger of extinction throughout all or a significant portion of its range, and a threatened species as a species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

In our analysis for this final rule we initially evaluated the status of and threats to the species throughout its entire range. The polar bear is broadly distributed throughout the circumpolar Arctic, occurring in five countries and numbering from 20,000–25,000 in total population. The species has been delineated into 19 populations for management purposes by the PBSG (Aars et al. 2006, p. 33), and these populations have been aggregated into four ecoregions for population and habitat modeling exercises by Amstrup et al. (2007). In our evaluation of threats to the polar bear, we determined that populations are being affected, and will continue being affected, at different times, rates, and magnitudes depending on where they occur. Some of these differential effects can be distinguished at the ecoregional level, as demonstrated by Amstrup et al. (2007). On the basis of this evaluation, we determined that the entire species meets the definition of threatened under the Act due to the loss of sea ice habitat. The basis of this determination is captured within the analysis of each of the five listing factors, and the ''Finding'' immediately preceding this section.

Recognizing the differences in the timing, rate, and magnitude of threats, we evaluated whether there were any specific areas or populations that may be disproportionately threatened such that they currently meet the definition of an endangered species versus a threatened species. We first considered whether listing one or more Distinct Population Segments (DPS) as endangered may be warranted. We then considered whether there are any significant portions of the polar bear's range (SPR) where listing the species as endangered may be warranted. Our DPS and SPR analyses follow.

Our ''Policy Regarding the Recognition of Distinct Vertebrate Population Segments under the Act'' (61 FR 4725; February 7, 1996) outlines three elements that must be considered with regard to the potential recognition of a DPS as endangered or threatened: (1) Discreteness of the population segment in relation to the remainder of the species to which it belongs; (2) significance of the population segment in relation to the remainder of the taxon; and (3) conservation status of the population segment in relation to the Act's standards for listing (i.e., when treated as if it were a species, is the population segment endangered or threatened?).

Under our DPS Policy, a population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions: (1) It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors (quantitative measures of genetic or morphological discontinuity may provide evidence of this separation); or (2) it is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act.

Genetic studies of polar bears have documented that within-population genetic variation is similar to black and grizzly bears (Amstrup 2003, p. 590), but that among populations, genetic structuring or diversity is low (Paetkau et al. 1995, p. 347; Cronin et al. 2006, pp. 658–659). The latter has been attributed to extensive population mixing associated with large home ranges and movement patterns, as well as the more recent divergence of polar bears in comparison to grizzly and black bears (Talbot and Shields 1996a, p. 490; Talbot and Shields 1996b, p. 574; Paetkau et al. 1999, p. 1580). Genetic analyses support delineated boundaries between some populations (Paetkau et al. 1999, p. 1,571; Amstrup 2003, p. 590), while confirming the existence of overlap and mixing among others (Paetkau et al. 1999, p. 1,571; Cronin et al. 2006, p. 655). We have concluded that these small genetic differences are not sufficient to distinguish population segments under the DPS Policy. Moreover, there are no morphological or physiological differences across the range of the species that may indicate adaptations to environmental variations. Although polar bears within different populations or ecoregions (as defined by Amstrup et al. 2007) may have minor differences in demographic parameters, behavior, or life history strategies, in general polar bears have a similar dependence upon sea ice habitats, rely upon similar prey, and exhibit similar life history characteristics throughout their range.

Consideration might be given to utilizing international boundaries to satisfy the discreteness portion of the DPS Policy. However, each range country shares populations with other range countries, and many of the shared populations are also co-managed. Given that the threats to the polar bear's sea ice habitat is global in scale and not limited to the confines of a single country, and that populations are being managed collectively by the range countries (through bi-lateral and multi-lateral agreements), we do not find that differences in conservation status or management for polar bears across the range countries is sufficient to justify the use of international boundaries to satisfy the discreteness criterion of the DPS Policy. Therefore, we conclude that there are no population segments that satisfy the discreteness criterion of the DPS Policy. As a consequence, we could not identify any geographic areas or populations that would qualify as a DPS under our 1996 DPS Policy (61 FR 4722).

Having determined that the polar bear meets the definition of a threatened species rangewide and that there are no populations that meet the discreteness criteria under our DPS policy (and, therefore, that there are no Distinct Population Segments for the polar bear), we then considered whether there are any significant portions of its range where the species is in danger of extinction.

On March 16, 2007, a formal opinion was issued by the Solicitor of the Department of the Interior, ''The Meaning of 'In Danger of Extinction Throughout All or a Significant Portion of Its Range''' (USDI 2007c). We have summarized our interpretation of that opinion and the underlying statutory language below. A portion of a species' range is significant if it is part of the current range of the species and it contributes substantially to the representation, resiliency, or redundancy of the species. The contribution must be at a level such that its loss would result in a decrease in the ability to conserve the species.

Some may argue that lost historical range should be considered by the Service when evaluating effects posed to a significant portion of the species' range. While we disagree with this argument, we note that the polar bear currently occupies its entire historical range.

In determining whether a species is threatened or endangered in a significant portion of its range, we first identify any portions of the range of the species that warrant further consideration. The range of a species can theoretically be divided into portions in an infinite number of ways. However, there is no purpose to analyzing portions of the range that are not reasonably likely to be significant and threatened or endangered. To identify those portions that warrant further consideration, we determine whether there is substantial information indicating that (i) the portions may be significant and (ii) the species may be in danger of extinction there or likely to become so within the foreseeable future. In practice, a key part of this analysis is whether the threats are geographically concentrated in some way. If the threats to the species are essentially uniform throughout its range, no portion is likely to warrant further consideration. Moreover, if any concentration of threats applies only to portions of the range that are unimportant to the conservation of the species, such portions will not warrant further consideration.

If we identify any portions that warrant further consideration, we then determine whether in fact the species is threatened or endangered in any significant portion of its range. Depending on the biology of the species, its range, and the threats it faces, it may be more efficient for the Service to address the significance question first, or the status question first. Thus, if the Service determines that a portion of the range is not significant, the Service need not determine whether the species is threatened or endangered there. If the Service determines that the species is not threatened or endangered in a portion of its range, the Service need not determine if that portion is significant. If the Service determines that both a portion of the range of a species is significant and the species is threatened or endangered there, the Service will specify that portion of the range as threatened or endangered pursuant to section 4(c)(1) of the Act.

The terms ''resiliency,'' ''redundancy,'' and ''representation'' are intended to be indicators of the conservation value of portions of the range. Resiliency of a species allows the species to recover from periodic disturbance. A species will likely be more resilient if large populations exist in high-quality habitat that is distributed throughout the range of the species in such a way as to capture the environmental variability found within the range of the species. In addition, the portion may contribute to resiliency for other reasons—for instance, it may contain an important concentration of certain types of habitat that are necessary for the species to carry out its life-history functions, such as breeding, feeding, migration, dispersal, or wintering. Redundancy of populations may be needed to provide a margin of safety for the species to withstand catastrophic events. This does not mean that any portion that provides redundancy is a significant portion of the range of a species. The idea is to conserve enough areas of the range such that random perturbations in the system act on only a few populations. Therefore, each area must be examined based on whether that area provides an increment of redundancy that is important to the conservation of the species. Adequate representation ensures that the species' adaptive capabilities are conserved. Specifically, the portion should be evaluated to see how it contributes to the genetic diversity of the species. The loss of genetically based diversity may substantially reduce the ability of the species to respond and adapt to future environmental changes. A peripheral population may contribute meaningfully to representation if there is evidence that it provides genetic diversity due to its location on the margin of the species' habitat requirements.

To determine whether any portions of the range of the polar bear warrant further consideration as possible endangered significant portions of the range, we reviewed the entire supporting record for this final listing determination with respect to the geographic concentration of threats and the significance of portions of the range to the conservation of the species. As previously mentioned, we evaluated whether substantial information indicated that (i) the portions may be significant and (ii) the species in that portion may currently be in danger of extinction. We recognize that the level, rate, and timing of threats are uneven across the Arctic and, thus, that polar bear populations will be affected at different rates and magnitudes depending on where they occur and the resiliency of each specific population. On this basis, we determined that some portions of the polar bear's range might warrant further consideration as possible endangered significant portions of the range.

To determine which areas may warrant further consideration, we initially evaluated the four ecoregions defined by Amstrup et al. (2007), each of which consists of a subset of the 19 IUCN-defined management populations, plus a new population—the Queen Elizabeth Islands—created by the authors. The four ecoregions are: (1) the Seasonal Ice ecoregion; (2) the Archipelago ecoregion of the central Canadian Arctic; (3) the polar basin Divergent ecoregion; and (4) the polar basin Convergent ecoregion. On the basis of observational results from long-term studies of polar bear populations and sea ice conditions, plus projections from GCM climate simulations and the results of preliminary Carrying Capacity and Bayesian Network modeling exercises by Amstrup et al. (2007), we have determined that there is substantial information that polar bear populations in the Seasonal Ice and polar basin Divergent ecoregions may face a greater level of threat than populations in the Archipelago and polar basin Convergent ecoregions (see detailed discussion under Factor A). The large geographic area included in each of these ecoregions, plus the substantial proportion of the total polar bear population inhabiting those ecoregions, also indicate that they may be significant portions of the range. Having met these two initial tests, a further evaluation was deemed necessary to determine if these two portions of the range are both significant and endangered (that analysis follows below). We determined that the Archipelago and polar Convergent ecoregions do not satisfy the two initial tests, because there is not substantial information to suggest that the species in those portions may currently be in danger of extinction.

After reviewing the four ecoregions, we proceeded to an evaluation of the 19 populations delineated for management purposes by the IUCN PBSG (Aars et al. 2006, p. 33) plus the Queen Elizabeth Island population created by Amstrup et al. (2007). For fourteen of the PBSG-defined populations, population status is considered stable, increasing, or data deficient, and there is not substantial information indicating that they may currently be in danger of extinction. We eliminated these populations from further consideration. We also eliminated the Queen Elizabeth Island population because there is no current evidence of decline in the population, and because it occurs in the polar basin Convergent ecoregion where sea ice is projected to persist longest into the future (along with the Archipelago ecoregion). Thus, there is not substantial information indicating that this population may currently be in danger of extinction. For the remaining five populations, there is some information indicating actual or projected population declines according to the most recent subpopulation viability analysis conducted by the PBSG (i.e., Southern Beaufort Sea, Norwegian Bay, Western Hudson Bay, Kane Basin, Baffin Bay) (Aars et al. 2006, pp. 34–35). Two of these populations—Norwegian Bay and Kane Basin—occur within the Archipelago ecoregion, and are small both in terms of geographic area included within their boundaries and number of polar bears in the population. Even if these two populations are considered together, the overall geographic area they occupy and overall population size are still small. On this basis we determined that these two populations do not satisfy one portion of the initial test, because there is not substantial information to suggest that these areas are significant portions of the range. In addition, the two populations occur in the Archipelago ecoregion, where sea ice is projected to persist the longest into the future. In addition, available population estimates for these two populations are less reliable because they are older (circa 1998) and are based on limited years and incomplete coverage of sampling. Because of the projected persistence of sea ice in this area throughout the foreseeable future, and the lack of reliable information on population trends, we have determined that there is not substantial information to indicate that these populations are currently in danger of extinction. Having not satisfied either of the two initial tests, we have determined that these two populations do not warrant any further consideration in this analysis.

The relatively larger area and population size of each of the three remaining populations—Southern Beaufort Sea, Western Hudson Bay, Baffin Bay—indicate that they may be significant portions of the range. For these three populations there is information indicating actual or potential population declines according to the most recent subpopulation viability analysis conducted by the PBSG (Baffin Bay) and other recent studies (Regehr et al. 2007a for Western Hudson Bay; Regehr et al. 2007b for Southern Beaufort Sea), as well as projected population declines based on recent modeling exercises (Hunter et al. 2007; Amstrup et al. 2007). Having met these two initial tests, a further evaluation was deemed necessary to determine if these three populations are both significant and endangered (that analysis follows below). Based on our review of the record, we did not find substantial information indicating that any other portions of the polar bear's range might be considered significant and qualify as endangered.

Having identified the five portions of the range that warrant further consideration (two ecoregions and three populations), we then proceeded to determine whether any of those portions are both significant and endangered. We initially discuss our evaluation of the two ecoregions identified above, and then proceed to discuss our evaluation of the three populations identified above.

On an ecoregional level, the most significant results suggesting that the two ecoregions may be endangered comes from the results of Bayesian network modeling (BM) exercises by Amstrup et al. (2007). In particular, the BM exercise results suggest that polar bear populations in the Seasonal Ice and polar basin Divergent ecoregions may be lost by the mid-21st century given rates of sea ice recession projected in the 10-GCM ensemble used by the authors. As previously discussed above under the heading ''Bayesian Network Model'' within Factor A, we believe that this initial effort has several limitations that reduce our confidence in the actual numerical probabilities associated with each outcome of the BM, as opposed to the general direction and magnitude of the projected outcomes. The BM analysis is a preliminary effort that requires additional development (Amstrup et al. 2007, p. 27). The current prototype is based on qualitative input from a single expert, and input from additional polar bear experts is needed to advance the model beyond the alpha prototype stage. There are also uncertainties associated with statistical estimation of various parameters such as the extent of sea ice or size of polar bear populations (Amstrup et al. 2007, p. 23). In addition, the BM needs further refinement to develop variance estimates to go with its outcomes. Because of these uncertainties associated with the complex BM, it is more appropriate to focus on the general direction and magnitude of the projected outcomes rather than the actual numerical probabilities associated with each outcome. Because of these limitations, we have determined that the BM model outcomes are not a sufficient basis, in light of the other available scientific information, to find that threats to polar bears currently warrant a determination of endangered status for the two ecoregions. However, despite these limitations, we also recognize that the BM results are a useful contribution to the overall weight of evidence and likelihood regarding changing sea ice, population stressors, and effects. We believe that the results are consistent with other available scientific information, including results of the CM (see discussion under ''Carrying Capacity Model'' under Factor A), and quantitative evidence of the gradual rate of population decline in three populations within the ecoregions. We further note that, although these Seasonal Ice and polar basin Divergent ecoregions face differential threats, both ecoregions currently are estimated to have large numbers of polar bears, and there is no evidence of any population currently undergoing a precipitous decline. Therefore, we find that the polar bear is not currently in danger of extinction in either the Seasonal Ice ecoregion or the polar basin Divergent ecoregion.

The three populations identified above as actually or potentially declining are the Western Hudson Bay, Southern Beaufort Sea, and Baffin Bay populations. Over an 18-year period, Regehr et al. (2007, p. 2,673) documented a statistically significant decline in the Western Hudson Bay polar bear population of 22 percent. For this period, the mean annual growth rate was 0.986 (with a 95 percent confidence interval of 0.978–0.995), indicative of a gradual population decline. The decline has been attributed primarily to the effects of climate change (earlier break-up of sea ice in the spring), with harvest also playing a role (see discussion of ''Western Hudson Bay'' under Factor A). A reduction in harvest quota in this population (from 54 to 38) for the 2007–2008 harvest season might begin to reduce the effect of harvest; however, we expect continued population declines from earlier and earlier break-up of sea ice and corresponding longer fasting periods of bears on land (Stirling and Parkinson 2006). Nonetheless, we note that the Western Hudson Bay population remains greater than 900 bears, and that reproduction and recruitment are still occurring in the population (Regehr et al. 2006). Because the current rate of decline for the Western Hudson Bay population is gradual rather than precipitous, reproduction and recruitment are still occurring, and the current size of the population remains reasonably large, we have determined that the population is not currently in danger of extinction, but is likely to become so within the foreseeable future.

The apparent decline in the Southern Beaufort Sea population, documented over a 20-year period, has not been demonstrated to be statistically significant. However, available information indicates that there will be a statistically-significant population decline in the coming decades. Hunter et al. (2007) conducted a sophisticated demographic analysis of the Southern Beaufort Sea population using both deterministic and stochastic demographic models, and parameters estimated from capture-recapture data collected between 2001 and 2006. The authors focused on measures of long-term population growth rate and on projections of population size over the next 100 years. Taking the average observed frequency of bad sea ice years (0.21), they predicted a gradual population decline of about one percent per year (similar to the rate of decline observed in Western Hudson Bay), and an extinction probability of around 35–40 percent at year 45 (see Figure 14 of Hunter et al. 2007). However, the precision of vital rates used in the analysis (estimated by Regehr et al. (2007b, pp. 17–18)) was subject to large degrees of sampling and model selection uncertainty (Hunter et al. 2007, p. 6), the length of the study period (5 years) was short, and the spatial resolution of the GCMs at the scale of the southern Beaufort Sea is less reliable than at the scale of the entire range of the polar bear. These sources of uncertainty lead us to have greater confidence in the general direction and magnitude of the trend of the model outcomes in Hunter et al. (2007) than in the specific percentages associated with each outcome. In addition, we note that the Southern Beaufort Sea population remains fairly large, that reproduction and recruitment is still occurring in the population, and that changes in the sea ice have not yet been associated with changes in the size of the population (Regehr et al. 2007, p. 2). These results all indicate that this population is not currently in danger of extinction but is likely to become so in the foreseeable future.

As regards Baffin Bay, the recent population estimates of 2,074 bears in 1998 and 1,546 bears in 2004 have limited reliability because of the population survey methods used. There is clear evidence that the population has been overharvested (Aars et al. 2006). Although the PBSG subpopulation viability analysis projects a declining trend, most likely as a result of overharverst, there is no reliable estimate of population trend based on valid population survey results. In recent years, some efforts have been made to reduce harvest of the Baffin Bay population. Greenland put a quota system in place for Baffin Bay in 2006; its current quota is 75 bears. Stirling and Parkinson (2006, p. 268) have documented earlier spring sea ice break-up dates in Baffin Bay since 1978 (i.e., ice breakup has been occurring 6 to 7 days earlier per decade since late 1978). Earlier breakup is likely to lead to longer periods of fasting onshore, with concomitant effects on bear body condition as documented in other populations. However, there are no data on body condition of polar bears or the survival of cubs or subadults from Baffin Bay (Stirling and Parkinson 2006, p. 269) that would allow an analysis of the relationship between changes in body condition and changes in sea ice habitat. In terms of projecting sea ice trends in Baffin Bay in the foreseeable future, Overland and Wang (2007) evaluated a suite of the 12 most applicable GCMs, and found that, ''according to these models, Baffin Bay does not show significant ice loss by 2050.'' These results are at apparent odds with observed sea ice trends, which further complicates projecting future effects of sea ice loss on polar bears. Without statistically reliable indices of declines in survival, body condition indices, or population size, and with evidence of earlier spring breakup dates but equivocal information on future sea ice conditions, we cannot conclude that the species is currently in danger of extinction in Baffin Bay, but can conclude it is likely to become so in the foreseeable future.

Therefore, on the basis of the discussion presented in the previous three paragraphs, we find that the polar bear populations of Western Hudson Bay, Southern Beaufort Sea, and Baffin Bay are not currently in danger of extinction, but are likely to become so in the foreseeable future.

As a result, while the best scientific data available allows us to make a determination as to the rangewide status of the polar bear, we have determined that when analyzed on a population or even an ecoregion level, the available data show that there are no significant portions of the range in which the species is currently in danger of extinction. Because we find that the polar bear is not endangered in the five portions of the range that we previously determined to warrant further consideration (two ecoregions and three populations), we need not address the question of significance for those five portions.

Critical Habitat

Critical habitat is defined in section 3(5) of the Act as: (i) the specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) that may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by a species at the time it is listed, upon a determination that such areas are essential for the conservation of the species. ''Conservation'' is defined in section 3(3) of the Act as meaning the use of all methods and procedures needed to bring the species to the point at which listing under the Act is no longer necessary. The primary regulatory effect of critical habitat is the requirement, under section 7(a)(2) of the Act, that Federal agencies shall ensure that any action they authorize, fund, or carry out is not likely to result in the destruction or adverse modification of designated critical habitat.

Section 4(a)(3) of the Act and implementing regulations (50 CFR 424.12) require that, to the maximum extent prudent and determinable, we designate critical habitat at the time a species is determined to be endangered or threatened. Critical habitat may only be designated within the jurisdiction of the United States, and may not be designated for jurisdictions outside of the United States (50 CFR 424(h)). Our regulations (50 CFR 424.12(a)(1)) state that designation of critical habitat is not prudent when one or both of the following situations exist: (1) the species is threatened by taking or other activity and the identification of critical habitat can be expected to increase the degree of threat to the species; or (2) such designation of critical habitat would not be beneficial to the species. Our regulations (50 CFR 424.12(a)(2)) further state that critical habitat is not determinable when one or both of the following situations exist: (1) Information sufficient to perform required analysis of the impacts of the designation is lacking; or (2) the biological needs of the species are not sufficiently well known to permit identification of an area as critical habitat.

Delineation of critical habitat requires, within the geographical area occupied by the polar bear, identification of the physical and biological features essential to the conservation of the species. In general terms, physical and biological features essential to the conservation of the polar bear may include (1) annual and perennial marine sea ice habitats that serve as a platform for hunting, feeding, traveling, resting, and to a limited extent, for denning, and (2) terrestrial habitats used by polar bears for denning and reproduction for the recruitment of new animals into the population, as well as for seasonal use in traveling or resting. The most important polar bear life functions that occur in these habitats are feeding (obtaining adequate nutrition) and reproduction. These habitats may be influenced by several factors and the interaction among these factors, including: (1) water depth; (2) atmospheric and oceanic currents or events; (3) climatologic phenomena such as temperature, winds, precipitation and snowfall; (4) proximity to the continental shelf; (5) topographic relief (which influences accumulation of snow for denning); (6) presence of undisturbed habitats; and (7) secure resting areas that provide refuge from extreme weather or other bears or humans. Unlike some other marine mammal species, polar bears generally do not occur at high-density focal areas such as rookeries and haulout sites. However, certain terrestrial areas have a history of higher use, such as core denning areas, or are experiencing an increasing tendancy of use for resting, such as coastal areas during the fall open water phase for which polar bear use has been increasing in duration for additional and expanded areas. During the winter period, when energetic demands are the greatest, nearshore lead systems (linear openings or cracks in the sea ice) and emphemeral or recurrent polynyas (areas of open sea surrounded by sea ice) are areas of importance for seals and, correspondingly for polar bears that hunt seals for nutrition. During the spring period, nearshore lead systems continue to be important habitat for bears for hunting seals and feeding. Also the shorefast ice zone where ringed seals construct subnivean birth lairs for pupping is an important feeding habitat during this season. In northern Alaska, while denning habitat is more diffuse than in other areas where core, high-density denning has been identified, certain areas such as barrier islands, river bank drainages, much of the North Slope coastal plain (including the Arctic NWR), and coastal bluffs that occur at the interface of mainland and marine habitat receive proportionally greater use for denning than other areas. Habitat suitable for the accumulation of snow and use for denning has been delineated on the North Slope.

While information regarding important polar bear life functions and habitats associated with these functions has expanded greatly in Alaska during the past 20 years, the identification of specific physical and biological features and specific geographic areas for consideration as critical habitat is complicated, and the future values of these habitats may change in a rapidly changing environment. Arctic sea ice provides a platform for critical life-history functions, including hunting, feeding, travel, and nuturing cubs. That habitat is projected to be significantly reduced within the next 45 years, and some models project complete absence of sea ice during summer months in shorter timeframes.

A careful assessment of the designation of marine areas as critical habitat will require additional time to fully evaluate physical and biological features essential to the conservation of the polar bear and how those features are likely to change over the foreseeable future. In addition, near-shore and terrestrial habitats that may qualify for designation as critical habitat will require a similar thorough assessment and evaluation in light of projected climate change and other threats. Additionally, we have not gathered sufficient economic and other data on the impacts of a critical habitat designation. These factors must be considered as part of the designation procedure. Thus, we find that critical habitat is not determinable at this time.

Available Conservation Measures

The Service will continue to work with other countries that have jurisdiction in the Arctic, the IUCN/SSC Polar Bear Specialist Group, U.S. government agencies (e.g., NASA, NOAA), species experts, Native organizations, and other parties as appropriate to consider new information as it becomes available to track the status of polar bear populations over time, to develop a circumpolar monitoring program for the species, and to develop management actions to conserve the polar bear. Using current ongoing and future monitoring programs for the 19 IUCN-designated populations we will continue to evaluate the status of the species in relation to its listing under the Act. In addition, status of domestic populations will continue to be evaluated as required under the MMPA.

Conservation measures provided to species listed as endangered or threatened under the Act include recognition of the status, increased priority for research and conservation funding, recovery actions, requirements for Federal protection, and prohibitions against certain activities. Recognition through listing results in public awareness and conservation actions by Federal, State, and local agencies, private organizations, and individuals. The Act provides for possible land acquisition and cooperation with the States, and for conservation actions to be carried out for listed species.

The listing of the polar bear will lead to the development of a recovery plan for this species in Alaska. The recovery plan will bring together international, Federal, State, and local agencies, and private efforts, for the conservation of this species. A recovery plan for Alaska will establish a framework for interested parties to coordinate activities and to cooperate with each other in conservation efforts. The plan will set recovery priorities, identify responsibilities, and estimate the costs of the tasks necessary to accomplish the priorities. Under section 6 of the Act, we would be able to grant funds to the State of Alaska for management actions promoting the conservation of the polar bear.

Additionally, the Service will pursue conservation strategies among all countries that share management of polar bears. The existing multilateral agreement provides an international framework to pursue such strategies, and the outcome of the June 2007 meeting of polar bear range countries (held at the National Conservation Training Center in West Virginia) clearly documents the shared interest by all to pursue such an effort. Range-wide strategies will be particularly important as the sea ice habitat likely to persist the longest is not in U.S. jurisdiction and collaborative efforts to support ongoing research and management actions for purposes of restoring or supplementing the most dramatically affected population will be important. The PBSG is recognized as the technical advisor for the 1973 Agreement for the Conservation of Polar Bears and provides recommendations to each of the range states on conservation and management; recommendations from this group will be sought throughout the entire process.

Section 7(a) of the Act, as amended, requires Federal agencies to evaluate their actions with respect to any species that is listed as endangered or threatened and with respect to its critical habitat, if any is designated. Regulations implementing this interagency cooperation provision of the Act are codified at 50 CFR part 402. For threatened species such as the polar bear, section 7(a)(2) of the Act requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of the species. If a Federal action may affect a polar bear, the responsible Federal agency must consult with us under the provisions of section 7(a)(2) of the Act.

Several Federal agencies are expected to have involvement under section 7 of the Act regarding the polar bear. The National Marine Fisheries Service may become involved, such as if a joint rulemaking for the incidental take of marine mammals is undertaken. The EPA may become involved through its permitting authority under the Clean Water Act and Clean Air Act for activities conducted in Alaska. The U.S Army Corps of Engineers may become involved through its responsibilities and permitting authority under section 404 of the Clean Water Act and through future development of harbor projects. The MMS may become involved through administering their programs directed toward offshore oil and gas development, and the BLM for onshore activities in NPRA. The Denali Commission may be involved through its potential funding of fuel and power generation projects. The U.S. Coast Guard may become involved through their deployment of icebreakers in the Arctic Ocean.

Much of Alaska oil and gas development occurs within the range of polar bears, and the Service has worked effectively with the industry for a number of years to minimize impacts to polar bears through implementation of the incidental take program authorized under the MMPA. Under the MMPA, incidental take cannot be authorized unless the Service finds that any take that is reasonably likely to occur will have no more than a negligible impact on the species. Incidental take authorization has been in place for the Beaufort Sea region since 1993 and for the Chukchi Sea in 2006 and 2007. New MMPA incidental take authorization covering oil and gas exploration activities in the Chukchi Sea was proposed in June 2007. Mitigation measures required under these authorizations minimize potential impacts to polar bears and ensure that any take remains at the negligible level; these measures are implemented on a case-by-case basis through Letters of Authorization (LOAs) under the MMPA. Because the MMPA negligible impact standard is a tighter management standard than ensuring that an activity is not likely to jeopardize the continued existence of the species under section 7 of the Act, we do not anticipate that any entity holding incidental take authorization for polar bears under the MMPA and in compliance with all mitigation measures under that authorization will be required to implement further measures under the section 7 consultation process.

Regulatory Implications for Consultations under Section 7 of the Act

When a species is listed as threatened under the Act, section 7(a)(2) provides that Federal agencies must insure that any actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of designated critical habitat. Furthermore, under the authority of section 4(d), the Secretary shall establish regulatory provisions on the take of threatened species that are ''necessary and advisable to provide for the conservation of the species'' (16 U.S.C. 1533(d)).

The coverage of the section 9 taking prohibition is much broader than a simple prohibition against killing an individual of the species. Section 3(19) of the Act defines the term ''take'' as ''* * * harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct.'' Federal regulations promulgated by the Service (50 CFR 17.3) define the terms ''harm'' and ''harass'' as:

Harass in the definition of ''take'' in the Act means an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. This definition, when applied to captive wildlife does not include generally accepted: (1) animal husbandry practices that meet or exceed the minimum standards for facilities and care under the Animal Welfare Act, (2) breeding procedures, or (3) provisions of veterinary care for confining, tranquilizing, or anesthetizing, when such practices, procedures, or provisions are not likely to result in injury to the wildlife.

Harm in the definition of ''take'' in the Act means an act that actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behaviorial patterns, including breeding, feeding, or sheltering.

Certain levels of incidental take may be authorized through provisions under section 7(b)(4) and (o)(2) (incidental take statements for Federal agency actions) and section 10(a)(1)(B) (incidental take permits).

In making a determination to authorize incidental take under section 7 or section 10, the Service must assess the effects of the proposed action to evaluate the potential negative and positive impacts that are expected to occur as a result of the action. Under Section 7, this would be done through a consultation between the Service and the Federal agency on a specific proposed agency action. Section 7 consultation regulations generally limit the Service's review of the effects of the proposed action to the direct and indirect effects of the action and any activities that are interrelated or interdependent with the proposed action. ''Indirect'' effects are caused by the proposed action, later in time, and are ''reasonably certain to occur.'' Essentially, the Service evaluates those effects that would not occur ''but for'' the action under consultation and that are also reasonably certain to occur. Cumulative effects, which are the effects of future non-Federal actions that are also reasonably certain to occur within the action area of the proposed action, must also be taken into consideration. The direct, indirect, and cumulative effects are then analyzed along with the status of the species and the environmental baseline to determine whether the action under consultation is likely to reduce appreciably both the survival and recovery of the listed species or result in the destruction or adverse modification of critical habitat. If the Service determines that the action is not likely to jeopardize the continued existence of a listed species, a ''no jeopardy'' opinion will be issued, along with an incidental take statement. The purpose of the incidental take statement is to identify the amount or extent of take that is reasonably likely to result from the proposed action and to minimize the impact of any take through reasonable and prudent measures (RPMs). The regulations require, however, that any RPM's be only a ''minor change'' to the proposed action. If the Federal agency and any applicant comply with the terms and conditions of the incidental take statement, then section 7(o)(2) of the Act provides an exception to the take prohibition.

The 9th Circuit Court of Appeals has determined that the Service cannot use the consultation process or the issuance of an Incidental Take Statement as a form of regulation limiting what are otherwise legal activities by action agencies, if no incidental take is reasonably likely to occur as a result of the Federal action (*Arizona Cattle Growers' Association* v. *U.S. Fish and Wildlife Service,* 273 F.3d 1229 (9th Cir. 2001)). In that case, the court reviewed several biological opinions that were the result of consultations on numerous grazing permits. The 9th Circuit analyzed the Service's discussion of effects and the incidental take statements for several specific grazing allotments. The court found that the Service, in some allotments, assumed there would be ''take'' without explaining how the agency action (in this case, cattle grazing) would cause the take of specific individuals of the listed species. Further, for other permits the court did not see evidence or argument to demonstrate how cattle grazing in one part of the permit area would take listed species in another part of that permit area. The court concluded that the Service must ''connect the dots'' between its evaluation of effects of the action and its assessment of take. That is, the Service cannot simply speculate that take may occur. The Service must first articulate the causal connection between the effects of the action under consultation and the anticipated take. It must then demonstrate that the take is reasonably likely to occur.

The significant cause of the decline of the polar bear, and thus the basis for this action to list it as a threatened species, is the loss of arctic sea ice that is expected to continue to occur over the next 45 years. The best scientific information available to us today, however, has not established a causal connection between specific sources and locations of emissions to specific impacts posed to polar bears or their habitat.

Some commenters to the proposed rule suggested that the Service should require other agencies (e.g., the Environmental Protection Agency) to regulate emissions from all sources, including automobile and power plants. The best scientific information available today would neither allow nor require the Service to take such action.

First, the primary substantive mandate of section 7(a)(2)—the duty to avoid likely jeopardy to an endangered or threatened species—rests with the Federal action agency and not with the Service. The Service consults with the Federal action agency on proposed Federal actions that may affect an endangered or threatened species, but its consultative role under section 7 does not allow for encroachment on the Federal action agency's jurisdiction or policy-making role under the statutes it administers.

Second, the Federal action agency decides when to initiate formal consultation on a particular proposed action, and it provides the project description to the Service. The Service may request the Federal action agency to initiate formal consultation for a particular proposed action, but it cannot compel the agency to consult, regardless of the type of action or the magnitude of its projected effects.

Recognizing the primacy of the Federal action agency's role in determining how to conform its proposed actions to the requirements of section 7, and taking into account the requirement to examine the ''effects of the action'' through the formal consultation process, the Service does not anticipate that the listing of the polar bear as a threatened species will result in the initiation of new section 7 consultations on proposed permits or licenses for facilities that would emit GHGs in the conterminous 48 States. Formal consultation is required for proposed Federal actions that ''may affect'' a listed species, which requires an examination of whether the direct and indirect effects of a particular action meet this regulatory threshold. GHGs that are projected to be emitted from a facility would not, in and of themselves, trigger formal section 7 consultation for a particular licensure action unless it is established that such emissions constitute an ''indirect effect'' of the proposed action. To constitute an ''indirect effect,'' the impact to the species must be later in time, must be caused by the proposed action, and must be ''reasonably certain to occur'' (50 CFR 402.02 (definition of ''effects of the action'')). As stated above, the best scientific data available today are not sufficient to draw a causal connection between GHG emissions from a facility in the conterminous 48 States to effects posed to polar bears or their habitat in the Arctic, nor are there sufficient data to establish that such impacts are ''reasonably certain to occur'' to polar bears. Without sufficient data to establish the required causal connection—to the level of ''reasonable certainty''—between a new facility's GHG emissions and impacts to polar bears, section 7 consultation would not be required to address impacts to polar bears.

A question has also been raised regarding the possible application of section 7 to effects posed to polar bears that may arise from oil and gas development activities conducted on Alaska's North Slope or in the Chukchi Sea. It is clear that any direct effects from oil and gas development operations, such as drilling activities, vehicular traffic to and from drill sites, and other on-site operational support activities, that pose adverse effects to polar bears would need to be evaluated through the section 7 consultation process. It is also clear that any ''indirect effects'' from oil and gas development activities, such as impacts from the spread of contaminants (accidental oil spills, or the unintentional release of other contaminants) that result from the oil and gas development activities and that are ''reasonably certain to occur,'' that flow from the ''footprint'' of the action and spread into habitat areas used by polar bears would also need to be evaluated through the section 7 consultation process.

However, the future effects of any emissions that may result from the consumption of petroleum products refined from crude oil pumped from a particular North Slope drilling site would not constitute ''indirect effects'' and, therefore, would not be considered during the section 7 consultation process. The best scientific data available to the Service today does not provide the degree of precision needed to draw a causal connection between the oil produced at a particular drilling site, the GHG emissions that may eventually result from the consumption of the refined petroleum product, and a particular impact to a polar bear or its habitat. At present there is a lack of scientific or technical knowledge to determine a relationship between an oil and gas leasing, development, or production activity and the effects of the ultimate consumption of petroleum products (GHG emissions). There are discernible limits to the establishment of a causal connection, such as uncertainties regarding the productive yield from an oil and gas field; whether any or all of such production will be refined for plastics or other products that will not be burned; what mix of vehicles or factories might use the product; and what mitigation measures would offset consumption. Furthermore, there is no traceable nexus between the ultimate consumption of the petroleum product and any particular effect to a polar bear or its habitat. In short, the emissions effects resulting from the consumption of petroleum derived from North Slope or Chukchi Sea oil fields would not constitute an ''indirect effect'' of any federal agency action to approve the development of that field.

Other Provisions of the Act

Section 9 of the Act, except as provided in sections 6(g)(2) and 10 of the Act, prohibits take (within the United States and on the high seas) and import into or export out of the United States of endangered species. The Act defines take to mean harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. However, the Act also provides for the authorization of take and exceptions to the take prohibitions. Take of endangered wildlife species by non-Federal property owners can be permitted through the process set forth in section 10 of the Act. The Service has issued regulations (50 CFR 17.31) that generally afford to fish and wildlife species listed as threatened the prohibitions that section 9 of the Act establishes with respect to species listed as endangered.

The Service may also develop a special rule specifically tailored to the conservation needs of a threatened species instead of applying the general threatened species regulations. In today's **Federal Register** we have published a special rule for the polar bear that generally adopts existing conservation regulatory requirements under the MMPA and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as the appropriate regulatory provisions for this threatened species.

Section 10(e) of the Act provides an exemption for any Indian, Aleut, or Eskimo who is an Alaskan Native and who resides in Alaska to take a threatened or endangered species if such taking is primarily for subsistence purposes and the taking is not accomplished in a wasteful manner. Non-native permanent residents of an Alaska native village are also covered by this exemption, but since such persons are not covered by the similar exemption under the MMPA, take of polar bears for subsistence purposes by non-native permanent residents of an Alaskan native village would not be lawful. While the collaborative co-management mechanisms to institute sustainable harvest levels are in place, the challenges of managing harvest for declining populations are new and will require extensive dialogue with the Alaska Native hunting community and their leadership organizations. Development of risk assessment models that describe the probability and effect of a range of harvest levels interrelated to demographic population life tables are needed. Any future consideration of harvest regulation will be done with the full involvement of the subsistence community through the Alaska Nanuuq Commission and North Slope Borough and should build upon the co-management approach to harvest management that we have developed through the Inupiat-Inuvialuit Agreement and which we will work to expand through the United States-Russia Bilateral Agreement. The Inupiat-Inuvialuit Agreement is a voluntary harvest agreement between the native peoples of Alaska and Canada who share access to the Southern Beaufort Sea polar bear population. The agreement includes harvest restrictions, including a quota. A 10-year review of the agreement published in 2002 revealed high compliance rates and support for the agreement. The United States-Russia Bilateral Agreement calls for the active involvement of the United States, Russian Federation, and native people of both countries in managing subsistence harvest. The Service is currently developing recommendations for the Bilateral Commission that will direct research and establish sustainable and enforceable harvest limits needed to address current potential population declines due to overharvest of the stock. Development of population estimates and harvest monitoring protocols must be developed in a cooperative bilateral manner. The Alaska Nanuuq Commission, the North Slope Borough, USGS, and the Alaska Department of Fish and Game (ADF&G) have indicated support for these future efforts and wish to be a part of implementation of this agreement.

Under the section 10(e) exemption, nonedible byproducts of species taken pursuant to this section may be sold in interstate commerce when made into authentic native articles of handicrafts and clothing. It is illegal to possess, sell, deliver, carry, transport, or ship any such wildlife that has been taken illegally. Further, it is illegal for any person to commit, to solicit another person to commit, or cause to be committed, any of these acts. Certain exceptions to the prohibitions apply to our agents and State conservation agencies. See our special rule published in today's edition of the **Federal Register** that would align allowable activities with authentic native articles of handicrafts and clothing made from polar bear parts with existing provisions under the MMPA.

Under the general threatened species regulations at 50 CFR 17.32, permits to carry out otherwise prohibited activities may be issued for particular purposes, including scientific purposes, enhancement of the propagation or survival of the species, zoological exhibitions, educational purposes, incidental take in the course of otherwise lawful activities, or special purposes consistent with the purposes of the Act. However, see today's **Federal Register** for our rule that presents provisions specifically tailored to the conservation needs of the polar bear that generally adopts provisions of the MMPA and CITES. Requests for copies of the regulations that apply to the polar bear and inquiries about prohibitions and permits may be addressed to the Endangered Species Coordinator, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

It is our policy, published in the **Federal Register** on July 1, 1994 (59 FR 34272), to identify, to the maximum extent practicable at the time a species is listed, those activities that would or would not likely constitute a violation of regulations at 50 CFR 17.31. The intent of this policy is to increase public awareness of the effects of the listing on proposed and ongoing activities within a species' range.

For the polar bear we have not yet determined which, if any, provisions under section 9 would apply, provided these activities are carried out in accordance with existing regulations and permit requirements. Some permissible uses or actions have been identified below. Note that the special rule for polar bears (see the special rule published in today's **Federal Register**) affects certain activities otherwise regulated under the Act.

(1) Possession and noncommercial interstate transport of authentic native articles of handicrafts and clothing made from polar bears taken for subsistence purposes in a nonwasteful manner by Alaska Natives;

(2) Any action authorized, funded, or carried out by a Federal agency that may affect the polar bear, when the action is conducted in accordance with the terms and conditions of authorizations under section 101(a)(5) of the MMPA and the terms and conditions of an incidental take statement issued by us under section 7 of the Act;

(3) Any action carried out for scientific purposes, to enhance the propagation or survival of polar bears, for zoological exhibitions, for educational purposes, or for special purposes consistent with the purposes of the Act that is conducted in accordance with the conditions of a permit issued by us under 50 CFR 17.32; and

(4) Any incidental take of polar bears resulting from an otherwise lawful activity conducted in accordance with the conditions of an incidental take permit issued under 50 CFR 17.32. Non-Federal applicants may design a habitat conservation plan (HCP) for the species and apply for an incidental take permit. HCPs may be developed for listed species and are designed to minimize and mitigate impacts to the species to the greatest extent practicable. See also requirements for incidental take of a polar bear under (3) above.

We believe the following activities could potentially result in a violation of the special rule for polar bears; however, possible violations are not limited to these actions alone:

(1) Unauthorized killing, collecting, handling, or harassing of individual polar bears;

(2) Possessing, selling, transporting, or shipping illegally taken polar bears or their parts;

(3) Unauthorized destruction or alteration of denning, feeding, or resting habitats, or of habitats used for travel, that actually kills or injures individual polar bears by significantly impairing their essential behavioral patterns, including breeding, feeding, or sheltering; and

(4) Discharge or dumping of toxic chemicals, silt, or other pollutants (i.e., sewage, oil, pesticides, and gasoline) into the marine environment that actually kills or injures individual polar bears by significantly impairing their essential behavioral patterns, including breeding, feeding, or sheltering.

We will review other activities not identified above on a case-by-case basis to determine whether they may be likely to result in a violation of 50 CFR 17.31. We do not consider these lists to be exhaustive and provide them as information to the public. You may direct questions regarding whether specific activities may constitute a violation of the Act to the Field Supervisor, U.S. Fish and Wildlife Service, Fairbanks Fish and Wildlife Field Office, 101 12th Avenue, Box 110, Fairbanks, Alaska 99701.

Regarding ongoing importation of sport-hunted polar bear trophies from Canada, under sections 101(a)(3)(B) and 102(b) of the MMPA, it is unlawful to import into the United States any marine mammal that has been designated as a depleted species or stock unless the importation is for the purpose of scientific research or enhancement of the survival or recovery of the species. Under the MMPA, the polar bear will be a depleted species as of the effective date of the rule. Under sections 102(b) and 101(a)(3)(B) of the MMPA therefore, as a depleted species, polar bears and their parts cannot be imported into the United States except for scientific research or enhancement. Therefore, sport-hunted polar bear trophies from Canada cannot be imported after the effective date of this listing rule. Nothing in the special rule for polar bears published in today's **Federal Register** affects these provisions under the MMPA.

Future Opportunities

Earlier in the preamble to this final rule, we determined that polar bear habitat—principally sea ice—is declining throughout the species' range, that this decline is expected to continue for the foreseeable future, and that this loss threatens the species throughout all of its range. We also determined that there are no known regulatory mechanisms in place, and none that we are aware of that could be put in place, at the national or international level, that directly and effectively address the rangewide loss of sea ice habitat within the foreseeable future. We also acknowledged that existing regulatory mechanisms to address anthropogenic causes of climate change are not expected to be effective in counteracting the worldwide growth of GHG emissions within the foreseeable future, as defined in this rule.

Fully aware of the current situation and projected trends within the foreseeable future, and recognizing the great challenges ahead of us, we remain optimistic that the future can be a bright one for the polar bear. The root causes and consequences of the loss of Arctic sea ice extend well beyond the five countries that border the Arctic and comprise the range of the polar bear, and will extend beyond the foreseeable future as determined in this rule. This is a global issue and will be resolved as the global community comes together and acts in concert to achieve that resolution. Polar bear range countries are working, individually and cooperatively, to conserve polar bears and alleviate stressors on polar bear populations that may exacerbate the threats posed by sea ice loss. The global community is also beginning to act more cohesively, by developing national and international regulatory mechanisms and implementing measures to mitigate the anthropogenic causes of climate change.

In December 2007, the United States joined other Nations at the United Nations (UN) Climate Change Conference in Bali to launch a comprehensive ''roadmap'' for global climate negotiations. The Bali Action Plan is a critical step in moving the UN negotiation process forward toward a comprehensive and effective post-2012 arrangement by 2009. (Please note that measures in the Bali Action Plan, in and of themselves, were not considered as offsetting or otherwise dimishing the risk of sea ice loss in our determination of the appropriate listing classification for the polar bear.) In December 2007, President Bush signed the Energy Independence and Security Act of 2007, which responded to his ''Twenty in Ten'' challenge in his 2006 State of the Union Address to improve vehicle fuel economy and increase alternative fuels. This bill will help improve energy efficiency and cut GHG emissions.

With the world community acting in concert, we are confident the future of the polar bear can be secured.

National Environmental Policy Act

We have determined that we do not need to prepare an environmental assessment or an environmental impact statement as defined under the authority of the National Environmental Policy Act of 1969, in connection with regulations adopted under section 4(a) of the Act. We published a notice outlining our reasons for this determination in the **Federal Register** on October 25, 1983 (48 FR 49244).

Government-to-Government Relationship with Tribes

In accordance with the President's memorandum of April 29, 1994, ''Government-to-Government Relations with Native American Tribal Governments'' (59 FR 22951), Executive Order 13175, Secretarial Order 3225, and the Department of Interior's manual at 512 DM 2, we readily acknowledge our responsibility to communicate meaningfully with recognized Federal Tribes on a government-to-government basis. Since 1997, we have signed cooperative agreements annually with The Alaska Nanuuq Commission (Commission) to fund their activities. The Commission was established in 1994 to represent the interests of subsistence users and Alaska Native polar bear hunters when working with the Federal government on the conservation of polar bears in Alaska. We attended Commission board meetings during the preparation of the proposed rule and subsequent public comment period, regularly briefing the board of commissioners and staff on relevant issues. We also requested the Commission to act as a peer reviewer of the *Polar Bear Status Review* (Schliebe et al. 2006a) and the proposed rule to list the species throughout its range (72 FR 1064). In addition to working closely with the Commission, we sent copies of the proposed rule (72 FR 1064) to, or contacted directly, 46 Alaska Native Tribal Councils and specifically requested their comments on the proposed listing action. As such, we believe that we have and will continue to coordinate with affected Tribal entities in compliance with the applicable Executive and Secretarial Orders.

References Cited

A complete list of all references cited in this rule is available upon request. You may request a list of all references cited in this document from the Supervisor, Marine Mammals Management Office (see **ADDRESSES** section).

Authors

The primary authors of this rule are Scott Schliebe, Marine Mammals Management Office (see **ADDRESSES** section), and Kurt Johnson, PhD, Branch of Listing, Endangered Species Program, Arlington, VA.

List of Subjects in 50 CFR Part 17

Endangered and threatened species, Exports, Imports, Reporting and recordkeeping requirements, Transportation.

Final Regulation Promulgation

■ Accordingly, part 17, subchapter B of chapter I, title 50 of the Code of Federal Regulations, is amended as set forth below:

PART 17—[AMENDED]

■ 1. The authority citation for part 17 continues to read as follows:

Authority: 16 U.S.C. 1361–1407; 16 U.S.C. 1531–1544; 16 U.S.C. 4201–4245; Pub. L. 99–625, 100 Stat. 3500; unless otherwise noted.

■ 2. Amend § 17.11(h) by adding an entry for ''Bear, polar'' in alphabetical order under MAMMALS, to the List of Endangered and Threatened Wildlife to read as follows:

§ 17.11 Endangered and threatened wildlife.

* * * * *

(h) * * *

Species		Historic Range	Vertebrate population where endangered or threatened	Status	When listed	Critical habitat	Special rules
Common name	Scientific name						
MAMMALS							
*	*	*	*	*	*	*	
Bear, polar	*Ursus maritimus*	U.S.A. (AK), Canada, Russia, Denmark (Greenland), Norway.	Entire	T	....	NA	NA
*	*	*	*	*	*	*	

Dated: May 14, 2008.

Dirk Kempthorne,

Secretary of the Interior.

[FR Doc. E8–11105 Filed 5–14–08; 3:15 pm]

BILLING CODE 4310–55–P

Acc. No. 0581 *Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea-Level Rise* can be viewed on the docket:
http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0582 *The Potential Energy and GHG Implications of Plug-in Hybrid Vehicles: A Scenario Analysis* can be viewed on the docket: http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0583 *Stern Review on the Economics of Climate Change* can be viewed on the docket: http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

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Global Climate Projections

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This chapter should be cited as:

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Table of Contents

Supplementary Material

The following Supplementary Material is available on CD-ROM and in on-line versions of this report.

Supplementary Figures S10.1 to S10.4

Figures Showing Individual Model Results for Different Climate Variables

Executive Summary

The future climate change results assessed in this chapter are based on a hierarchy of models, ranging from Atmosphere-Ocean General Circulation Models (AOGCMs) and Earth System Models of Intermediate Complexity (EMICs) to Simple Climate Models (SCMs). These models are forced with concentrations of greenhouse gases and other constituents derived from various emissions scenarios ranging from non-mitigation scenarios to idealised long-term scenarios. In general, we assess non-mitigated projections of future climate change at scales from global to hundreds of kilometres. Further assessments of regional and local climate changes are provided in Chapter 11. Due to an unprecedented, joint effort by many modelling groups worldwide, climate change projections are now based on multi-model means, differences between models can be assessed quantitatively and in some instances, estimates of the probability of change of important climate system parameters complement expert judgement. New results corroborate those given in the Third Assessment Report (TAR). Continued greenhouse gas emissions at or above current rates will cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century.

Mean Temperature

All models assessed here, for all the non-mitigation scenarios considered, project increases in global mean surface air temperature (SAT) continuing over the 21st century, driven mainly by increases in anthropogenic greenhouse gas concentrations, with the warming proportional to the associated radiative forcing. There is close agreement of globally averaged SAT multi-model mean warming for the early 21st century for concentrations derived from the three non-mitigated IPCC Special Report on Emission Scenarios (SRES: B1, A1B and A2) scenarios (including only anthropogenic forcing) run by the AOGCMs (warming averaged for 2011 to 2030 compared to 1980 to 1999 is between +0.64°C and +0.69°C, with a range of only 0.05°C). Thus, this warming rate is affected little by different scenario assumptions or different model sensitivities, and is consistent with that observed for the past few decades (see Chapter 3). Possible future variations in natural forcings (e.g., a large volcanic eruption) could change those values somewhat, but about half of the early 21st-century warming is committed in the sense that it would occur even if atmospheric concentrations were held fixed at year 2000 values. By mid-century (2046–2065), the choice of scenario becomes more important for the magnitude of multi-model globally averaged SAT warming, with values of +1.3°C, +1.8°C and +1.7°C from the AOGCMs for B1, A1B and A2, respectively. About a third of that warming is projected to be due to climate change that is already committed. By late century (2090–2099), differences between scenarios are large, and only about 20% of that warming arises from climate change that is already committed.

An assessment based on AOGCM projections, probabilistic methods, EMICs, a simple model tuned to the AOGCM responses, as well as coupled climate carbon cycle models, suggests that for non-mitigation scenarios, the future increase in global mean SAT is *likely* to fall within –40 to +60% of the multi-model AOGCM mean warming simulated for a given scenario. The greater uncertainty at higher values results in part from uncertainties in the carbon cycle feedbacks. The multi-model mean SAT warming and associated uncertainty ranges for 2090 to 2099 relative to 1980 to 1999 are B1: +1.8°C (1.1°C to 2.9°C), B2: +2.4°C (1.4°C to 3.8°C), A1B: +2.8°C (1.7°C to 4.4°C), A1T: 2.4°C (1.4°C to 3.8°C), A2: +3.4°C (2.0°C to 5.4°C) and A1FI: +4.0°C (2.4°C to 6.4°C). It is not appropriate to compare the lowest and highest values across these ranges against the single range given in the TAR, because the TAR range resulted only from projections using an SCM and covered all SRES scenarios, whereas here a number of different and independent modelling approaches are combined to estimate ranges for the six illustrative scenarios separately. Additionally, in contrast to the TAR, carbon cycle uncertainties are now included in these ranges. These uncertainty ranges include only anthropogenically forced changes.

Geographical patterns of projected SAT warming show greatest temperature increases over land (roughly twice the global average temperature increase) and at high northern latitudes, and less warming over the southern oceans and North Atlantic, consistent with observations during the latter part of the 20th century (see Chapter 3). The pattern of zonal mean warming in the atmosphere, with a maximum in the upper tropical troposphere and cooling throughout the stratosphere, is notable already early in the 21st century, while zonal mean warming in the ocean progresses from near the surface and in the northern mid-latitudes early in the 21st century, to gradual penetration downward during the course of the 21st century.

An expert assessment based on the combination of available constraints from observations (assessed in Chapter 9) and the strength of known feedbacks simulated in the models used to produce the climate change projections in this chapter indicates that the equilibrium global mean SAT warming for a doubling of atmospheric carbon dioxide (CO_2), or 'equilibrium climate sensitivity', is *likely* to lie in the range 2°C to 4.5°C, with a most likely value of about 3°C. Equilibrium climate sensitivity is *very likely* larger than 1.5°C. For fundamental physical reasons, as well as data limitations, values substantially higher than 4.5°C still cannot be excluded, but agreement with observations and proxy data is generally worse for those high values than for values in the 2°C to 4.5°C range. The 'transient climate response' (TCR, defined as the globally averaged SAT change at the time of CO_2 doubling in the 1% yr^{-1} transient CO_2 increase experiment) is better constrained than equilibrium climate sensitivity. The TCR is *very likely* larger than 1°C and *very unlikely* greater than 3°C based on climate models, in agreement with constraints from the observed surface warming.

Temperature Extremes

It is *very likely* that heat waves will be more intense, more frequent and longer lasting in a future warmer climate. Cold episodes are projected to decrease significantly in a future warmer climate. Almost everywhere, daily minimum temperatures are projected to increase faster than daily maximum temperatures, leading to a decrease in diurnal temperature range. Decreases in frost days are projected to occur almost everywhere in the middle and high latitudes, with a comparable increase in growing season length.

Mean Precipitation

For a future warmer climate, the current generation of models indicates that precipitation generally increases in the areas of regional tropical precipitation maxima (such as the monsoon regimes) and over the tropical Pacific in particular, with general decreases in the subtropics, and increases at high latitudes as a consequence of a general intensification of the global hydrological cycle. Globally averaged mean water vapour, evaporation and precipitation are projected to increase.

Precipitation Extremes and Droughts

Intensity of precipitation events is projected to increase, particularly in tropical and high latitude areas that experience increases in mean precipitation. Even in areas where mean precipitation decreases (most subtropical and mid-latitude regions), precipitation intensity is projected to increase but there would be longer periods between rainfall events. There is a tendency for drying of the mid-continental areas during summer, indicating a greater risk of droughts in those regions. Precipitation extremes increase more than does the mean in most tropical and mid- and high-latitude areas.

Snow and Ice

As the climate warms, snow cover and sea ice extent decrease; glaciers and ice caps lose mass owing to a dominance of summer melting over winter precipitation increases. This contributes to sea level rise as documented for the previous generation of models in the TAR. There is a projected reduction of sea ice in the 21st century in both the Arctic and Antarctic with a rather large range of model responses. The projected reduction is accelerated in the Arctic, where some models project summer sea ice cover to disappear entirely in the high-emission A2 scenario in the latter part of the 21st century. Widespread increases in thaw depth over much of the permafrost regions are projected to occur in response to warming over the next century.

Carbon Cycle

There is unanimous agreement among the coupled climate-carbon cycle models driven by emission scenarios run so far that future climate change would reduce the efficiency of the Earth system (land and ocean) to absorb anthropogenic CO_2. As a result, an increasingly large fraction of anthropogenic CO_2 would stay airborne in the atmosphere under a warmer climate. For the A2 emission scenario, this positive feedback leads to additional atmospheric CO_2 concentration varying between 20 and 220 ppm among the models by 2100. Atmospheric CO_2 concentrations simulated by these coupled climate-carbon cycle models range between 730 and 1,020 ppm by 2100. Comparing these values with the standard value of 836 ppm (calculated beforehand by the Bern carbon cycle-climate model without an interactive carbon cycle) provides an indication of the uncertainty in global warming due to future changes in the carbon cycle. In the context of atmospheric CO_2 concentration stabilisation scenarios, the positive climate-carbon cycle feedback reduces the land and ocean uptake of CO_2, implying that it leads to a reduction of the compatible emissions required to achieve a given atmospheric CO_2 stabilisation. The higher the stabilisation scenario, the larger the climate change, the larger the impact on the carbon cycle, and hence the larger the required emission reduction.

Ocean Acidification

Increasing atmospheric CO_2 concentrations lead directly to increasing acidification of the surface ocean. Multi-model projections based on SRES scenarios give reductions in pH of between 0.14 and 0.35 units in the 21st century, adding to the present decrease of 0.1 units from pre-industrial times. Southern Ocean surface waters are projected to exhibit undersaturation with regard to calcium carbonate for CO_2 concentrations higher than 600 ppm, a level exceeded during the second half of the century in most of the SRES scenarios. Low-latitude regions and the deep ocean will be affected as well. Ocean acidification would lead to dissolution of shallow-water carbonate sediments and could affect marine calcifying organisms. However, the net effect on the biological cycling of carbon in the oceans is not well understood.

Sea Level

Sea level is projected to rise between the present (1980–1999) and the end of this century (2090–2099) under the SRES B1 scenario by 0.18 to 0.38 m, B2 by 0.20 to 0.43 m, A1B by 0.21 to 0.48 m, A1T by 0.20 to 0.45 m, A2 by 0.23 to 0.51 m, and A1FI by 0.26 to 0.59 m. These are 5 to 95% ranges based on the spread of AOGCM results, not including uncertainty in carbon cycle feedbacks. For each scenario, the midpoint of the range is within 10% of the TAR model average for 2090-2099. The ranges are narrower than in the TAR mainly because of improved information about some uncertainties in the projected contributions. In all scenarios, the average rate of rise during the 21st century *very likely* exceeds the 1961 to 2003 average rate (1.8 ± 0.5 mm yr^{-1}). During 2090 to 2099 under A1B, the central estimate of the rate of rise is 3.8 mm yr^{-1}. For an average model, the scenario spread in sea level rise is only 0.02 m by the middle of the century, and by the end of the century it is 0.15 m.

Thermal expansion is the largest component, contributing 70 to 75% of the central estimate in these projections for all scenarios. Glaciers, ice caps and the Greenland Ice Sheet are also projected to contribute positively to sea level. General Circulation Models indicate that the Antarctic Ice Sheet will receive increased snowfall without experiencing substantial surface melting, thus gaining mass and contributing negatively to sea level. Further accelerations in ice flow of the kind recently observed in some Greenland outlet glaciers and West Antarctic ice streams could substantially increase the contribution from the ice sheets. For example, if ice discharge from these processes were to scale up in future in proportion to global average surface temperature change (taken as a measure of global climate change), it would add 0.1 to 0.2 m to the upper bound of sea level rise by 2090 to 2099. In this example, during 2090 to 2099 the rate of scaled-up Antarctic discharge would roughly balance the expected increased rate of Antarctic accumulation, being under A1B a factor of 5 to 10 greater than in recent years. Understanding of these effects is too limited to assess their likelihood or to give a best estimate.

Sea level rise during the 21st century is projected to have substantial geographical variability. The model median spatial standard deviation is 0.08 m under A1B. The patterns from different models are not generally similar in detail, but have some common features, including smaller than average sea level rise in the Southern Ocean, larger than average in the Arctic, and a narrow band of pronounced sea level rise stretching across the southern Atlantic and Indian Oceans.

Mean Tropical Pacific Climate Change

Multi-model averages show a weak shift towards average background conditions which may be described as ‘El Niño-like’, with sea surface temperatures in the central and east equatorial Pacific warming more than those in the west, weakened tropical circulations and an eastward shift in mean precipitation.

El Niño

All models show continued El Niño-Southern Oscillation (ENSO) interannual variability in the future no matter what the change in average background conditions, but changes in ENSO interannual variability differ from model to model. Based on various assessments of the current multi-model data set, in which present-day El Niño events are now much better simulated than in the TAR, there is no consistent indication at this time of discernible changes in projected ENSO amplitude or frequency in the 21st century.

Monsoons

An increase in precipitation is projected in the Asian monsoon (along with an increase in interannual season-averaged precipitation variability) and the southern part of the west African monsoon with some decrease in the Sahel in northern summer, as well as an increase in the Australian monsoon in southern summer in a warmer climate. The monsoonal precipitation in Mexico and Central America is projected to decrease in association with increasing precipitation over the eastern equatorial Pacific through Walker Circulation and local Hadley Circulation changes. However, the uncertain role of aerosols in general, and carbon aerosols in particular, complicates the nature of future projections of monsoon precipitation, particularly in the Asian monsoon.

Sea Level Pressure

Sea level pressure is projected to increase over the subtropics and mid-latitudes, and decrease over high latitudes (order several millibars by the end of the 21st century) associated with a poleward expansion and weakening of the Hadley Circulation and a poleward shift of the storm tracks of several degrees latitude with a consequent increase in cyclonic circulation patterns over the high-latitude arctic and antarctic regions. Thus, there is a projected positive trend of the Northern Annular Mode (NAM) and the closely related North Atlantic Oscillation (NAO) as well as the Southern Annular Mode (SAM). There is considerable spread among the models for the NAO, but the magnitude of the increase for the SAM is generally more consistent across models.

Tropical Cyclones (Hurricanes and Typhoons)

Results from embedded high-resolution models and global models, ranging in grid spacing from 100 km to 9 km, project a *likely* increase of peak wind intensities and notably, where analysed, increased near-storm precipitation in future tropical cyclones. Most recent published modelling studies investigating tropical storm frequency simulate a decrease in the overall number of storms, though there is less confidence in these projections and in the projected decrease of relatively weak storms in most basins, with an increase in the numbers of the most intense tropical cyclones.

Mid-latitude Storms

Model projections show fewer mid-latitude storms averaged over each hemisphere, associated with the poleward shift of the storm tracks that is particularly notable in the Southern Hemisphere, with lower central pressures for these poleward-shifted storms. The increased wind speeds result in more extreme wave heights in those regions.

Atlantic Ocean Meridional Overturning Circulation

Based on current simulations, it is *very likely* that the Atlantic Ocean Meridional Overturning Circulation (MOC) will slow down during the course of the 21st century. A multi-model ensemble shows an average reduction of 25% with a broad range from virtually no change to a reduction of over 50% averaged over 2080 to 2099. In spite of a slowdown of the MOC in most models, there is still warming of surface temperatures around the North Atlantic Ocean and Europe due to the much larger radiative effects of the increase in greenhouse gases. Although the MOC weakens in most model runs for the three SRES scenarios, none shows a collapse of the MOC by the year 2100 for the scenarios considered. No coupled model simulation of the Atlantic MOC shows a mean increase in the MOC in response to global warming by 2100. It is *very unlikely* that the MOC will undergo a large abrupt transition during the course of the 21st century. At this stage, it is too early to assess the likelihood of a large abrupt change of the MOC beyond the end of the 21st century. In experiments with the low (B1) and medium (A1B) scenarios, and for which the atmospheric greenhouse gas concentrations are stabilised beyond 2100, the MOC recovers from initial weakening within one to several centuries after 2100 in some of the models. In other models the reduction persists.

Radiative Forcing

The radiative forcings by long-lived greenhouse gases computed with the radiative transfer codes in twenty of the AOGCMs used in the Fourth Assessment Report have been compared against results from benchmark line-by-line (LBL) models. The mean AOGCM forcing over the period 1860 to 2000 agrees with the mean LBL value to within 0.1 W m^{-2} at the tropopause. However, there is a range of 25% in longwave forcing due to doubling atmospheric CO_2 from its concentration in 1860 across the ensemble of AOGCM codes. There is a 47% relative range in longwave forcing in 2100 contributed by all greenhouse gases in the A1B scenario across the ensemble of AOGCM simulations. These results imply that the ranges in climate sensitivity and climate response from models discussed in this chapter may be due in part to differences in the formulation and treatment of radiative processes among the AOGCMs.

Climate Change Commitment (Temperature and Sea Level)

Results from the AOGCM multi-model climate change commitment experiments (concentrations stabilised for 100 years at year 2000 for 20th-century commitment, and at 2100 values for B1 and A1B commitment) indicate that if greenhouse gases were stabilised, then a further warming of 0.5°C would occur. This should not be confused with 'unavoidable climate change' over the next half century, which would be greater because forcing cannot be instantly stabilised. In the very long term, it is plausible that climate change could be less than in a commitment run since forcing could be reduced below current levels. Most of this warming occurs in the first several decades after stabilisation; afterwards the rate of increase steadily declines. The globally averaged precipitation commitment 100 years after stabilising greenhouse gas concentrations amounts to roughly an additional increase of 1 to 2% compared to the precipitation values at the time of stabilisation.

If concentrations were stabilised at A1B levels in 2100, sea level rise due to thermal expansion in the 22nd century would be similar to that in the 21st, and would amount to 0.3 to 0.8 m (relative to 1980 to 1999) above present by 2300. The ranges of thermal expansion overlap substantially for stabilisation at different levels, since model uncertainty is dominant; A1B is given here because most model results are available for that scenario. Thermal expansion would continue over many centuries at a gradually decreasing rate, reaching an eventual level of 0.2 to 0.6 m per °C of global warming relative to present. Under sustained elevated temperatures, some glacier volume may persist at high altitudes, but most could disappear over centuries.

If greenhouse gas concentrations could be reduced, global temperatures would begin to decrease within a decade, although sea level would continue to rise due to thermal expansion for at least another century. Earth System Models of Intermediate Complexity with coupled carbon cycle model components show that for a reduction to zero emissions at year 2100 the climate would take of the order of 1 kyr to stabilise. At year 3000, the model range for temperature increase is 1.1°C to 3.7°C and for sea level rise due to thermal expansion is 0.23 to 1.05 m. Hence, they are projected to remain well above their pre-industrial values.

The Greenland Ice Sheet is projected to contribute to sea level after 2100, initially at a rate of 0.03 to 0.21 m per century for stabilisation in 2100 at A1B concentrations. The contribution would be greater if dynamical processes omitted from current models increased the rate of ice flow, as has been observed in recent years. Except for remnant glaciers in the mountains, the Greenland Ice Sheet would largely be eliminated, raising sea level by about 7 m, if a sufficiently warm climate were maintained for millennia; it would happen more rapidly if ice flow accelerated. Models suggest that the global warming required lies in the range 1.9°C to 4.6°C relative to the pre-industrial temperature. Even if temperatures were to decrease later, it is possible that the reduction of the ice sheet to a much smaller extent would be irreversible.

The Antarctic Ice Sheet is projected to remain too cold for widespread surface melting, and to receive increased snowfall, leading to a gain of ice. Loss of ice from the ice sheet could occur through increased ice discharge into the ocean following weakening of ice shelves by melting at the base or on the surface. In current models, the net projected contribution to sea level rise is negative for coming centuries, but it is possible that acceleration of ice discharge could become dominant, causing a net positive contribution. Owing to limited understanding of the relevant ice flow processes, there is presently no consensus on the long-term future of the ice sheet or its contribution to sea level rise.

10.1 Introduction

Since the Third Assessment Report (TAR), the scientific community has undertaken the largest coordinated global coupled climate model experiment ever attempted in order to provide the most comprehensive multi-model perspective on climate change of any IPCC assessment, the World Climate Research Programme (WCRP) Coupled Model Intercomparison Project phase three (CMIP3), also referred to generically throughout this report as the 'multi-model data set' (MMD) archived at the Program for Climate Model Diagnosis and Intercomparison (PCMDI). This open process involves experiments with idealised climate change scenarios (i.e., 1% yr^{-1} carbon dioxide (CO_2) increase, also included in the earlier WCRP model intercomparison projects CMIP2 and CMIP2+ (e.g., Covey et al., 2003; Meehl et al., 2005b), equilibrium $2 \times CO_2$ experiments with atmospheric models coupled to non-dynamic slab oceans, and idealised stabilised climate change experiments at $2 \times CO_2$ and $4 \times$ atmospheric CO_2 levels in the 1% yr^{-1} CO_2 increase simulations).

In the idealised 1% yr^{-1} CO_2 increase experiments, there is no actual real year time line. Thus, the rate of climate change is not the issue in these experiments, but what is studied are the types of climate changes that occur at the time of doubling or quadrupling of atmospheric CO_2 and the range of, and difference in, model responses. Simulations of 20th-century climate have been completed that include temporally evolving natural and anthropogenic forcings. For projected climate change in the 21st century, a subset of three IPCC Special Report on Emission Scenarios (SRES; Nakićenović and Swart, 2000) scenario simulations have been selected from the six commonly used marker scenarios. With respect to emissions, this subset (B1, A1B and A2) consists of a 'low', 'medium' and 'high' scenario among the marker scenarios, and this choice is solely made by the constraints of available computer resources that did not allow for the calculation of all six scenarios. This choice, therefore, does not imply a qualification of, or preference over, the six marker scenarios. In addition, it is not within the scope of the Working Group I contribution to the Fourth Assessment Report (AR4) to assess the plausibility or likelihood of emission scenarios.

In addition to these non-mitigation scenarios, a series of idealised model projections is presented, each of which implies some form and level of intervention: (i) stabilisation scenarios in which greenhouse gas concentrations are stabilised at various levels, (ii) constant composition commitment scenarios in which greenhouse gas concentrations are fixed at year 2000 levels, (iii) zero emission commitment scenarios in which emissions are set to zero in the year 2100 and (iv) overshoot scenarios in which greenhouse gas concentrations are reduced after year 2150.

The simulations with the subset A1B, B1 and A2 were performed to the year 2100. Three different stabilisation scenarios were run, the first with all atmospheric constituents fixed at year 2000 values and the models run for an additional 100 years, and the second and third with constituents fixed at year 2100 values for A1B and B1, respectively, for another 100 to 200 years. Consequently, the concept of climate change commitment (for details and definitions see Section 10.7) is addressed in much wider scope and greater detail than in any previous IPCC assessment. Results based on this Atmosphere-Ocean General Circulation Model (AOGCM) multi-model data set are featured in Section 10.3.

Uncertainty in climate change projections has always been a subject of previous IPCC assessments, and a substantial amount of new work is assessed in this chapter. Uncertainty arises in various steps towards a climate projection (Figure 10.1). For

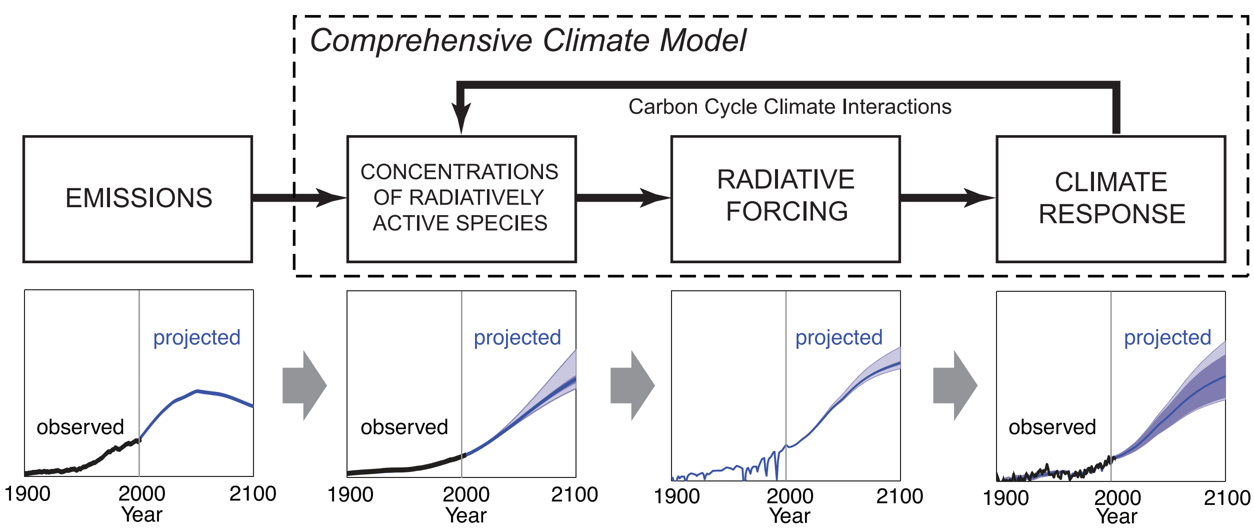

Figure 10.1. *Several steps from emissions to climate response contribute to the overall uncertainty of a climate model projection. These uncertainties can be quantified through a combined effort of observation, process understanding, a hierarchy of climate models, and ensemble simulations. In a comprehensive climate model, physical and chemical representations of processes permit a consistent quantification of uncertainty. Note that the uncertainty associated with the future emission path is of an entirely different nature and not addressed in Chapter 10. Bottom row adapted from Figure 10.26, A1B scenario, for illustration only.*

a given emissions scenario, various biogeochemical models are used to calculate concentrations of constituents in the atmosphere. Various radiation schemes and parametrizations are required to convert these concentrations to radiative forcing. Finally, the response of the different climate system components (atmosphere, ocean, sea ice, land surface, chemical status of atmosphere and ocean, etc.) is calculated in a comprehensive climate model. In addition, the formulation of, and interaction with, the carbon cycle in climate models introduces important feedbacks which produce additional uncertainties. In a comprehensive climate model, physical and chemical representations of processes permit a consistent quantification of uncertainty. Note that the uncertainties associated with the future emission path are of an entirely different nature and not considered in this chapter.

Many of the figures in Chapter 10 are based on the mean and spread of the multi-model ensemble of comprehensive AOGCMs. The reason to focus on the multi-model mean is that averages across structurally different models empirically show better large-scale agreement with observations, because individual model biases tend to cancel (see Chapter 8). The expanded use of multi-model ensembles of projections of future climate change therefore provides higher quality and more quantitative climate change information compared to the TAR. Even though the ability to simulate present-day mean climate and variability, as well as observed trends, differs across models, no weighting of individual models is applied in calculating the mean. Since the ensemble is strictly an 'ensemble of opportunity', without sampling protocol, the spread of models does not necessarily span the full possible range of uncertainty, and a statistical interpretation of the model spread is therefore problematic. However, attempts are made to quantify uncertainty throughout the chapter based on various other lines of evidence, including perturbed physics ensembles specifically designed to study uncertainty within one model framework, and Bayesian methods using observational constraints.

In addition to this coordinated international multi-model experiment, a number of entirely new types of experiments have been performed since the TAR to quantify uncertainty regarding climate model response to external forcings. The extent to which uncertainties in parametrizations translate into the uncertainty in climate change projections is addressed in much greater detail. New calculations of future climate change from the larger suite of SRES scenarios with simple models and Earth System Models of Intermediate Complexity (EMICs) provide additional information regarding uncertainty related to the choice of scenario. Such models also provide estimates of long-term evolution of global mean temperature, ocean heat uptake and sea level rise due to thermal expansion beyond the 21st century, and thus allow climate change commitments to be better constrained.

Climate sensitivity has always been a focus in the IPCC assessments, and this chapter assesses more quantitative estimates of equilibrium climate sensitivity and transient climate response (TCR) in terms of not only ranges but also probabilities within these ranges. Some of these probabilities are now derived from ensemble simulations subject to various observational constraints, and no longer rely solely on expert judgement. This permits a much more complete assessment of model response uncertainties from these sources than ever before. These are now standard benchmark calculations with the global coupled climate models, and are useful to assess model response in the subsequent time-evolving climate change scenario experiments.

With regard to these time-evolving experiments simulating 21st-century climate, since the TAR increased computing capabilities now allow routine performance of multi-member ensembles in climate change scenario experiments with global coupled climate models. This provides the capability to analyse more multi-model results and multi-member ensembles, and yields more probabilistic estimates of time-evolving climate change in the 21st century.

Finally, while future changes in some weather and climate extremes (e.g., heat waves) were addressed in the TAR, there were relatively few studies on this topic available for assessment at that time. Since then, more analyses have been performed regarding possible future changes in a variety of extremes. It is now possible to assess, for the first time, multi-model ensemble results for certain types of extreme events (e.g., heat waves, frost days, etc.). These new studies provide a more complete range of results for assessment regarding possible future changes in these important phenomena with their notable impacts on human societies and ecosystems. A synthesis of results from studies of extremes from observations and model is provided in Chapter 11.

The use of multi-model ensembles has been shown in other modelling applications to produce simulated climate features that are improved over single models alone (see discussion in Chapters 8 and 9). In addition, a hierarchy of models ranging from simple to intermediate to complex allows better quantification of the consequences of various parametrizations and formulations. Very large ensembles (order hundreds) with single models provide the means to quantify parametrization uncertainty. Finally, observed climate characteristics are now being used to better constrain future climate model projections.

10.2 Projected Changes in Emissions, Concentrations and Radiative Forcing

The global projections discussed in this chapter are extensions of the simulations of the observational record discussed in Chapter 9. The simulations of the 19th and 20th centuries are based upon changes in long-lived greenhouse gases (LLGHGs) that are reasonably constrained by the observational record. Therefore, the models have qualitatively similar temporal evolutions of their radiative forcing time histories for LLGHGs (e.g., see Figure 2.23). However, estimates of future concentrations of LLGHGs and other radiatively active species are clearly subject to significant uncertainties. The evolution of these species is governed by a variety of factors that are difficult to predict, including changes in population, energy use, energy sources and emissions. For these reasons, a range of projections of future climate change has been conducted using coupled AOGCMs. The future concentrations of LLGHGs and the anthropogenic emissions of sulphur dioxide (SO_2), a chemical precursor of sulphate aerosol, are obtained from several scenarios considered representative of low, medium and high emission trajectories. These basic scenarios and other forcing agents incorporated in the AOGCM projections, including several types of natural and anthropogenic aerosols, are discussed in Section 10.2.1. Developments in projecting radiatively active species and radiative forcing for the early 21st century are considered in Section 10.2.2.

10.2.1 Emissions Scenarios and Radiative Forcing in the Multi-Model Climate Projections

The temporal evolution of the LLGHGs, aerosols and other forcing agents are described in Sections 10.2.1.1 and 10.2.1.2. Typically, the future projections are based upon initial conditions extracted from the end of the simulations of the 20th century. Therefore, the radiative forcing at the beginning of the model projections should be approximately equal to the radiative forcing for present-day concentrations relative to pre-industrial conditions. The relationship between the modelled radiative forcing for the year 2000 and the estimates derived in Chapter 2 is evaluated in Section 10.2.1.3. Estimates of the radiative forcing in the multi-model integrations for one of the standard scenarios are also presented in this section. Possible explanations for the range of radiative forcings projected for 2100 are discussed in Section 10.2.1.4, including evidence for systematic errors in the formulations of radiative transfer used in AOGCMs. Possible implications of these findings for the range of global temperature change and other climate responses are summarised in Section 10.2.1.5.

10.2.1.1 The Special Report on Emission Scenarios and Constant-Concentration Commitment Scenarios

The future projections discussed in this chapter are based upon the standard A2, A1B and B2 SRES scenarios (Nakićenović and Swart, 2000). The emissions of CO_2, methane (CH_4) and SO_2, the concentrations of CO_2, CH_4 and nitrous oxide (N_2O) and the total radiative forcing for the SRES scenarios are illustrated in Figure 10.26 and summarised for the A1B scenario in Figure 10.1. The models have been integrated to year 2100 using the projected concentrations of LLGHGs and emissions of SO_2 specified by the A1B, B1 and A2 emissions scenarios. Some of the AOGCMs do not include sulphur chemistry, and the simulations from these models are based upon concentrations of sulphate aerosols from Boucher and Pham (2002; see Section 10.2.1.2). The simulations for the three scenarios were continued for another 100 to 200 years with all anthropogenic forcing agents held fixed at values applicable to the year 2100. There is also a new constant-concentration commitment scenario that assumes concentrations are held fixed at year 2000 levels (Section 10.7.1). In this idealised scenario, models are initialised from the end of the simulations for the 20th century, the concentrations of radiatively active species are held constant at year 2000 values from these simulations, and the models are integrated to 2100.

For comparison with this constant composition case, it is useful to note that constant emissions would lead to much larger radiative forcing. For example, constant CO_2 emissions at year 2000 values would lead to concentrations reaching about 520 ppm by 2100, close to the B1 case (Friedlingstein and Solomon, 2005; Hare and Munschausen, 2006; see also FAQ 10.3).

10.2.1.2 Forcing by Additional Species and Mechanisms

The forcing agents applied to each AOGCM used to make climate projections are summarised in Table 10.1. The radiatively active species specified by the SRES scenarios are CO_2, CH_4, N_2O, chlorofluorocarbons (CFCs) and SO_2, which is listed in its aerosol form as sulphate (SO_4) in the table. The inclusion, magnitude and temporal evolution of the remaining forcing agents listed in Table 10.1 were left to the discretion of the individual modelling groups. These agents include tropospheric and stratospheric ozone, all of the non-sulphate aerosols, the indirect effects of aerosols on cloud albedo and lifetime, the effects of land use and solar variability.

The scope of the treatments of aerosol effects in AOGCMs has increased markedly since the TAR. Seven of the AOGCMs include the first indirect effects and five include the second indirect effects of aerosols on cloud properties (Section 2.4.5). Under the more emissions-intensive scenarios considered in this chapter, the magnitude of the first indirect (Twomey) effect can saturate. Johns et al. (2003) parametrize the first indirect effect of anthropogenic sulphur (S) emissions as perturbations to the effective radii of cloud drops in simulations of the B1, B2, A2 and A1FI scenarios using UKMO-HadCM3. At 2100, the first indirect forcing ranges from –0.50 to

Table 10.1. *Radiative forcing agents in the multi-model global climate projections. See Table 8.1 for descriptions of the models. Entries mean Y: forcing agent is included; C: forcing agent varies with time during the 20th Century Climate in Coupled Models (20C3M) simulations and is set to constant or annually cyclic distribution for scenario integrations; E: forcing agent represented using equivalent CO_2; and n.a.: forcing agent is not specified in either the 20th-century or scenario integrations. Numeric codes indicate that the forcing agent is included using data described at 1: http://www.cnrm.meteo.fr/ensembles/public/results/results.html; 2: Boucher and Pham (2002); 3: Yukimoto et al. (2006); 4: Meehl, et al., 2006b; 5: http://aom.giss.nasa.gov/IN/GHGA1B.LP; and 6: http://sres.ciesin.org/final_data.html.*

Model	Forcing Agents																	
	Greenhouse Gases						Aerosols										Other	
	CO_2	CH_4	N_2O	Stratospheric Ozone	Tropospheric Ozone	CFCs	SO_4	Urban	Black carbon	Organic carbon	Nitrate	1st Indirect	2nd Indirect	Dust	Volcanic	Sea Salt	Land Use	Solar
BCC-CM1	Y	Y	Y	Y	C	4	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	C	C
BCCR-BCM2.0	1	1	1	C	C	1	2	C	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	C	C	C
CCSM3	4	4	4	4	4	4	4	n.a.	4	4	n.a.	n.a.	n.a.	Y	C	Y	n.a.	C
CGCM3.1(T47)	Y	Y	Y	C	C	Y	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	C	C	C	C
CGCM3.1(T63)	Y	Y	Y	C	C	Y	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	C	C	C	C
CNRM-CM3	1	1	1	Y	Y	1	2	C	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	C	n.a.	n.a.
CSIRO-MK3.0	Y	E	E	Y	Y	E	Y	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
ECHAM5/MPI-OM	1	1	1	Y	C	1	2	n.a.	n.a.	n.a.	n.a.	Y	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
ECHO-G	1	1	1	C	Y	1	6	n.a.	n.a.	n.a.	n.a.	Y	n.a.	n.a.	C	n.a.	n.a.	C
FGOALS-g1.0	4	4	4	C	C	4	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C
GFDL-CM2.0	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	n.a.	n.a.	n.a.	C	C	C	C	C
GFDL-CM2.1	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	n.a.	n.a.	n.a.	C	C	C	C	C
GISS-AOM	5	5	5	C	C	5	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Y	n.a.	n.a.
GISS-EH	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	Y	n.a.	Y	C	Y	C	Y	Y
GISS-ER	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	Y	n.a.	Y	C	Y	C	Y	Y
INM-CM3.0	4	4	4	C	C	n.a.	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	n.a.	C
IPSL-CM4	1	1	1	n.a.	n.a.	1	2	n.a.	n.a.	n.a.	n.a.	Y	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
MIROC3.2(H)	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	n.a.	Y	Y	Y	C	Y	C	C
MIROC3.2(M)	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	n.a.	Y	Y	Y	C	Y	C	C
MRI-CGCM2.3.2	3	3	3	C	C	3	3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	n.a.	C
PCM	Y	Y	Y	Y	Y	Y	Y	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	n.a.	C
UKMO-HadCM3	Y	Y	Y	Y	Y	Y	Y	n.a.	n.a.	n.a.	n.a.	Y	n.a.	n.a.	C	n.a.	n.a.	C
UKMO-HadGEM1	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	n.a.	Y	Y	n.a.	C	Y	Y	C

–0.79 W m^{-2}. The normalised indirect forcing (the ratio of the forcing (W m^{-2}) to the mass burden of a species (mg m^{-2}), leaving units of W mg^{-1}) decreases by a factor of four, from approximately –7 W mgS^{-1} in 1860 to between –1 and –2 W mgS^{-1} by the year 2100. Boucher and Pham (2002) and Pham et al. (2005) find a comparable projected decrease in forcing efficiency of the indirect effect, from –9.6 W mgS^{-1} in 1860 to between –2.1 and –4.4 W mgS^{-1} in 2100. Johns et al. (2003) and Pham et al. (2005) attribute the projected decline to the decreased sensitivity of clouds to greater sulphate concentrations at sufficiently large aerosol burdens.

10.2.1.3 Comparison of Modelled Forcings to Estimates in Chapter 2

The forcings used to generate climate projections for the standard SRES scenarios are not necessarily uniform across the multi-model ensemble. Differences among models may be caused by different projections for radiatively active species (see Section 10.2.1.2) and by differences in the formulation of radiative transfer (see Section 10.2.1.4). The AOGCMs in the ensemble include many species that are not specified or constrained by the SRES scenarios, including ozone, tropospheric non-sulphate aerosols, and stratospheric volcanic aerosols. Other types of forcing that vary across the ensemble include solar variability, the indirect effects of aerosols on clouds and the effects of land use change on land surface albedo and other land surface properties (Table 10.1). While the time series of LLGHGs for the future scenarios are mostly identical across the ensemble, the concentrations of these gases in the 19th and early 20th centuries were left to the discretion of individual modelling groups. The differences in radiatively active species and the formulation of radiative transfer affect both the 19th- and 20th-century simulations and the scenario integrations initiated from these historical simulations. The resulting differences in the forcing complicate the separation of forcing and response across the multi-model ensemble. These differences can be quantified by comparing the range of shortwave and longwave forcings across the multi-model ensemble against standard estimates of radiative forcing over the historical record. Shortwave and longwave forcing refer to modifications of the solar and infrared atmospheric radiation fluxes, respectively, that are caused by external changes to the climate system (Section 2.2).

The longwave radiative forcings for the SRES A1B scenario from climate model simulations are compared against estimates using the TAR formulae (see Chapter 2) in Figure 10.2a. The graph shows the longwave forcings from the TAR and 20 AOGCMs in the multi-model ensemble from 2000 to 2100. The forcings from the models are diagnosed from changes in top-of-atmosphere fluxes and the forcing for doubled atmospheric CO_2 (Forster and Taylor, 2006). The TAR and median model estimates of the longwave forcing are in very good agreement over the 21st century, with differences ranging from –0.37 to +0.06 W m^{-2}. For the year 2000, the global mean values from the TAR and median model differ by only –0.13 W m^{-2}. However, the 5th to 95th percentile range of the models for the period 2080 to 2099 is approximately 3.1 W m^{-2}, or approximately 47% of the median longwave forcing for that time period.

The corresponding time series of shortwave forcings for the SRES A1B scenario are plotted in Figure 10.2b. It is evident that the relative differences among the models and between the models and the TAR estimates are larger for the shortwave band. The TAR value is larger than the median model forcing by 0.2 to 0.3 W m^{-2} for individual 20-year segments of the integrations. For the year 2000, the TAR estimate is larger by 0.42 W m^{-2}. In addition, the range of modelled forcings is sufficiently large that it includes positive and negative values

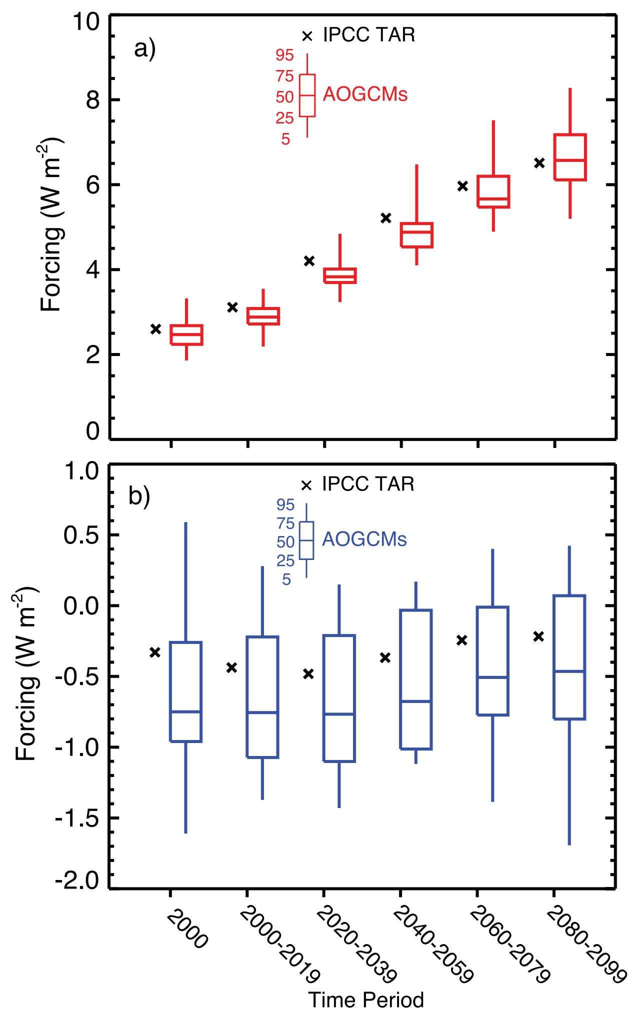

Figure 10.2. *Radiative forcings for the period 2000 to 2100 for the SRES A1B scenario diagnosed from AOGCMs and from the TAR (IPCC, 2001) forcing formulas (Forster and Taylor, 2006). (a) Longwave forcing; (b) shortwave forcing. The AOGCM results are plotted with box-and-whisker diagrams representing percentiles of forcings computed from 20 models in the AR4 multi-model ensemble. The central line within each box represents the median value of the model ensemble. The top and bottom of each box shows the 75th and 25th percentiles, and the top and bottom of each whisker displays the 95th and 5th percentile values in the ensemble, respectively. The models included are CCSM3, CGCM3.1 (T47 and T63), CNRM-CM3, CSIRO-MK3, ECHAM5/MPI-OM, ECHO-G, FGOALS-g1.0, GFDL-CM2.0, GFDL-CM2.1, GISS-EH, GISS-ER, INM-CM3.0, IPSL-CM4, MIROC3.2 (medium and high resolution), MRI-CGCM2.3.2, PCM1, UKMO-HadCM3 and UKMO-HadGEM1 (see Table 8.1 for model details).*

Table 10.2. *All-sky radiative forcing for doubled atmospheric CO_2. See Table 8.1 for model details.*

Model[Source]	Longwave (W m–2)	Shortwave (W m–2)
CGCM 3.1 (T47/T63)[a]	3.39	–0.07
CSIRO-MK3.0[b]	3.42	0.05
GISS-EH/ER[a]	4.21	–0.15
GFDL-CM2.0/2.1[b]	3.62	–0.12
IPSL-CM4[c]	3.50	–0.02
MIROC 3.2-hires[d]	3.06	0.08
MIROC 3.2-medres[d]	2.99	0.10
ECHAM5/MPI-OM[a]	3.98	0.03
MRI-CGCM2.3.2[b]	3.75	–0.28
CCSM3[a]	4.23	–0.28
UKMO-HadCM3[a]	4.03	–0.22
UKMO-HadGEM1[a]	4.02	–0.24
Mean ± standard deviation[e]	3.80 ± 0.33	–0.13 ± 0.11

Notes:

[a] Forster and Taylor (2006) based upon forcing data from PCMDI for 200 hPa. Longwave forcing accounts for stratospheric adjustment; shortwave forcing does not.

[b] Forcings derived by individual modelling groups using the method of Gregory et al. (2004b).

[c] Based upon forcing data from PCMDI for 200 hPa. Longwave and shortwave forcing account for stratospheric adjustment.

[d] Forcings at diagnosed tropopause.

[e] Mean and standard deviation are calculated just using forcings at 200 hPa, with each model and model version counted once.

for every 20-year period. For the year 2100, the shortwave forcing from individual AOGCMs ranges from approximately –1.7 W m^{-2} to +0.4 W m^{-2} (5th to 95th percentile). The reasons for this large range include the variety of the aerosol treatments and parametrizations for the indirect effects of aerosols in the multi-model ensemble.

Since the large range in both longwave and shortwave forcings may be caused by a variety of factors, it is useful to determine the range caused just by differences in model formulation for a given (identical) change in radiatively active species. A standard metric is the global mean, annually averaged all-sky forcing at the tropopause for doubled atmospheric CO_2. Estimates of this forcing for 15 of the models in the ensemble are given in Table 10.2. The shortwave forcing is caused by absorption in the near-infrared bands of CO_2. The range in the longwave forcing at 200 mb is 0.84 W m^{-2}, and the coefficient of variation, or ratio of the standard deviation to mean forcing, is 0.09. These results suggest that up to 35% of the range in longwave forcing in the ensemble for the period 2080 to 2099 is due to the spread in forcing estimates for the specified increase in CO_2. The findings also imply that it is not appropriate to use a single best value of the forcing from doubled atmospheric CO_2 to relate forcing and response (e.g., climate sensitivity) across a multi-model ensemble. The relationships for a given model should be derived using the radiative forcing produced by the radiative parametrizations in that model. Although the shortwave forcing has a coefficient of variation close to one, the range across the ensemble explains less than 17% of the range in shortwave forcing at the end of the 21st-century simulations. This suggests that species and forcing agents other than CO_2 cause the large variation among modelled shortwave forcings.

10.2.1.4 Results from the Radiative-Transfer Model Intercomparison Project: Implications for Fidelity of Forcing Projections

Differences in radiative forcing across the multi-model ensemble illustrated in Table 10.2 have been quantified in the Radiative-Transfer Model Intercomparison Project (RTMIP, W.D. Collins et al., 2006). The basis of RTMIP is an evaluation of the forcings computed by 20 AOGCMs using five benchmark line-by-line (LBL) radiative transfer codes. The comparison is focused on the instantaneous clear-sky radiative forcing by the LLGHGs CO_2, CH_4, N_2O, CFC-11, CFC-12 and the increased water vapour expected in warmer climates. The results of this intercomparison are not directly comparable to the estimates of forcing at the tropopause (Chapter 2), since the latter include the effects of stratospheric adjustment. The effects of adjustment on forcing are approximately –2% for CH_4, –4% for N_2O, +5% for CFC-11, +8% for CFC-12 and –13% for CO_2 (IPCC, 1995; Hansen et al., 1997). The total (longwave plus shortwave) radiative forcings at 200 mb, a surrogate for the tropopause, are shown in Table 10.3 for climatological mid-latitude summer conditions.

Table 10.3. *Total instantaneous forcing at 200 hPa (W m–2) from AOGCMs and LBL codes in RTMIP (W.D. Collins et al., 2006). Calculations are for cloud-free climatological mid-latitude summer conditions.*

Radiative Species	CO_2	CO_2	N_2O + CFCs	CH_4 + CFCs	All LLGHGs	Water Vapour
Forcing[a]	2000–1860	2x–1x	2000–1860	2000–1860	2000–1860	1.2x–1x
AOGCM mean	1.56	4.28	0.47	0.95	2.68	4.82
AOGCM std. dev.	0.23	0.66	0.15	0.30	0.30	0.34
LBL mean	1.69	4.75	0.38	0.73	2.58	5.08
LBL std. dev.	0.02	0.04	0.12	0.12	0.11	0.16

Notes:

[a] 2000–1860 is the forcing due to an increase in the concentrations of radiative species between 1860 and 2000. 2x–1x[x] and 1.2x–1x are forcings from increases in radiative species by 100% and 20% relative to 1860 concentrations.

Total forcings calculated from the AOGCM and LBL codes due to the increase in LLGHGs from 1860 to 2000 differ by less than 0.04, 0.49 and 0.10 W m^{-2} at the top of model, surface and pseudo-tropopause at 200mb, respectively (Table 10.3). Based upon the Student t-test, none of the differences in mean forcings shown in Table 10.3 is statistically significant at the 0.01 level. This indicates that the ensemble mean forcings are in reasonable agreement with the LBL codes. However, the forcings from individual models, for example from doubled atmospheric CO_2, span a range at least 10 times larger than that exhibited by the LBL models.

The forcings from doubling atmospheric CO_2 from its concentration at 1860 AD are shown in Figure 10.3a at the top of the model (TOM), 200 hPa (Table 10.3), and the surface. The AOGCMs tend to underestimate the longwave forcing at these three levels. The relative differences in the mean forcings are less than 8% for the pseudo-tropopause at 200 hPa but increase to approximately 13% at the TOM and to 33% at the surface. In general, the mean shortwave forcings from the LBL and AOGCM codes are in good agreement at all three surfaces. However, the range in shortwave forcing at the surface from individual AOGCMs is quite large. The coefficient of variation (the ratio of the standard deviation to the mean) for the surface shortwave forcing from AOGCMs is 0.95. In response to a doubling in atmospheric CO_2, the specific humidity increases by approximately 20% through much of the troposphere. The changes in shortwave and longwave fluxes due to a 20% increase in water vapour are illustrated in Figure 10.3b. The mean longwave forcing from increasing water vapour is quite well simulated with the AOGCM codes. In the shortwave, the only significant difference between the AOGCM and LBL calculations occurs at the surface, where the AOGCMs tend to underestimate the magnitude of the reduction in insolation. In general, the biases in the AOGCM forcings are largest at the surface level.

10.2.1.5 Implications for Range in Climate Response

The results from RTMIP imply that the spread in climate response discussed in this chapter is due in part to the diverse representations of radiative transfer among the members of the multi-model ensemble. Even if the concentrations of LLGHGs were identical across the ensemble, differences in radiative transfer parametrizations among the ensemble members would lead to different estimates of radiative forcing by these species. Many of the climate responses (e.g., global mean temperature) scale linearly with the radiative forcing to first approximation. Therefore, systematic errors in the calculations of radiative forcing should produce a corresponding range in climate responses. Assuming that the RTMIP results (Table 10.3) are globally applicable, the range of forcings for 1860 to 2000 in the AOGCMs should introduce a ±18% relative range (the 5 to 95% confidence interval) for 2000 in the responses that scale with forcing. The corresponding relative range for doubled atmospheric CO_2, which is comparable to the change in CO_2 in the B1 scenario by 2100, is ± 25%.

10.2.2 Recent Developments in Projections of Radiative Species and Forcing for the 21st Century

Estimation of ozone forcing for the 21st century is complicated by the short chemical lifetime of ozone compared to atmospheric transport time scales and by the sensitivity of the radiative forcing to the vertical distribution of ozone. Gauss et al. (2003) calculate the forcing by anthropogenic increases

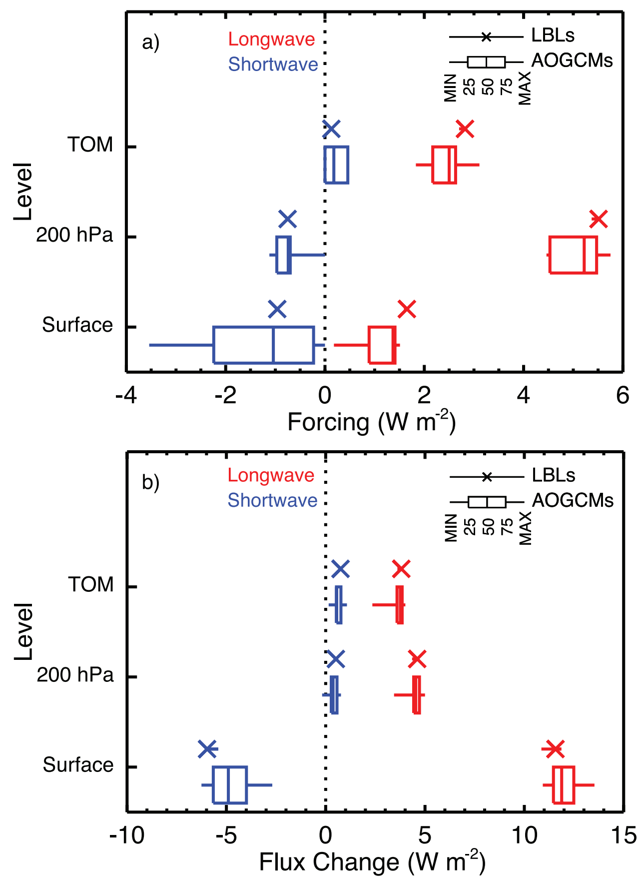

Figure 10.3. *Comparison of shortwave and longwave instantaneous radiative forcings and flux changes computed from AOGCMs and line-by-line (LBL) radiative transfer codes (W.D. Collins et al., 2006). (a) Instantaneous forcing from doubling atmospheric CO_2 from its concentration in 1860; b) changes in radiative fluxes caused by the 20% increase in water vapour expected in the climate produced from doubling atmospheric CO_2. The forcings and flux changes are computed for clear-sky conditions in mid-latitude summer and do not include effects of stratospheric adjustment. No other well-mixed greenhouse gases are included. The minimum-to-maximum range and median are plotted for five representative LBL codes. The AOGCM results are plotted with box-and-whisker diagrams (see caption for Figure 10.2) representing percentiles of forcings from 20 models in the AR4 multi-model ensemble. The AOGCMs included are BCCR-BCM2.0, CCSM3, CGCM3.1(T47 and T63), CNRM-CM3, ECHAM5/MPI-OM, ECHO-G, FGOALS-g1.0, GFDL-CM2.0, GFDL-CM2.1, GISS-EH, GISS-ER, INM-CM3.0, IPSL-CM4, MIROC3.2 (medium and high resolution), MRI-CGCM2.3.2, PCM, UKMO-HadCM3, and UKMO-HadGEM1 (see Table 8.1 for model details). The LBL codes are the Geophysical Fluid Dynamics Laboratory (GFDL) LBL, the Goddard Institute for Space Studies (GISS) LBL3, the National Center for Atmospheric Research (NCAR)/Imperial College of Science, Technology and Medicine (ICSTM) general LBL GENLN2, the National Aeronautics and Space Administration (NASA) Langley Research Center MRTA and the University of Reading Reference Forward Model (RFM).*

of tropospheric ozone through 2100 from 11 different chemical transport models integrated with the SRES A2p scenario. The A2p scenario is the preliminary version of the marker A2 scenario and has nearly identical time series of LLGHGs and forcing. Since the emissions of CH_4, carbon monoxide (CO), reactive nitrogen oxides (NO_x) and volatile organic compounds (VOCs), which strongly affect the formation of ozone, are maximised in the A2p scenario, the modelled forcings should represent an upper bound for the forcing produced under more constrained emissions scenarios. The 11 models simulate an increase in tropospheric ozone of 11.4 to 20.5 Dobson units (DU) by 2100, corresponding to a range of radiative forcing from 0.40 to 0.78 W m^{-2}. Under this scenario, stratospheric ozone increases by between 7.5 and 9.3 DU, which raises the radiative forcing by an additional 0.15 to 0.17 W m^{-2}.

One aspect of future direct aerosol radiative forcing omitted from all but 2 (the GISS-EH and GISS-ER models) of the 23 AOGCMS analysed in AR4 (see Table 8.1 for list) is the role of nitrate aerosols. Rapid increases in NO_x emissions could produce enough nitrate aerosol to offset the expected decline in sulphate forcing by 2100. Adams et al. (2001) compute the radiative forcing by sulphate and nitrate accounting for the interactions among sulphate, nitrate and ammonia. For 2000, the sulphate and nitrate forcing are –0.95 and –0.19 W m^{-2}, respectively. Under the SRES A2 scenario, by 2100 declining SO_2 emissions cause the sulphate forcing to drop to –0.85 W m^{-2}, while the nitrate forcing rises to –1.28 W m^{-2}. Hence, the total sulphate-nitrate forcing increases in magnitude from –1.14 W m^{-2} to –2.13 W m^{-2} rather than declining as models that omit nitrates would suggest. This projection is consistent with the large increase in coal burning forecast as part of the A2 scenario.

Recent field programs focused on Asian aerosols have demonstrated the importance of black carbon (BC) and organic carbon (OC) for regional climate, including potentially significant perturbations of the surface energy budget and hydrological cycle (Ramanathan et al., 2001). Modelling groups have developed a multiplicity of projections for the concentrations of these aerosol species. For example, Takemura et al. (2001) use data sets for BC released by fossil fuel and biomass burning (Cooke and Wilson, 1996) under current conditions and scale them by the ratio of future to present-day CO_2. The emissions of OC are derived using OC:BC ratios estimated for each source and fuel type. Koch (2001) models the future radiative forcing of BC by scaling a different set of present-day emission inventories by the ratio of future to present-day CO_2 emissions. There are still large uncertainties associated with current inventories of BC and OC (Bond et al., 2004), the ad hoc scaling methods used to produce future emissions, and considerable variation among estimates of the optical properties of carbonaceous aerosols (Kinne et al., 2006). Given these uncertainties, future projections of forcing by BC and OC should be quite model dependent.

Recent evidence suggests that there are detectable anthropogenic increases in stratospheric sulphate (e.g., Myhre et al., 2004), water vapour (e.g., Forster and Shine, 2002), and condensed water in the form of aircraft contrails. However, recent modelling studies suggest that these forcings are relatively minor compared to the major LLGHGs and aerosol species. Marquart et al. (2003) estimate that the radiative forcing by contrails will increase from 0.035 W m^{-2} in 1992 to 0.094 W m^{-2} in 2015 and to 0.148 W m^{-2} in 2050. The rise in forcing is due to an increase in subsonic aircraft traffic following estimates of future fuel consumption (Penner et al., 1999). These estimates are still subject to considerable uncertainties related to poor constraints on the microphysical properties, optical depths and diurnal cycle of contrails (Myhre and Stordal, 2001, 2002; Marquart et al., 2003). Pitari et al. (2002) examine the effect of future emissions under the A2 scenario on stratospheric concentrations of sulphate aerosol and ozone. By 2030, the mass of stratospheric sulphate increases by approximately 33%, with the majority of the increase contributed by enhanced upward fluxes of anthropogenic SO_2 through the tropopause. The increase in direct shortwave forcing by stratospheric aerosols in the A2 scenario during 2000 to 2030 is –0.06 W m^{-2}.

Some recent studies have suggested that the global atmospheric burden of soil dust aerosols could decrease by between 20 and 60% due to reductions in desert areas associated with climate change (Mahowald and Luo, 2003). Tegen et al. (2004a,b) compared simulations by the European Centre for Medium Range Weather Forecasts/Max Planck Institute for Meteorology Atmospheric GCM (ECHAM4) and UKMO-HadCM3 that included the effects of climate-induced changes in atmospheric conditions and vegetation cover and the effects of increased CO_2 concentrations on vegetation density. These simulations are forced with identical (IS92a) time series for LLGHGs. Their findings suggest that future projections of changes in dust loading are quite model dependent, since the net changes in global atmospheric dust loading produced by the two models have opposite signs. They also conclude that dust from agriculturally disturbed soils is less than 10% of the current burden, and that climate-induced changes in dust concentrations would dominate land use changes under both minimum and maximum estimates of increased agricultural area by 2050.

10.3 Projected Changes in the Physical Climate System

The context for the climate change results presented here is set in Chapter 8 (evaluation of simulation skill of the control runs and inherent natural variability of the global coupled climate models), and in Chapter 9 (evaluation of the simulations of 20th-century climate using the global coupled climate models). Table 8.1 describes the characteristics of the models, and Table 10.4 summarises the climate change experiments that have been performed with the AOGCMs and other models that are assessed in this chapter.

Table 10.4. *Summary of climate change model experiments produced with AOGCMs. Numbers in each scenario column indicate how many ensemble members were produced for each model. Coloured fields indicate that some but not necessarily all variables of the specific data type (separated by climate system component and time interval) were available for download at the PCMDI to be used in this report; ISCCP is the International Satellite Cloud Climatology Project. Additional data has been submitted for some models and may subsequently become available. Where different colour shadings are given in the legend, the colour indicates whether data from a single or from multiple ensemble members is available. Details on the scenarios, variables and models can be found at the PCMDI webpage (http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php). Model IDs are the same as in Table 8.1, which provides details of the models.*

- time-independent land surface
- >1 | 1 monthly-mean atmosphere
- daily-mean atmosphere
- 3-hourly atmosphere
- time-independent ocean
- >1 | 1 monthly-mean ocean
- >1 | 1 Extreme Indices
- Forcing
- ISCCP Simulator

Model ID	Model, Country	Pre industr. control	Present day control	20th century	Commit-ment	SRES A2	SRES A1B	SRES B1	1% to $2xCO_2$	1% to $4xCO_2$	Slab ocean control	$2XCO_2$	AMIP
1	BCC-CM1, China		2	4		2		2	1	1			4
2	BCCR-BCM2.0, Norway	1		1	1	1	1	1	1				
3	CCSM3, USA *	2	1	9	5	5	7	8	1	1	1	1	1
4	CGCM3.1(T47), Canada	1		5	5	5	5	4	1	1	1	1	
5	CGCM3.1(T63), Canada	1		1			1	1	1		1	1	
6	CNRM-CM3, France	1		1	1	1	1	1	1	1			1
7	CSIRO-MK3.0, Australia	2		3	1	1	1	1	1		1	1	
8	ECHAM5/MPI-OM, Germany	1		4	3	3	4	3	3	1	1	1	3
9	ECHO-G, Germany/Korea	1	1	5	4	3	3	3	1	1			
10	FGOALS-g1.0, China	3		3	3		3	3	3				3
11	GFDL-CM2.0, USA	1		3	1	1	1	1	1	1			
12	GFDL-CM2.1, USA	1		3	1	1	1	1	1	1			
13	GISS-AOM, USA	2		2			2	2					
14	GISS-EH, USA	1		5			4		1				
15	GISS-ER, USA	1		9	1	1	5	1	1	1	1	1	4
16	INM-CM3.0, Russia	1		1	1	1	1	1	1	1	1	1	1
17	IPSL-CM4, France	1	1	2	1	1	1	1	1	1			6
18	MIROC3.2(hires), Japan	1		1			1	1	1		1	1	1
19	MIROC3.2(medres), Japan	1		3	1	3	3	3	3	3	1	1	3
20	MRI-CGCM2.3.2, Japan	1	1	5	1	5	5	5	1	1	1	1	1
21	PCM, USA	1	1	4	3	4	4	4	5	1			1
22	UKMO-HadCM3, UK	2		2	1	1	1	1	1				
23	UKMO-HadGEM1, UK	1		1		1	1		1		1	1	1

** Some of the ensemble members using the CCSM3 were run on the Earth Simulator in Japan in collaboration with the Central Research Institute of Electric Power Industry (CRIEPI).*

The TAR showed multi-model results for future changes in climate from simple 1% yr^{-1} CO_2 increase experiments, and from several scenarios including the older IS92a, and, new to the TAR, two SRES scenarios (A2 and B2). For the latter, results from nine models were shown for globally averaged temperature change and regional changes. As noted in Section 10.1, since the TAR, an unprecedented internationally coordinated climate change experiment has been performed by 23 models from around the world, listed in Table 10.4 along with the results submitted. This larger number of models running the same experiments allows better quantification of the multi-model signal as well as uncertainty regarding spread across the models (in this section), and also points the way to probabilistic estimates of future climate change (Section 10.5). The emission scenarios considered here include one of the SRES scenarios from the TAR, scenario A2, along with two additional scenarios, A1B and B1 (see Section 10.2 for details regarding the scenarios). This is a subset of the SRES marker scenarios used in the TAR, and they represent 'low' (B1), 'medium' (A1B) and 'high' (A2) scenarios with respect to the prescribed concentrations and the resulting radiative forcing, relative to the SRES range. This choice was made solely due to the limited computational resources for multi-model simulations using comprehensive AOGCMs and does not imply any preference or qualification of these three scenarios over the others. Qualitative conclusions derived from those three scenarios are in most cases also valid for other SRES scenarios.

Additionally, three climate change commitment experiments were performed, one where concentrations of greenhouse gases were held fixed at year 2000 values (constant composition commitment) and the models were run to 2100 (termed 20th-century stabilisation here), and two where concentrations were held fixed at year 2100 values for A1B and B1, and the models were run for an additional 100 to 200 years (see Section 10.7). The span of the experiments is shown in Figure 10.4.

This section considers the basic changes in climate over the next hundred years simulated by current climate models under non-mitigation anthropogenic forcing scenarios. While we assess all studies in this field, the focus is on results derived by the authors from the new data set for the three SRES scenarios. Following the TAR, means across the multi-model ensemble are used to illustrate representative changes. Means are able to simulate the contemporary climate more accurately than individual models, due to biases tending to compensate each other (Phillips and Gleckler, 2006). It is anticipated that this holds for changes in climate also (Chapter 9). The mean temperature trends from the 20th-century simulations are included in Figure 10.4. While the range of model results is indicated here, the consideration of uncertainty resulting from this range is addressed more completely in Section 10.5. The use of means has the additional advantage of reducing the 'noise' associated with internal or unforced variability in the simulations. Models are equally weighted here, but other options are noted in Section 10.5. Lists of the models used in the results are provided in the Supplementary Material for this Chapter.

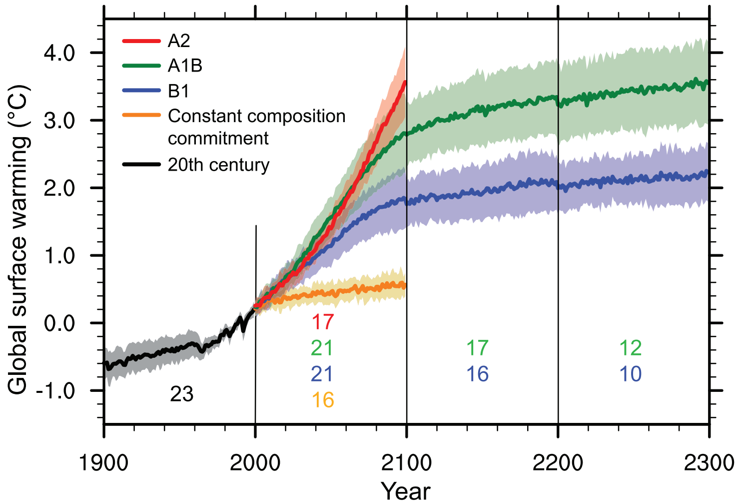

Figure 10.4. *Multi-model means of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th-century simulation. Values beyond 2100 are for the stabilisation scenarios (see Section 10.7). Linear trends from the corresponding control runs have been removed from these time series. Lines show the multi-model means, shading denotes the ±1 standard deviation range of individual model annual means. Discontinuities between different periods have no physical meaning and are caused by the fact that the number of models that have run a given scenario is different for each period and scenario, as indicated by the coloured numbers given for each period and scenario at the bottom of the panel. For the same reason, uncertainty across scenarios should not be interpreted from this figure (see Section 10.5.4.6 for uncertainty estimates).*

Standard metrics for response of global coupled models are the equilibrium climate sensitivity, defined as the equilibrium globally averaged surface air temperature change for a doubling of CO_2 for the atmosphere coupled to a non-dynamic slab ocean, and the TCR, defined as the globally averaged surface air temperature change at the time of CO_2 doubling in the 1% yr^{-1} transient CO_2 increase experiment. The TAR showed results for these 1% simulations, and Section 10.5.2 discusses equilibrium climate sensitivity, TCR and other aspects of response. Chapter 8 includes processes and feedbacks involved with these metrics.

10.3.1 Time-Evolving Global Change

The globally averaged surface warming time series from each model in the MMD is shown in Figure 10.5, either as a single member (if that was all that was available) or a multi-member ensemble mean, for each scenario in turn. The multi-model ensemble mean warming is also plotted for each case. The surface air temperature is used, averaged over each year, shown as an anomaly relative to the 1980 to 1999 period and offset by any drift in the corresponding control runs in order to extract the forced response. The base period was chosen to match the contemporary climate simulation that is the focus of previous chapters. Similar results have been shown in studies of these models (e.g., Xu et al., 2005; Meehl et al., 2006b; Yukimoto et al., 2006). Interannual variability is evident in each single-model series, but little remains in the ensemble mean because most of this is unforced and is a result of internal variability, as was presented in detail in Section 9.2.2 of TAR. Clearly, there is a range of model results for each year, but over time this range due to internal variability becomes smaller as a fraction of the mean warming. The range is somewhat smaller than the range of warming at the end of the 21st century for the A2 scenario in the comparable Figure 9.6 of the TAR, despite the larger number of models here (the ensemble mean warming is comparable, +3.0°C in the TAR for 2071 to 2100 relative to 1961 to 1990, and +3.13°C here for 2080 to 2099 relative to 1980 to 1999, Table 10.5). Consistent with the range of forcing presented in Section 10.2, the warming by 2100 is largest in the high greenhouse gas growth scenario A2, intermediate in the moderate growth A1B, and lowest in the low growth B1. Naturally, models with high sensitivity tend to simulate above-average warming in each scenario. The trends of the multi-model mean temperature vary somewhat over the century because of the varying forcings, including that of aerosols (see Section 10.2). This is illustrated in Figure 10.4, which shows the mean for A1B exceeding that for A2 around 2040. The time series beyond 2100 are derived from the extensions of the simulations (those available) under the idealised constant composition commitment experiments (Section 10.7.1).

Internal variability in the model response is reduced by averaging over 20-year time periods. This span is shorter than the traditional 30-year climatological period, in recognition of the transient nature of the simulations, and of the larger size of the ensemble. This analysis focuses on three periods over the coming century: an early-century period 2011 to 2030, a mid-century period 2046 to 2065 and the late-century period 2080 to 2099, all relative to the 1980 to 1999 means. The multi-model ensemble mean warmings for the three future periods in the different experiments are given in Table 10.5, among other results. The close agreement of warming for the early century, with a range of only 0.05°C among the SRES cases, shows that no matter which of these non-mitigation scenarios is followed, the warming is similar on the time scale of the next decade or two. Note that the precision given here is only relevant for comparison between these means. As evident in Figure 10.4 and discussed in Section 10.5, uncertainties in the projections are larger. It is also worth noting that half of the early-century climate change arises from warming that is already committed to under constant composition (0.37°C for the early century). By mid-century, the choice of scenario becomes more important for the magnitude of warming, with a range of 0.46°C, and with about one-third of that warming due to climate change that is already committed to. By the late century, there are clear consequences for which scenario is followed, with a range of 1.3°C in these results, with as little as 18% of that warming coming from climate change that is already committed to.

Global mean precipitation increases in all scenarios (Figure 10.5, right column), indicating an intensification of the hydrological cycle. Douville et al. (2002) show that this is associated with increased water-holding capacity of the atmosphere in addition to other processes. The multi-model

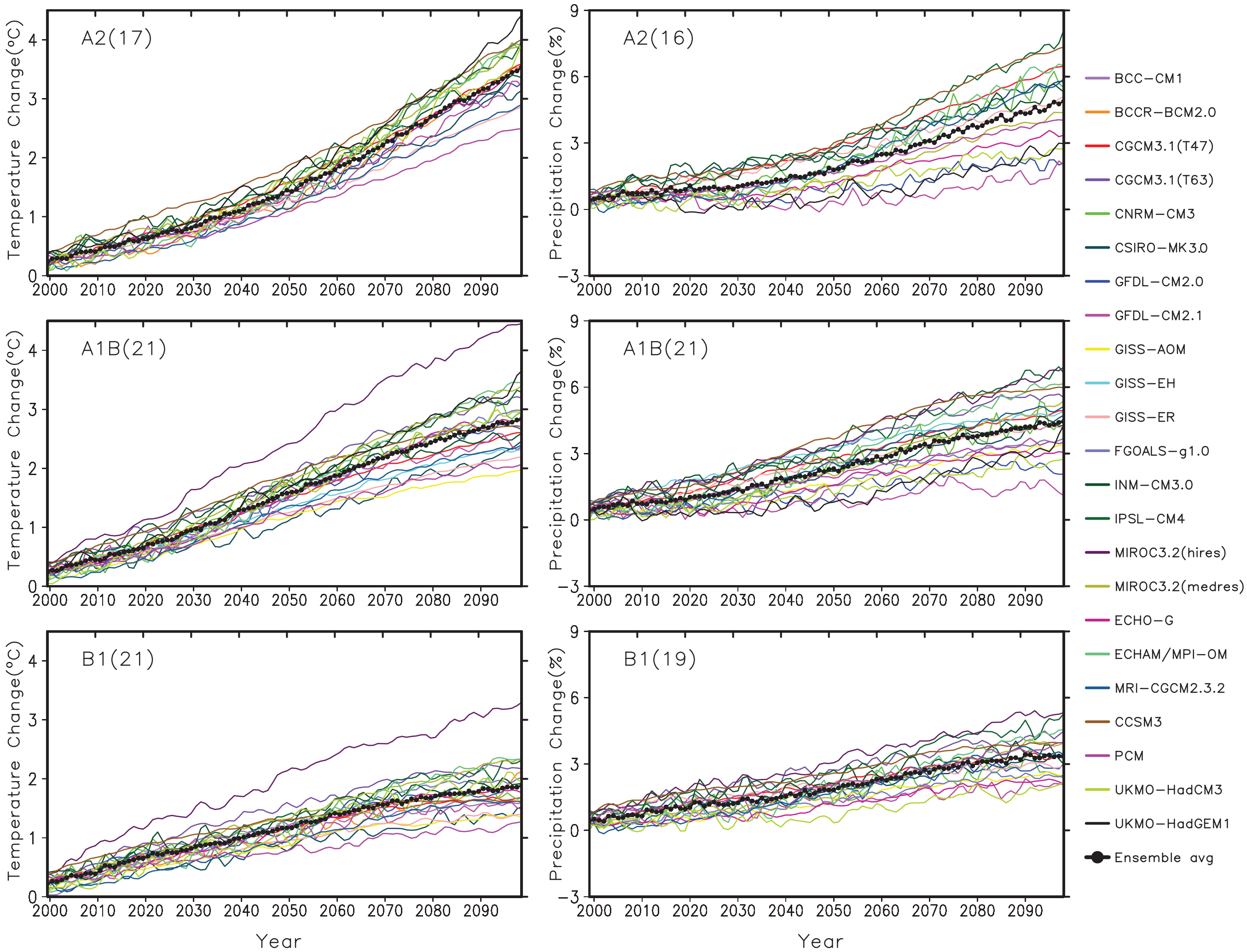

Figure 10.5. *Time series of globally averaged (left) surface warming (surface air temperature change, °C) and (right) precipitation change (%) from the various global coupled models for the scenarios A2 (top), A1B (middle) and B1 (bottom). Numbers in parentheses following the scenario name represent the number of simulations shown. Values are annual means, relative to the 1980 to 1999 average from the corresponding 20th-century simulations, with any linear trends in the corresponding control run simulations removed. A three-point smoothing was applied. Multi-model (ensemble) mean series are marked with black dots. See Table 8.1 for model details.*

Table 10.5. *Global mean warming (annual mean surface air temperature change) from the multi-model ensemble mean for four time periods relative to 1980 to 1999 for each of the available scenarios. (The mean for the base period is 13.6°C). Also given are two measures of agreement of the geographic scaled patterns of warming (the fields in Figure 10.8 normalised by the global mean), relative to the A1B 2080 to 2099 case. First the non-dimensional M value (see Section 10.3.2.1) and second (in italics) the global mean absolute error (*mae*, or difference, in °C/°C) between the fields, both multiplied by 100 for brevity. Here $M = (2/\pi) \arcsin[1 - \text{mse} / (V_X + V_Y + (G_X - G_Y)^2)]$, with* mse *the mean square error between the two fields X and Y, and V and G are variance and global mean of the fields (as subscripted). Values of 1 for M and 0 for* mae *indicate perfect agreement with the standard pattern. 'Commit' refers to the constant composition commitment experiment. Note that warming values for the end of the 21st century, given here as the average of years 2080 to 2099, are for a somewhat different averaging period than used in Figure 10.29 (2090–2099); the longer averaging period here is consistent with the comparable averaging period for the geographic plots in this section and is intended to smooth spatial noise.*

	Global mean warming (°C)				Measures of agreement (M × 100, *mae* × 100)			
	2011–2030	2046–2065	2080–2099	2180–2199	2011–2030	2046–2065	2080–2099	2180–2199
A2	0.64	1.65	3.13		83, *8*	91, *4*	93, *3*	
A1B	0.69	1.75	2.65	3.36	88, *5*	94, *4*	100, *0*	90, *5*
B1	0.66	1.29	1.79	2.10	86, *6*	89, *4*	92, *3*	86, *6*
Commit[a]	0.37	0.47	0.56		74, *11*	66, *13*	68, *13*	

Notes:
[a] Committed warming values are given relative to the 1980 to 1999 base period, whereas the commitment experiments started with stabilisation at year 2000. The committed warming trend is about 0.1°C per decade over the next two decades with a reduced rate after that (see Figure 10.4).

mean varies approximately in proportion to the mean warming, though uncertainties in future hydrological cycle behaviour arise due in part to the different responses of tropical precipitation across models (Douville et al., 2005). Expressed as a percentage of the mean simulated change for 1980 to 1999 (2.83 mm day^{-1}), the rate varies from about 1.4% °C^{-1} in A2 to 2.3% °C^{-1} in the constant composition commitment experiment (for a table corresponding to Table 10.5 but for precipitation, see the Supplementary Material, Table S10.1). These increases are less than increases in extreme precipitation events, consistent with energetic constraints (see Sections 9.5.4.2 and 10.3.6.1)

10.3.2 Patterns of Change in the 21st Century

10.3.2.1 Warming

The TAR noted that much of the regional variation of the annual mean warming in the multi-model means is associated with high- to low-latitude contrast. This can be better quantified from the new multi-model mean in terms of zonal averages. A further contrast is provided by partitioning the land and ocean values based on model data interpolated to a standard grid. Figure 10.6 illustrates the late-century A2 case, with all values shown both in absolute terms and relative to the global mean warming. Warming over land is greater than the mean except in the southern mid-latitudes, where the warming over ocean is a minimum. Warming over ocean is smaller than the mean except at high latitudes, where sea ice changes have an influence. This pattern of change illustrated by the ratios is quite similar across the scenarios. The commitment case (shown), discussed in Section 10.7.1, has relatively smaller warming of land, except in the far south, which warms closer to the global rate. At nearly all latitudes, the A1B and B1 warming ratios lie between A2 and commitment, with A1B particularly close to the A2 results. Aside from the commitment case, the ratios for the other time periods are also quite similar to those for A2. Regional patterns and precipitation contrasts are discussed in Section 10.3.2.3.

Figure 10.7 shows the zonal mean warming for the A1B scenario at each latitude from the bottom of the ocean to the top of the atmosphere for the three 21st-century periods used in Table 10.5. To produce this ensemble mean, the model data were first interpolated to standard ocean depths and atmospheric pressures. Consistent with the global transfer of excess heat from the atmosphere to the ocean, and the difference between warming over land and ocean, there is some discontinuity between the plotted means of the lower atmosphere and the upper ocean. The relatively uniform warming of the troposphere and cooling of the stratosphere in this multi-model mean are consistent with the changes shown in Figure 9.8 of the TAR, but now its evolution during the 21st century under this scenario can also be seen. Upper-tropospheric warming reaches a maximum in the tropics and is seen even in the early-century

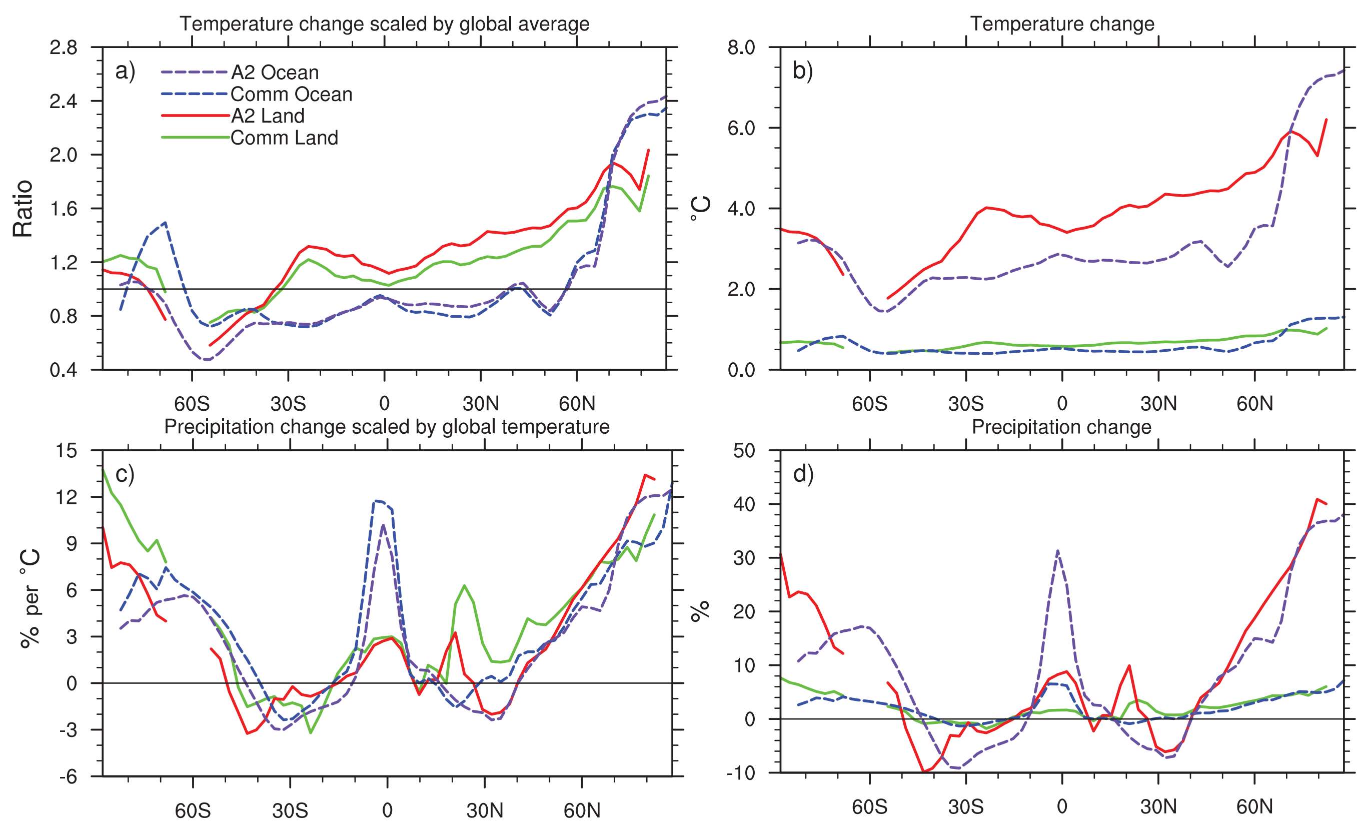

Figure 10.6. *Zonal means over land and ocean separately, for annual mean surface warming (a, b) and precipitation (c, d), shown as ratios scaled with the global mean warming (a, c) and not scaled (b, d). Multi-model mean results are shown for two scenarios, A2 and Commitment (see Section 10.7), for the period 2080 to 2099 relative to the zonal means for 1980 to 1999. Results for individual models can be seen in the Supplementary Material for this chapter.*

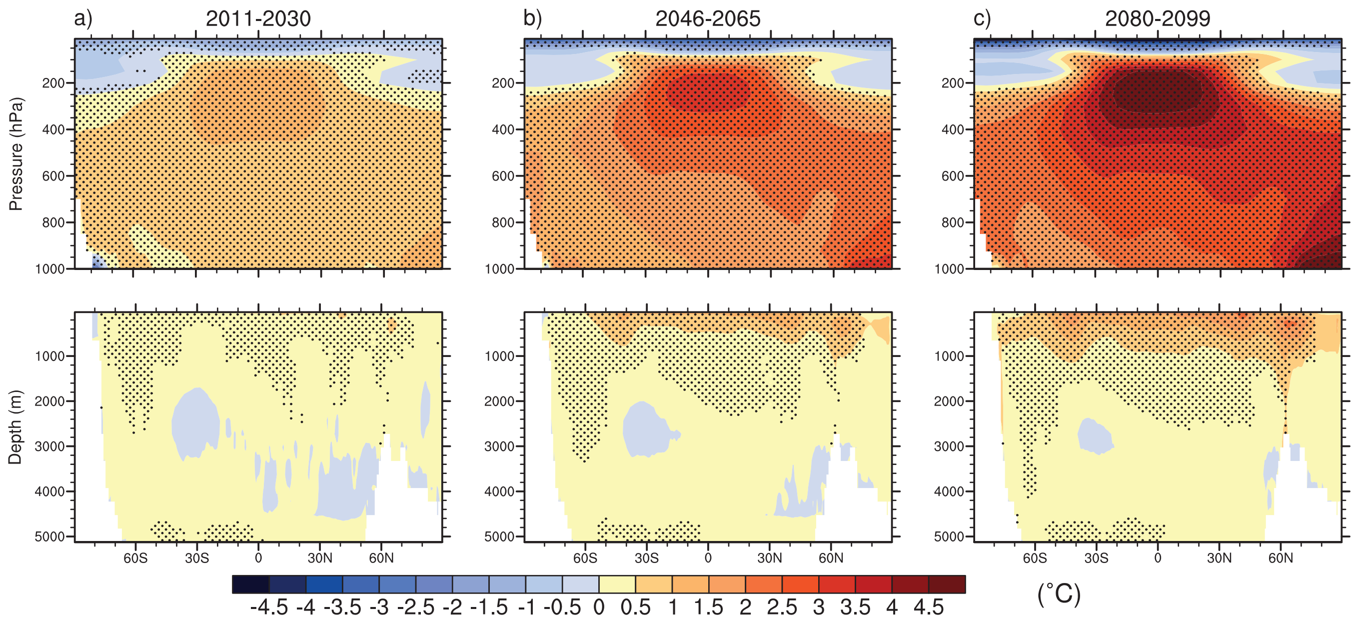

Figure 10.7. *Zonal means of change in atmospheric (top) and oceanic (bottom) temperatures (°C), shown as cross sections. Values are the multi-model means for the A1B scenario for three periods (a–c). Stippling denotes regions where the multi-model ensemble mean divided by the multi-model standard deviation exceeds 1.0 (in magnitude). Anomalies are relative to the average of the period 1980 to 1999. Results for individual models can be seen in the Supplementary Material for this chapter.*

time period. The pattern is very similar over the three periods, consistent with the rapid adjustment of the atmosphere to the forcing. These changes are simulated with good consistency among the models. The larger values of both signs are stippled, indicating that the ensemble mean is larger in magnitude than the inter-model standard deviation. The ratio of mean to standard deviation can be related to formal tests of statistical significance and confidence intervals, if the individual model results were to be considered a sample.

The ocean warming evolves more slowly. There is initially little warming below the mixed layer, except at some high latitudes. Even as a ratio with mean surface warming, later in the century the temperature increases more rapidly in the deep ocean, consistent with results from individual models (e.g., Watterson, 2003; Stouffer, 2004). This rapid warming of the atmosphere and the slow penetration of the warming into the ocean has implications for the time scales of climate change commitment (Section 10.7). It has been noted in a five-member multi-model ensemble analysis that, associated with the changes in temperature of the upper ocean in Figure 10.7, the tropical Pacific Ocean heat transport remains nearly constant with increasing greenhouse gases due to the compensation of the subtropical cells and the horizontal gyre variations, even as the subtropical cells change in response to changes in the trade winds (Hazeleger, 2005). Additionally, a southward shift of the Antarctic Circumpolar Current is projected to occur in a 15-member multi-model ensemble, due to changes in surface winds in a future warmer climate (Fyfe and Saenko, 2005). This is associated with a poleward shift of the westerlies at the surface (see Section 10.3.6) and in the upper troposphere particularly notable in the Southern Hemisphere (SH) (Stone and Fyfe, 2005), and increased relative angular momentum from stronger westerlies (Räisänen, 2003) and westerly momentum flux in the lower stratosphere particularly in the tropics and southern mid-latitudes (Watanabe et al., 2005). The surface wind changes are associated with corresponding changes in wind stress curl and horizontal mass transport in the ocean (Saenko et al., 2005).

Global-scale patterns for each of the three scenarios and time periods are given in Figure 10.8. In each case, greater warming over most land areas is evident (e.g., Kunkel and Liang, 2005). Over the ocean, warming is relatively large in the Arctic and along the equator in the eastern Pacific (see Sections 10.3.5.2 and 10.3.5.3), with less warming over the North Atlantic and the Southern Ocean (e.g., Xu et al., 2005). Enhanced oceanic warming along the equator is also evident in the zonal means of Figure 10.6, and can be associated with oceanic heat flux changes (Watterson, 2003) and forced by the atmosphere (Liu et al., 2005).

Fields of temperature change have a similar structure, with the linear correlation coefficient as high as 0.994 between the late-century A2 and A1B cases. As for the zonal means, the fields normalised by the mean warming are very similar. The strict agreement between the A1B field, as a standard, and the others is quantified in Table 10.5, by the absolute measure M (Watterson, 1996; a transformation of a measure of Mielke, 1991), with unity meaning identical fields and zero meaning no similarity (the expected value under random rearrangement of the data on the grid of the measure prior to the arcsin transformation). Values of M become progressively larger later in the 21st century, with values of 0.9 or larger for the late 21st century, thus confirming the closeness of the scaled patterns in the late-century cases. The deviation from unity is approximately proportional to the mean absolute difference. The earlier warming patterns are also similar to the standard case,

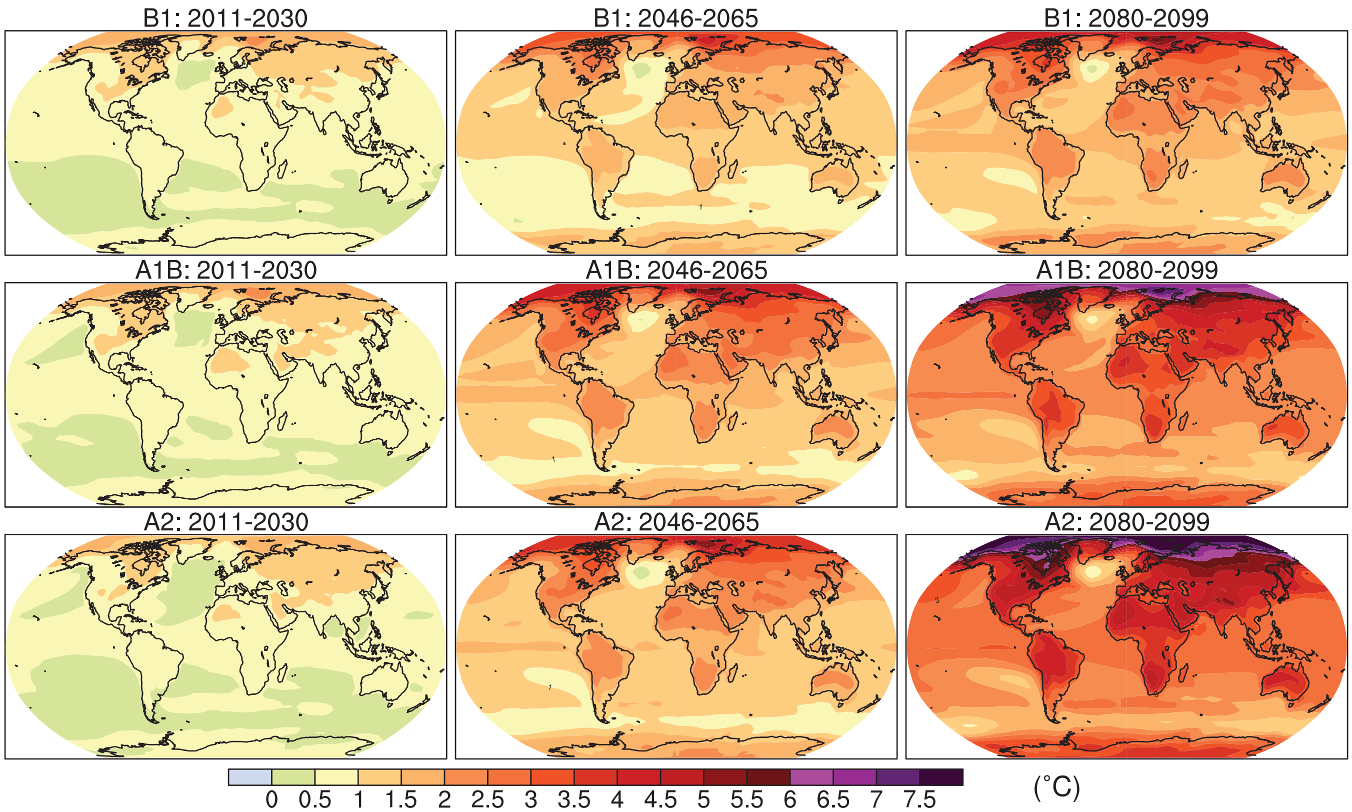

Figure 10.8. *Multi-model mean of annual mean surface warming (surface air temperature change, °C) for the scenarios B1 (top), A1B (middle) and A2 (bottom), and three time periods, 2011 to 2030 (left), 2046 to 2065 (middle) and 2080 to 2099 (right). Stippling is omitted for clarity (see text). Anomalies are relative to the average of the period 1980 to 1999. Results for individual models can be seen in the Supplementary Material for this chapter.*

particularly for the same scenario A1B. Furthermore, the zonal means over land and ocean considered above are representative of much of the small differences in warming ratio. While there is some influence of differences in forcing patterns among the scenarios, and of effects of oceanic uptake and heat transport in modifying the patterns over time, there is also support for the role of atmospheric heat transport in offsetting such influences (e.g., Boer and Yu, 2003b; Watterson and Dix, 2005). Dufresne et al. (2005) show that aerosol contributes a modest cooling of the Northern Hemisphere (NH) up to the mid-21st century in the A2 scenario.

Such similarities in patterns of change have been described by Mitchell (2003) and Harvey (2004). They aid the efficient presentation of the broad scale multi-model results, as patterns depicted for the standard A1B 2080 to 2099 case are usually typical of other cases. This largely applies to other seasons and also other variables under consideration here. Where there is similarity of normalised changes, values for other cases can be estimated by scaling by the appropriate ratio of global means from Table 10.5. Note that for some quantities like variability and extremes, such scaling is unlikely to work. The use of such scaled results in combination with global warmings from simple models is discussed in Section 11.10.1.

As for the zonal means (aside from the Arctic Ocean), consistency in local warmings among the models is high (stippling is omitted in Figure 10.8 for clarity). Only in the central North Atlantic and the far south Pacific in 2011 to 2030 is the mean change less than the standard deviation, in part a result of ocean model limitations there (Section 8.3.2). Some regions of high-latitude surface cooling occur in individual models.

The surface warming fields for the extratropical winter and summer seasons, December to February (DJF) and June to August (JJA), are shown for scenario A1B in Figure 10.9. The high-latitude warming is rather seasonal, being larger in winter as a result of sea ice and snow, as noted in Chapter 9 of the TAR. However, the relatively small warming in southern South America is more extensive in southern winter. Similar patterns of change in earlier model simulations are described by Giorgi et al. (2001).

10.3.2.2 Cloud and Diurnal Cycle

In addition to being an important link to humidity and precipitation, cloud cover plays an important role for the sensitivity of the general circulation models (GCMs; e.g., Soden and Held, 2006) and for the diurnal temperature range (DTR) over land (e.g., Dai and Trenberth, 2004 and references therein) so this section considers the projection of these variables now made possible by multi-model ensembles. Cloud radiative feedbacks to greenhouse gas forcing are sensitive to the elevation, latitude and hence temperature of the clouds, in addition to their optical

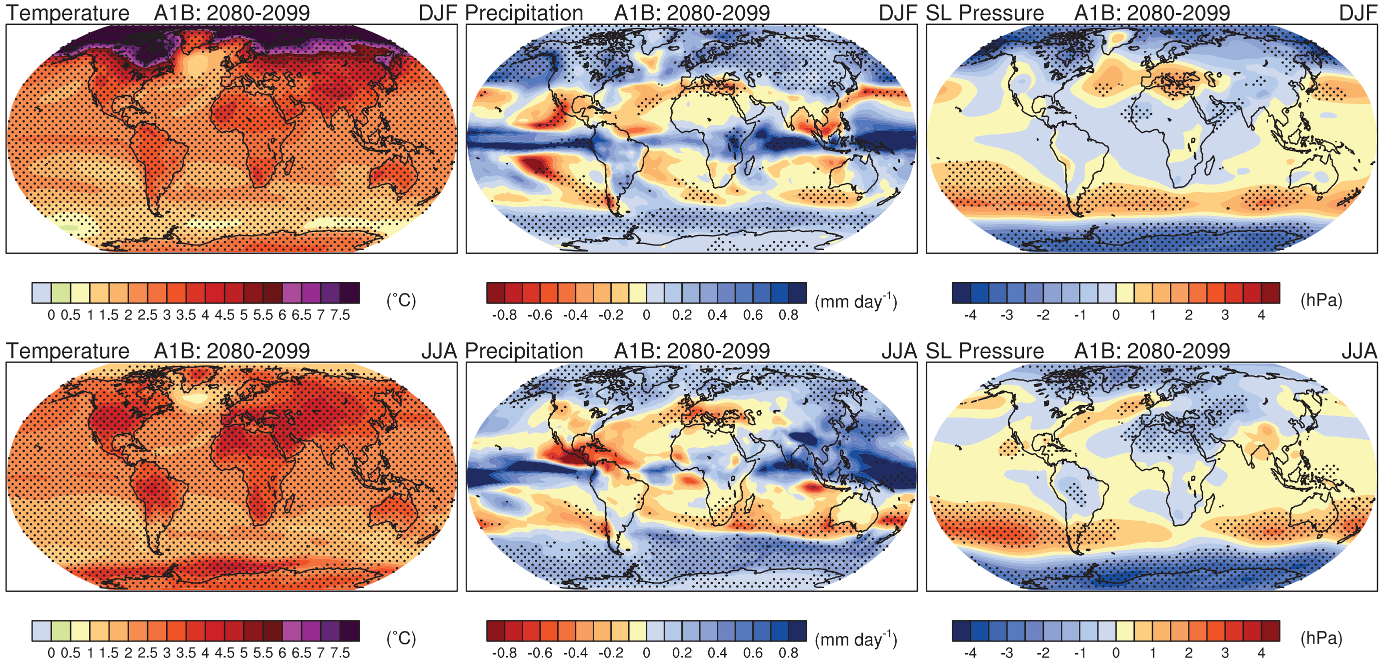

Figure 10.9. *Multi-model mean changes in surface air temperature (°C, left), precipitation (mm day^{-1}, middle) and sea level pressure (hPa, right) for boreal winter (DJF, top) and summer (JJA, bottom). Changes are given for the SRES A1B scenario, for the period 2080 to 2099 relative to 1980 to 1999. Stippling denotes areas where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation. Results for individual models can be seen in the Supplementary Material for this chapter.*

depth and their atmospheric environment (see Section 8.6.3.2). Current GCMs simulate clouds through various complex parametrizations (see Section 8.2.1.3) to produce cloud cover quantified by an area fraction within each grid square and each atmospheric layer. Taking multi-model ensemble zonal means of this quantity interpolated to standard pressure levels and latitudes shows increases in cloud cover at all latitudes in the vicinity of the tropopause, and mostly decreases below, indicating an increase in the altitude of clouds overall (Figure 10.10a). This shift occurs consistently across models. Outside the tropics the increases aloft are rather consistent, as indicated by the stippling in the figure. Near-surface amounts increase at some latitudes. The mid-level mid-latitude decreases are very consistent, amounting to as much as one-fifth of the average cloud fraction simulated for 1980 to 1999.

The total cloud area fraction from an individual model represents the net coverage over all the layers, after allowance for the overlap of clouds, and is an output included in the data set. The change in the ensemble mean of this field is shown in Figure 10.10b. Much of the low and middle latitudes experience a decrease in cloud cover, simulated with some consistency. There are a few low-latitude regions of increase, as well as substantial increases at high latitudes. The larger changes relate well to changes in precipitation discussed in Section 10.3.2.3. While clouds need not be precipitating, moderate spatial correlation between cloud cover and precipitation holds for seasonal means of both the present climate and future changes.

The radiative effect of clouds is represented by the cloud radiative forcing diagnostic (see Section 8.6.3.2). This can be

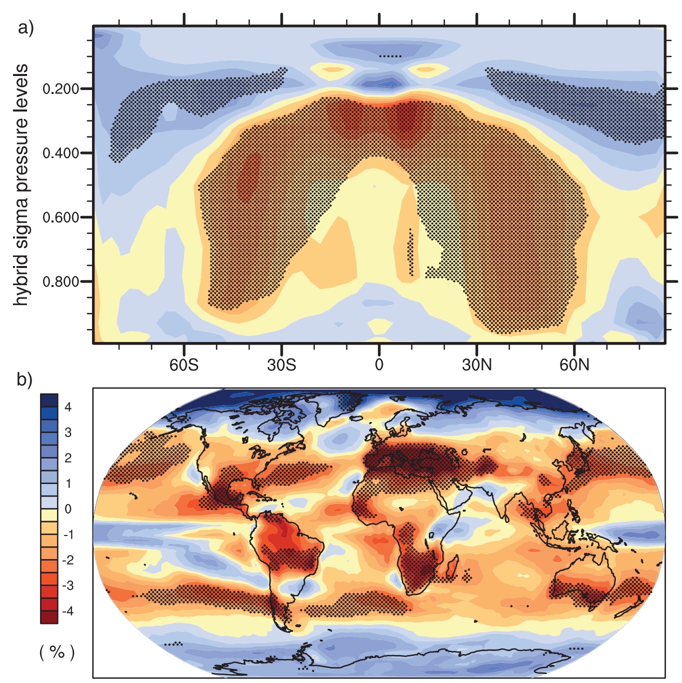

Figure 10.10. *Multi-model mean changes in (a) zonal mean cloud fraction (%), shown as a cross section though the atmosphere, and (b) total cloud area fraction (percent cover from all models). Changes are given as annual means for the SRES A1B scenario for the period 2080 to 2099 relative to 1980 to 1999. Stippling denotes areas where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation. Results for individual models can be seen in the Supplementary Material for this chapter.*

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FUEL ECONOMY AND AUTO SALES: AUTOMAKERS AND THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION IGNORE MARKET SIGNALS

MARK COOPER

AUGUST 2008

EXECUTIVE SUMMARY

This analysis explores important and fundamental flaws in the underlying economic assumptions made by the National Highway Traffic Safety Administration (NHTSA) in proposing its 2011-2015 fuel economy standards for autos and light trucks which render the draft environmental impact statement (DEIS) insufficient. NHTSA's proposed fleet wide standards, which reach a mere 31.7 miles per gallon in 2015, are grossly inadequate, robbing consumers and the nation of multiple billions of gallons of vital gasoline savings over the next decade. As a result, the DEIS measures the wrong alternatives and reaches the wrong conclusions about environmental impacts.

NHTSA's approach to setting fuel economy standards is to start with automaker product plans, assert that consumers undervalue fuel economy by demanding unrealistic economic returns from fuel saving technologies and assume that automakers are severely constrained in their ability to apply new fuel saving technology. Neither the product plans nor the assumptions about consumer and automaker behavior relied on in NHTSA's analysis bear any relationship to auto market reality.

- Consumers are looking for higher mileage today than NHTSA has mandated for seven years from now.
- The product plans on which NHTSA based its rule seven years in the future have already been torn up by the automakers, who have belatedly recognized the shift in consumer behavior toward greater fuel economy.
- The mix of cars and trucks that NHTSA projects bears no relationship to the vehicles that consumers are buying.

Relying on auto industry judgment in product plans, which are out of touch with the market reality, NHTSA has proposed fuel economy standards that are far too low. Not only did NHTSA assume that consumers are unwilling to buy fuel economy beyond a very narrow economic assumption, but it also assumed that higher fuel economy has no value in the marketplace (particularly in resale value). Our market behavior analysis and public opinion polling shows that consumers want more fuel-efficient cars than the automakers are offering them. The crucial role of a higher fuel economy standard is to push the automakers to deliver what the public wants, but NHTSA has failed to do so.

CFA made many of these points in its July comments filed in the rulemaking, but recent events have made the flaws in NHTSA's analysis and framework so much more obvious that we feel obliged to restate our objections to the proposed rule and incorporate new evidence into the record. Our earlier recommendations are all the more compelling in light of the mounting evidence that NHTSA has failed to propose a reasonable standard. NHTSA must:

- Raise the standards for 2011 and 2012; and

- Withdraw the proposed standards for 2013 through 2015, so it can fix its analytical framework and economic assumptions before promulgating fuel standards for those distant years.

The anecdotal evidence of the dramatic changes in the auto market is everywhere. In the past month, the Big Three have announced (or leaked) plans to abandon or slash their leasing businesses because the value of their gas-guzzlers at the end of the lease term is so low that the economics of leasing no longer makes sense. Clearly, fuel economy is a key determinant of the resale value, but NHTSA's analysis assumes that fuel economy has no impact on resale value of vehicles whatsoever.

While data on auto sales for the first half of 2008 make it clear that consumers are highly sensitive to fuel economy in their purchase decisions, our analysis shows that this shift in consumer behavior has been evident for three years. In addition, our analysis reveals that it is not just a shift between trucks (SUVs) and cars, but that it is has also been evident within the car and truck categories.

The automakers were slow to recognize this market change. They chose to continue to produce gas-guzzlers, trying to bribe consumers to purchase them with discounts, rebates and low interest financing. It was a fool's game, and the jig is up. In the past month, Ford Motor Company has declared its intention to dramatically alter its vehicle mix in the next two years, yet NHTSA assumes that automakers cannot make such changes rapidly. Assuming that vehicle manufacturers are unable to make such changes causes NHTSA to severely underestimate the fuel savings technologies that could be included in new vehicles. Pushing automakers to close the gap is precisely the role of fuel economy standards. The technologies exist to achieve almost twice the fuel savings that NHTSA's proposed rule achieve, but NHTSA has incorrectly assumed that consumers lack the desire and automakers lack the ability to get these technologies into the fleet.

Dramatic changes in the marketplace reflect a greater willingness of consumers to buy more fuel-efficient vehicles (new and used). However, at the core of NHTSA's analysis are assumptions that restrict the inclusion fuel saving technologies in new vehicles. NHTSA's base case fuel economy levels and vehicle mix simply do not reflect the reality of the auto market. Our survey evidence analyzed below demonstrates the motivation and willingness of consumers to purchase more fuel-efficient vehicles and reveals a shocking mismatch between what consumers want and what automakers have been offering.

The remainder of this report examines the increasing responsiveness of the auto market to fuel economy, which was not fully reflected in NHTSA's modeling. NHTSA has based its proposed rule on automaker product plans that are completely outdated. It did not have to set standards beyond 2012 in the current rulemaking and the choice to do so, despite clear evidence that the product plans do not reflect reality, violates the letter and spirit of the Energy Policy Conservation Act (EPCA) as recently amended by the Energy Independence and Security Act of 2007. Instead of proposing rules that achieve the maximum feasible increases in fuel economy, as obligated under the EPCA, NHTSA has proposed rules that are much closer to the minimum allowable.

In our initial comments we demonstrated that if NHTSA repaired the analytic framework and corrected its economic assumptions, it could easily go to a much higher standard that would push the fleet average for 2015 from 31.6 mpg to 34.5 mpg. Given the dynamic developments in the marketplace, NHTSA should certainly consider even higher levels for 2013 to 2015. The highest level of fuel economy that NHTSA considered, called the "technology exhaustion" standard, was based on erroneous assumptions about the inability of automakers to improve fuel economy. The technology exhaustion alternative, which would move the fleet to 41.4 mpg by 2015, is certainly technologically feasible and, under realistic assumptions about the value of oil and externalities, would not only save 50 billion gallons more gasoline, but also produce $30 billion more in net total benefits. With so much potential gain for consumers and the nation, NHTSA must adopt a more realistic model of consumer and automaker behavior, adjust the economic assumption and consider much higher levels of fuel economy.

This report is divided into three sections:

- Consumer Attitudes
- Fuel Economy and Year-Over-Year Changes in Auto Sales
- Changes in Consumer Behavior in Gasoline and Auto Markets

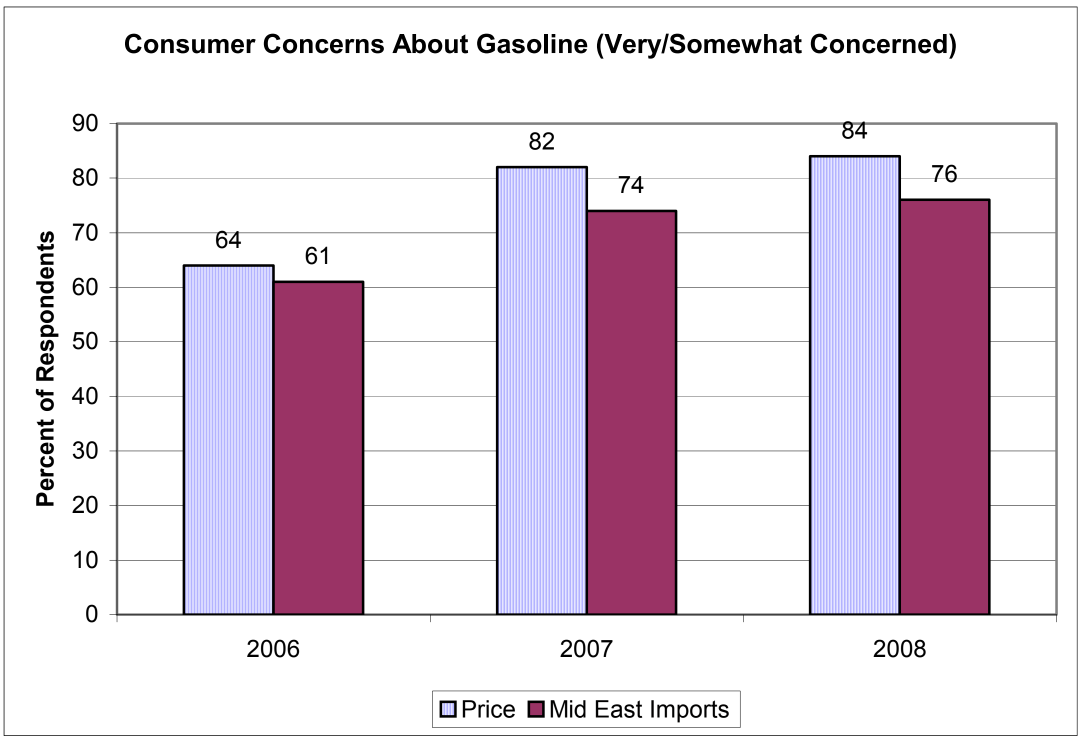
The next section presents a discussion of recent survey evidence on the shift in consumer and market behavior, which must inform NHTSA's analysis. We then analyze year-over-year changes in sales and fuel economy to ascertain when the shift in consumer behavior occurred. Finally, we review long run trends and present an econometric analysis of fuel economy over the past half-decade.

CONSUMER ATTITUDES

Our survey evidence demonstrates the motivation and willingness of consumers to purchase more fuel-efficient vehicles (see Exhibit 1).

- Eighty-four percent of respondents say they are concerned about rising gasoline prices (70 percent very concerned).[1]
- Seventy- six percent of respondents say they are concerned about Mid Eastern oil imports (57 percent very concerned).
- Both of these figures have been rising steadily since we began asking the question about two years ago.

Exhibit 1:



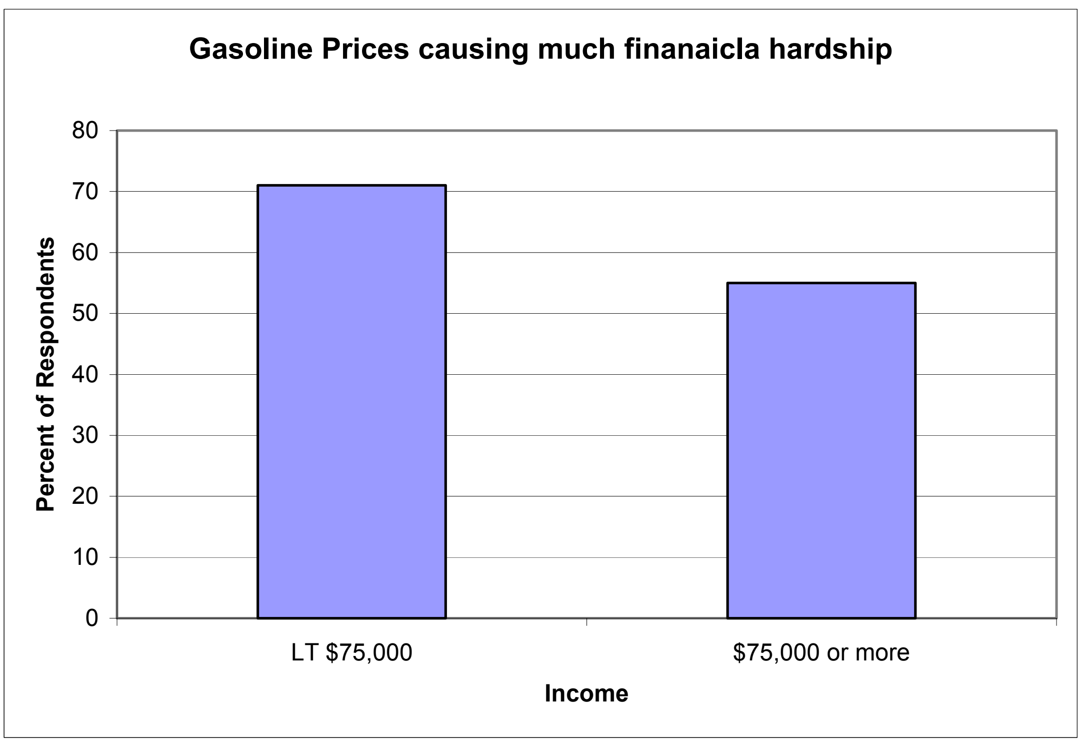
Source: National opinion polls conducted for the Consumer Federation of America by the Opinion Research Corporation. 2008, July 17-20; 2007, see Consumer Federation of America, *No Time to Waste*, available at http://www.consumerfed.org/pdfs/No_Time_To_Waste.pdf 2006 see Consumer Federation of America, *Consumers Still Greatly Concerned About Better Gas Mileage and Oil Imports Despite Falling Gas Prices, available at http://www.consumerfed.org/pdfs/Gas_Mileage_Consumer_Attitudes_Manu_Performance_Press_Release111306.pdf*

[1] "Thinking about the next five years, how concerned personally are you about gasoline prices, U.S. dependency on Mid Eastern oil, and global warming?"

There are no significant differences in these concerns across various demographic categories (age, income, education, gender) with one exception. Households with incomes of $35,000 per year or more are more likely to be concerned about Mid East imports (81 percent) than those with incomes below $35,000 (69 percent).

The concern about gasoline prices reflects the impact that rising gasoline prices are having on the respondents. Eighty-four percent of respondents say that rising gasoline prices have placed a financial burden on their household budgets (63 percent a severe burden). Not surprisingly (see Exhibit 2), households with incomes of $75,000 or more are less likely to say they have suffered much financial hardship (55 percent) than households with incomes below $75,000 (71 percent.) Also, rural households (those living outside of metropolitan areas) are more likely to say they have suffered much financial hardship as a result of gasoline costs (35 percent) compared to those living in urban areas (26 percent).

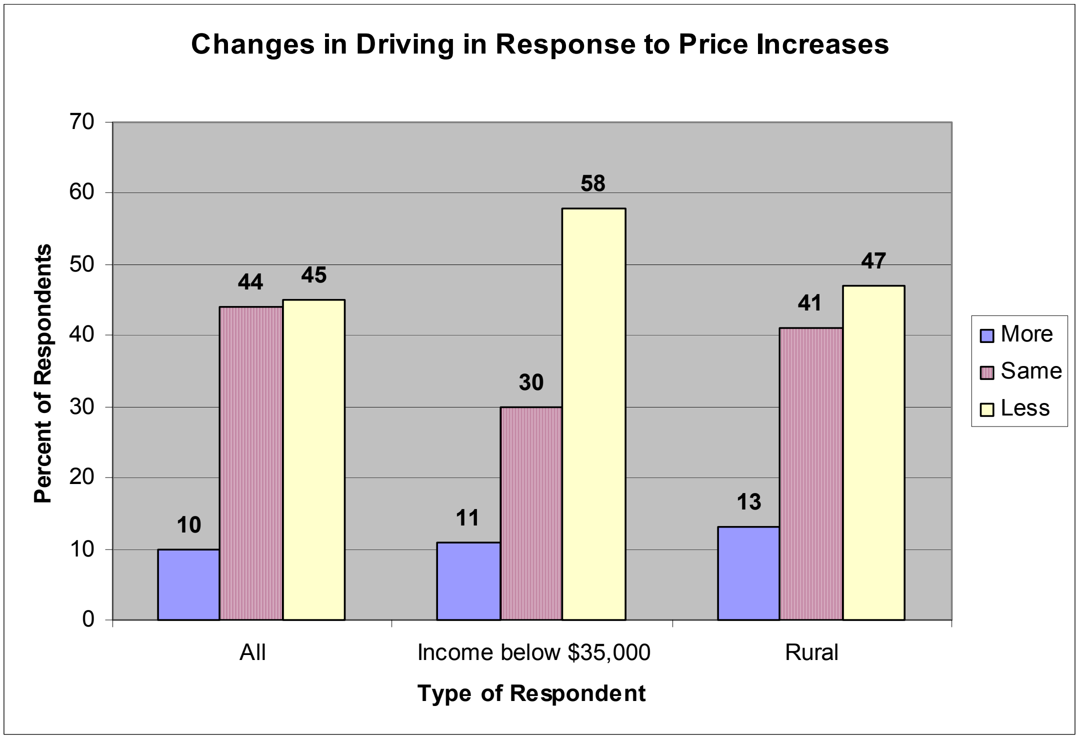
Exhibit 2:



Source: National opinion poll conducted for the Consumer Federation of America by the Opinion Research Corporation. 2008, July 17-20

Our April 2008 survey also helped reveal how Americans are responding to this hardship.[2] When asked (whether they were driving more or less than a year ago, 45 percent of respondents said less, and only 10 percent said more (see Exhibit 3). Lower income households were more likely to say that they were driving less (58 percent compared to 45 percent for all respondents).

Exhibit 3



Source: See Mark Cooper, *Ending America's Oil Addiction* (Washington, D.C.: Consumer Federation of America, April 2008). **http://www.consumerfed.org/pdfs/First_Quarterly_Gas_Report_2008.pdf**

The most striking result of the most recent survey can be found in responses to questions about the fuel economy of the vehicles consumers currently drive compared to the fuel economy they would like to get in their next vehicles.

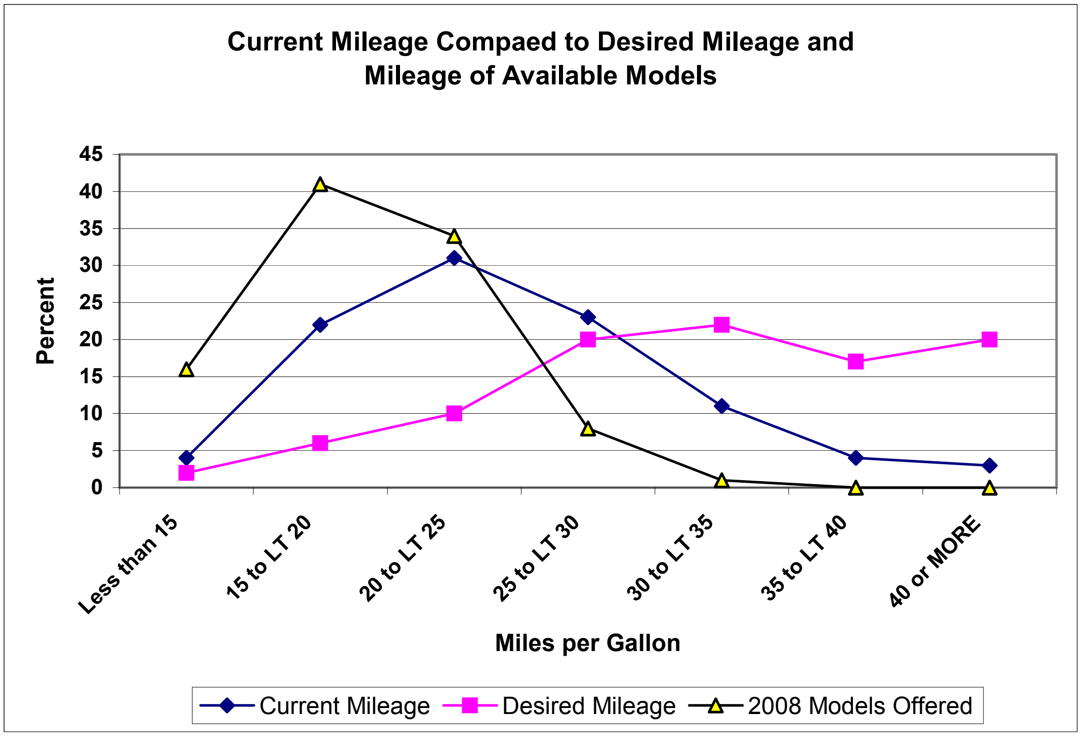
- Among those who drive and intend to purchase a new vehicle, the current average fuel economy is reported at about 24.1 miles per gallon.
- These respondents say they want to get 32.7 miles per gallon in the vehicle they purchase.

There is also a clear mismatch between the desires of consumers and the models that the automakers offered in 2008 (see Exhibit 4).

[2] See Mark Cooper, Ending America's Oil Addiction (Washington, D.C.: Consumer Federation of America, April 2008). http://www.consumerfed.org/pdfs/First_Quarterly_Gas_Report_2008.pdf

- Whereas 59 percent of the respondents say they want to get more than 35 miles per gallon in the next vehicle they purchase, only 1 percent of the 2008 models offered by automakers achieve that mileage.
- The average goal for consumers in the market today is 32.7 miles per gallon, well above the standard of 31.6 miles per gallon that NHTSA has set for 2015.

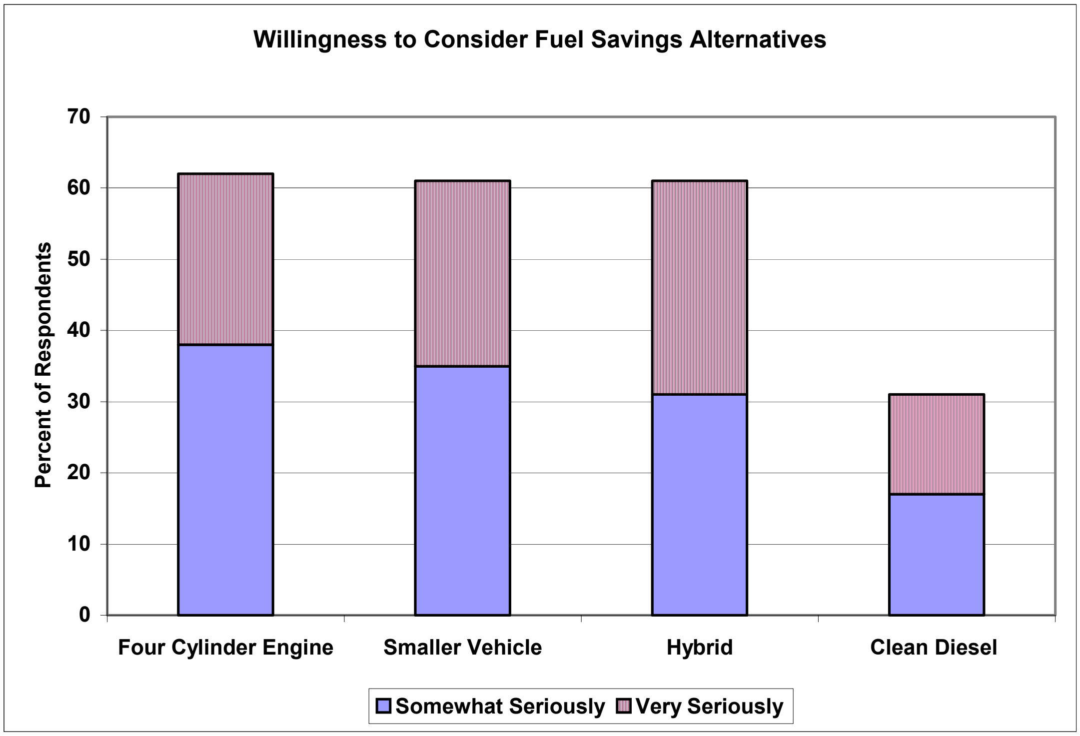
Exhibit 4: Current Mileage Compared to Desired Mileage and Models Available



Source: National opinion poll conducted for the Consumer Federation of America by the Opinion Research Corporation. 2008, July 17-20; CFA database on miles per gallon.

Consumers back up their desire to achieve higher fuel economy in their next vehicles with a willingness to consider alternatives that would lower fuel economy (see Exhibit 5.) When asked about four major ways to improve fuel economy, about 60 percent of respondents said they would very or somewhat seriously consider four cylinder engines, hybrids and small vehicles. Clean diesel engines would be considered by about one-third of respondents. There were few differences across demographic categories, with two exceptions. Respondents with incomes above $50,000 were more willing to consider a hybrid (68 percent) than those with incomes below $50,000 (57 percent). Younger (age 18-24) and older respondents (age 65 or more) were less likely (50 percent) to say they would consider a hybrid than respondents with ages between 25 and 65 (70 percent).

Exhibit 5:



Source: National opinion poll conducted for the Consumer Federation of America by the Opinion Research Corporation. 2008, July 17-20;

Fuel Economy and Year-Over-Year Changes in Auto Sales

Consumers do not just say they are feeling the pinch of rising gasoline prices, or claim to alter their behaviors in reaction to higher gasoline prices, or just express a desire to have more fuel efficient vehicles, the evidence on auto sales suggests that they are taking action. Moreover, while the headlines describing the current woes of the automakers point to a sudden shift in consumer purchasing patterns, a shift from light trucks and large SUVs to more fuel-efficient cars, a close look at the data indicates that:

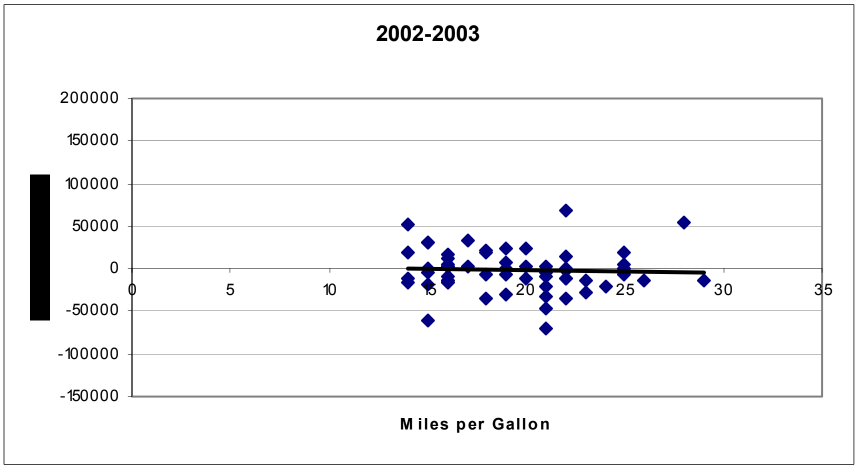
- There was nothing sudden about the shift;.
- It involves much more than a shift from trucks and SUVs to cars (higher fuel economy within vehicle types sells more vehicles); and
- Simply put, it did not take $4 gas to cause the change in consumer behavior, it started at least three years ago when gas was $2.50 per gallon and has been growing progressively.

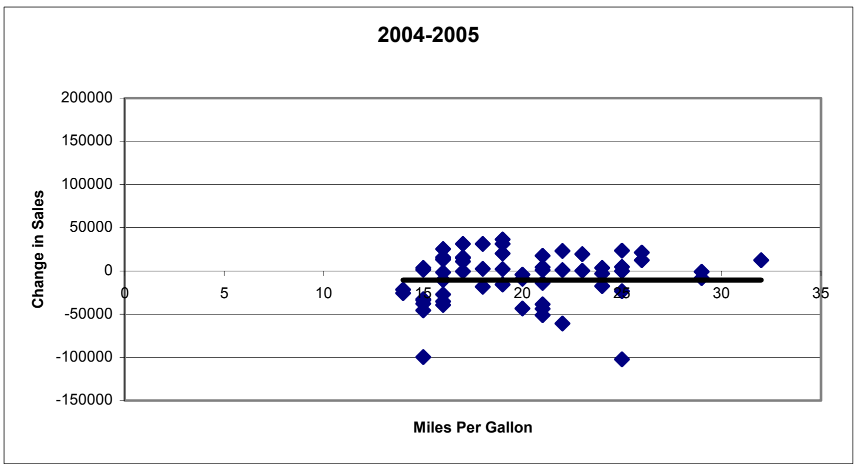
The auto makers not only missed the shift in consumer behavior, they actually tried to resist it by continuing to pump out gas guzzlers and trying to bribe consumers to buy them with rebates and low interest. To examine this issue we compiled a database of the top fifty models in each year and charted their sales (reported by Automotive News) and EPA mileage ratings across time. There is an average of 61 models in each year-to-year comparison (because different models will be included in the top fifty in one year, but not the next). A total of 83 models occurred in the top fifty over this period for which we had sales and mileage data. These models represent an average of approximately two-thirds of all units sold over the period.

Exhibit 6 shows the sales for the top sixty models, plotting EPA mileage ratings (all based on the new method) against the change in sales. From 2003-2005, there was no relationship between fuel economy and sales; the regression line was flat. Starting with the 2005-2006 comparison, there is a relationship; vehicles that got higher mileage fared better in the marketplace. The relationship persisted in 2006-2007 and through the first half of 2008. While the direction of the relationship remained about the same (i.e. the slope of the line did not change much) the relationship became much stronger (the scatter of the observations around the line became smaller in magnitude). In the first half of 2008, the level of fuel economy of the model accounts for over 40 percent of the variance in the change in sales. What about 2006-07 when the shift seems even more dramatic?

The graphs in Exhibit 5 exclude the Prius, which is the only hybrid to be ranked in the top fifty over this period and has been so popular that there have been delivery delays. (It is an outlier and its “poor” performance in recent years is not the result of a lack of demand but, rather, the result of a lack of supply. This is a circumstance that is radically different than that faced by vehicles with conventional engines).

Exhibit 6: Fuel Economy Affects Changes in Sales





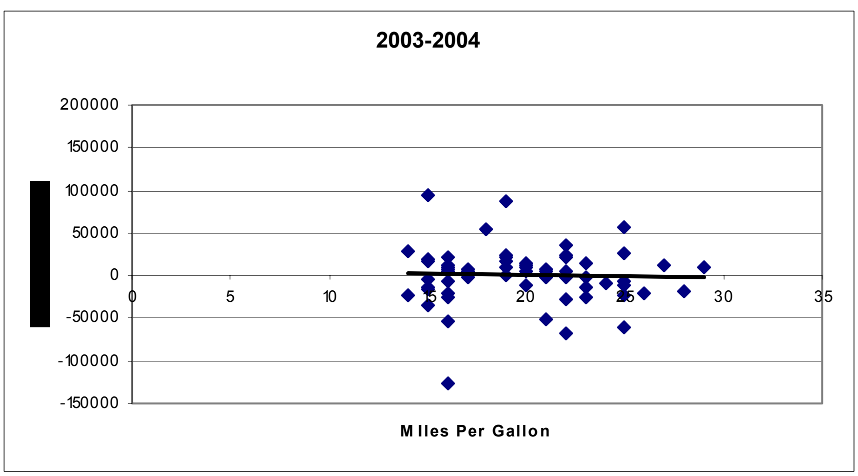
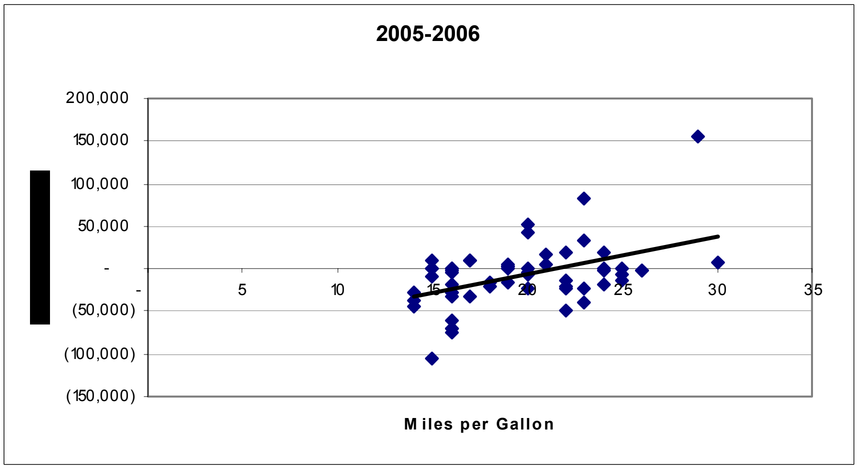
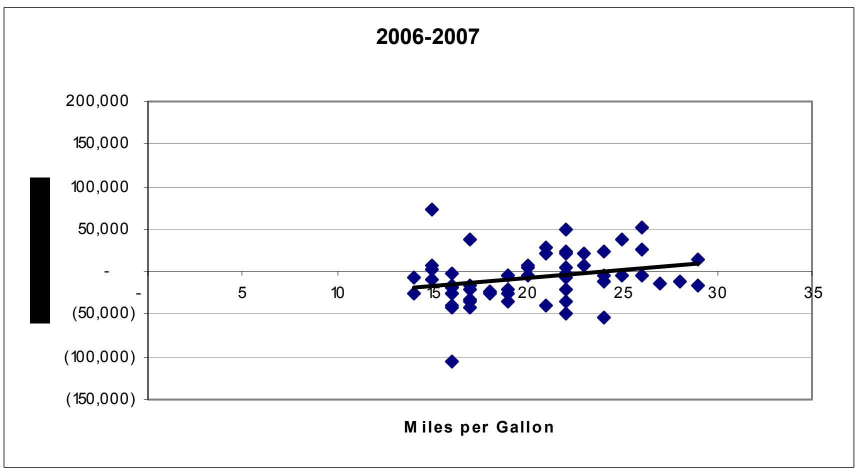
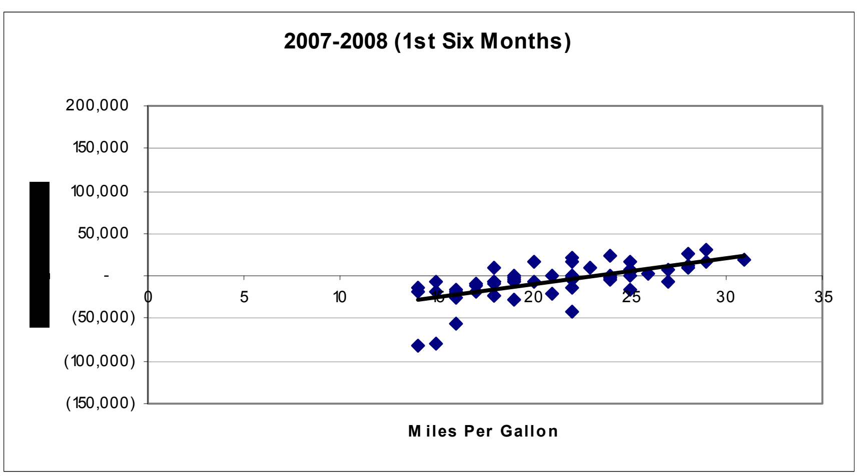


Exhibit 5 (cont'd):



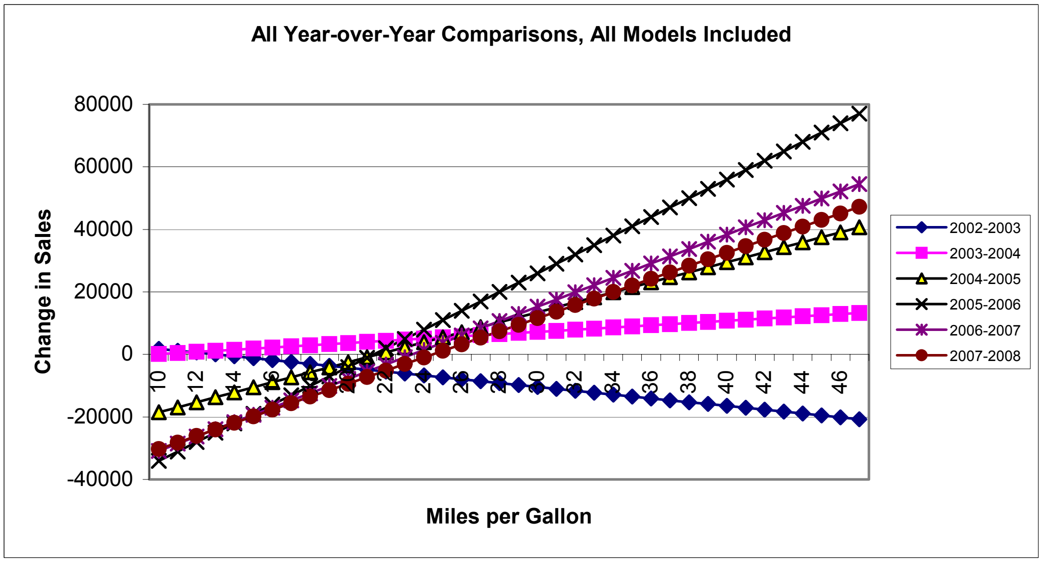


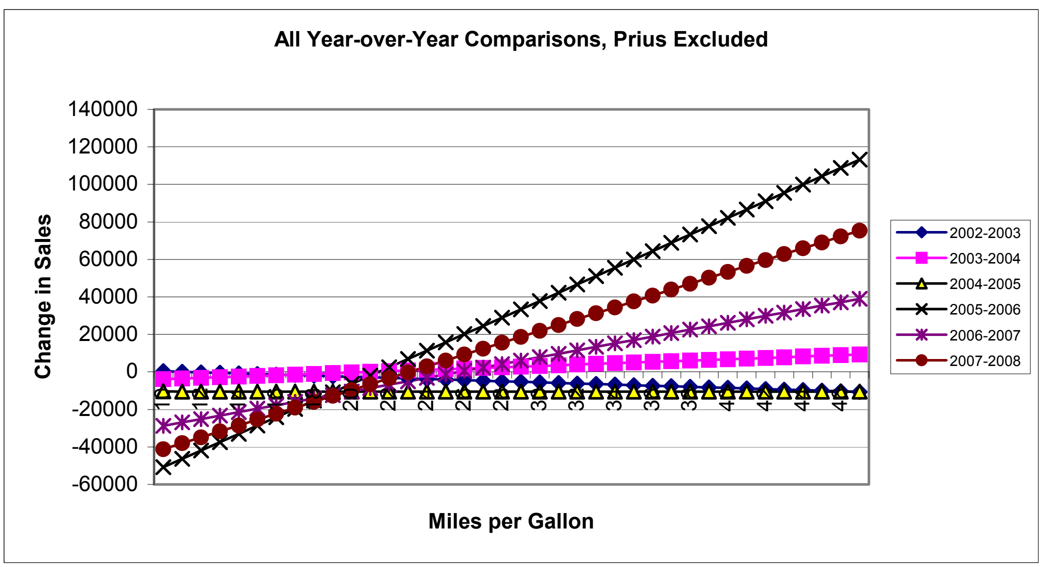


Source: CFA Data Base

Exhibit 7 shows the individual regression lines (without the data points) for all vehicles and vehicles with conventional engines. The graphs show that the shift in the market took place well before the first half of 2008. Including the Prius does not change that conclusion; it merely pushes the data of the market structural change back one year.

Exhibit 7





Source: CFA Data Base

The above analysis concludes that fuel economy played a key part in determining sales in recent years. We explored alternative explanations that might account for the shift in buying patterns. One obvious possibility is a shift in preference away from truck and SUVs. Exhibit 8 shows that the structural shift is not the result of a shift from trucks to cars. We examined this in two ways. In one set of regressions, we introduced trucks as a covariate, to control for the effect of being a truck model as opposed to a car model. Even controlling for the type of vehicle (car v. truck) fuel economy is an important determinant of the change in sales. A second approach is to examine the relationship between fuel economy and sales separately for cars and trucks. Our conclusion that the structural shift occurred well before the first half of 2008 is confirmed and strengthened. The structural shift occurred in 2006 for cars and somewhat earlier (2005) for trucks.

Exhibit 8: Regression Results: Fuel Economy as a Predictor of Sales

Year	All Light Duty Vehicles			All Light Duty Vehicles (Truck Covariate)			Cars Only			Truck Only		
	B	Sig.	R2	B	Sig.	R2	B	Sig.	R2	B	Sig	R2
2002-2003	-297	*	0	1697		3	4511	*	7	-179		0
2003-2004	-354		0	68		0	-624		0	2842		0
2004-2005	-4		0	1036		0	-940		0	4535	**	9
2005-2006	4429	***	21	5463	**	20	3020	*	0	3738		5
2006-2007	1833		2	4487	**	6	4191		6	4878	*	9
2007-2008	3150	***	42	3124	***	41	2752	***	31	3778	**	17

*** p< .10, ** p < .0,*** p < .01**

We also examined the issue of whether the change in mileage for a specific model, year over year, affected change in sales. While all of the coefficients were positive, indicating better mileage was associated with better sales performance, none was statistically significant and all were small. This should not be surprising because the improvement in fuel economy within models was quite small, only 1 mile per gallon, on average, over the five year period from 2002-2005. It is the much larger differences in mileage between models that are having the effect.

CHANGES IN CONSUMER BEHAVIOR IN GASOLINE AND AUTO MARKETS

Thus far we have seen that public opinion and new car sales indicate a clear shift in consumer attitudes toward fuel economy. A recent Congressional Budget Office Study[3] (CBO) explores similar issues and reinforces our findings. What are the effects of high prices on consumption patterns? After four years of rising prices (2002-06), CBO found that when gasoline prices rise significantly, people will:

- Use less gasoline;
- Drive less if they can;
- Drive more slowly;
- Use mass transit where it is available; and
- Buy more fuel-efficient cars, if they can find them.

The formal expression of this relationship in economic analysis is the price elasticity of demand. How much does a particular behavior change in response to a price change? The price elasticity of demand is usually calculated in percentages. A one-percentage point increase in prices that results in a one-percentage decline in the behavior is said to be an elasticity of -1 (-.01/+.01 = -1). CBO studied a variety of behaviors and calculated the elasticity of demand – the percentage change in a particular behavior in response to a change in gasoline prices. As Exhibit 9 shows, there is a small, negative price elasticity. The short- run elasticities are considerably less than -.1. A one percent increase in price leads to a reduction in consumption or changes in behavior that reduce consumption of less than one-tenth of one percent. In the long run, the elasticities are somewhat higher -.2 to -.4, but still quite low compared to other commodities. Moreover, the elasticity of demand has declined over time and is likely to continue to do so.

> *For a variety of reasons, consumers are currently only about one-fifth as responsive to short-run changes in gasoline prices as they were several decades ago. That decline in sensitivity has been attributed to growth in real income, which has rendered gasoline a smaller share of consumers' purchases from disposable income. Price sensitivity has also declined because a gallon of gasoline takes a car farther than it did in the past, in part because of fuel economy standards. The development of distant suburbs also has contributed by making consumers more reliant on the automobile. The longer commutes are balanced by lower housing costs.*[4]

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[3] Congressional Budget Office, *Effects of Gasoline Prices on Driving Behavior and Vehicle Markets*, January 2008.

[4] CBO, Effects of Gasoline Prices, pp. x-xi.

Exhibit 9: Price Elasticities of Demand for Various Gasoline Consumption-Related Behaviors Compared to Selected Other Products

Product	Study Trait	Period of Impact Short-terms	Long-term
Gasoline Related[a]			
Consumption	CFA (1997-2005 Expenditures)		-.28
	Recent	-.06	-.40
	1994-2006	-.02 to -.04	
	Higher prices	-.066 to -.074	
	1974-1989	-.05 to -.08	
	Older		-.38 to -.43
Travel Speed	CBO	-.06	
	Recent	-.05	
	Older		-.35
Miles Traveled	CBO	-.035	
	Recent	-.02 to -.03	-.11 to -.15
	Older	-.1 to -.16	-.26 to -.31
New Vehicle	CBO truck-car		
Fuel Economy	Switch to cars	.28	
(improvement)	CFA Implicit mpg	.1	
	CFA	.1	
Other Commodities[b]			
Eggs			- .1
Gasoline			- .2
Shoes			- .9
Foreign Travel			-1.2
Alcoholic Beverages			-1.5
Jewelry			-2.6

a) Congressional Budget Office, Effects of Gasoline Prices on Driving Behavior and Vehicle Markets (Washington, D.C.: January 2008).
b) Jon B. Taylor, *Economics* (Boston: Houghton Mifflin, 1998), *p*. 99.

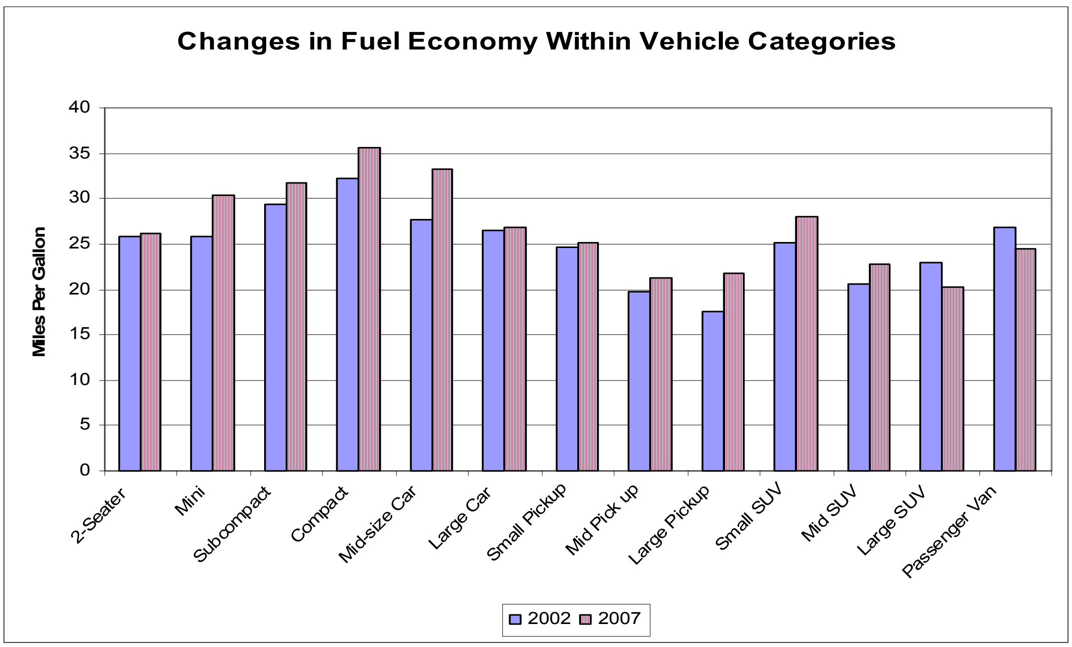
To track the trends in vehicle fuel economy, the CBO relied on Environmental Protection Agency (EPA) mileage estimates and auto sales from *Automotive News.* CFA compiled a database on fuel economy and sales using NHTSA data.[5] Our analysis includes more recent data than was used by the CBO, allowing us to extend some analyses to 2007 with preliminary sales data. We find similar patterns of shifts to more fuel-efficient vehicles in consumer purchasing behavior, and with these data, we can explore some important aspects of the automotive market in greater detail.

[5] Jack Gillis and Mark Cooper, *Still Stuck in Neutral: America's Continued Failure to Improve Motor Vehicle Fuel Efficiency: 1996:2005,* July, 2007, available at http://www.consumerfed.org/pdfs/Still_Stuck.pdf; Jack Gillis, Stuck *in Neutral: America's Failure to Improve Motor Vehicle Fuel Efficiency: 1996-2005,* November 2006; available at http://www.consumerfed.org/pdfs/Stuck_in_Neutral.pdf.

As gasoline prices rise, people switch from less fuel-efficient trucks to cars. As the CBO noted, "Price spikes in the spring of 2005, in October 2005 (after Hurricane Katrina), and in the spring of 2006 all coincided with sharp increases in the new-car market share. Market shares for leading categories of light trucks – especially SUVs – went the opposite way, dipping as gasoline prices rose."[6] In our data, with annual sales, the shift is 2.3 percent. Applying the shift coefficient calculated by CBO to the average difference between cars and trucks in our data, we find that the switch results in an improvement of fuel economy of about .1 percent for every 1 percent increase in gasoline prices. We arrive at a similar estimate by calculating the change in the fleet average fuel economy compared to the average real price of gasoline.

One of the key findings of the CBO study is that fuel economy improved both because consumers shifted their purchases away from less fuel-efficient types of vehicles (trucks and large SUVs) and because "the average fuel economy of cars and light trucks alike have been increasing since 2002."[7] Our data shows (see Exhibit 10)

Exhibit 10:



Source: Mark Cooper, *Ending America's Oil Addiction* (Washington, D.C.: Consumer Federation of America, April 2008).
http://www.consumerfed.org/pdfs/First_Quarterly_Gas_Report_2008.pdf

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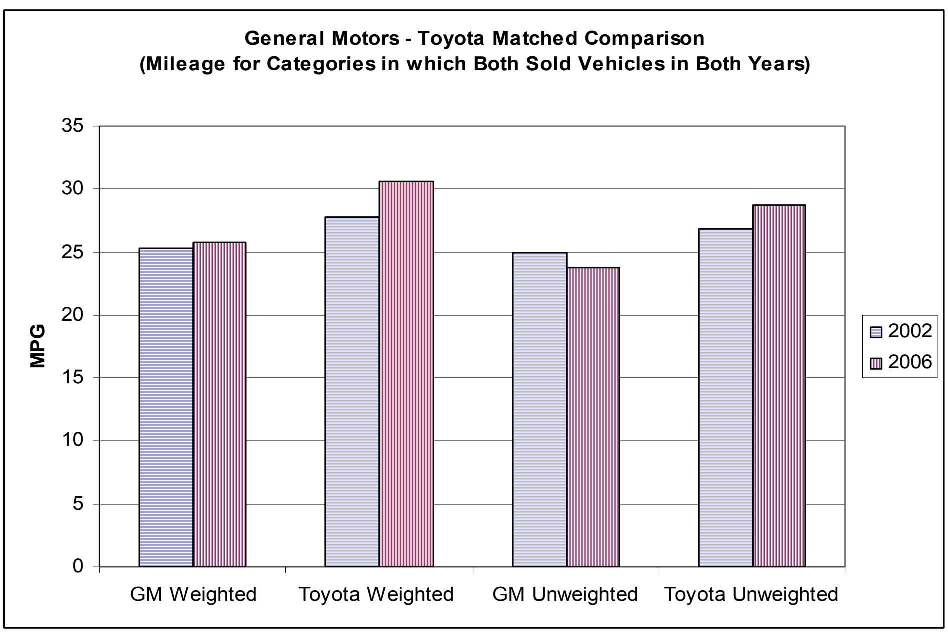
[6] CBO, Effects of Gasoline Prices, p. 16.

[7] CBO, Effects of Gasoline Prices, p. 20.

that the overall improvement in fuel economy was just under one mile per gallon (for 2002-2006) and 2 miles per gallon for 2002-2007; much less than consumers now say they want (8 mpg). And, the improvement in the fuel economy within the individual categories of cars and light trucks is uneven. The largest improvements came in minis, compacts, and mid-sized cars. Passenger vans and large SUVs did not improve much (which is why sales plummeted). While many consumers shifted to smaller more fuel-efficient vehicles, those who required larger vehicles could not find the fuel- efficiency they needed and wanted.

Fuel economy improvement was also very uneven across auto manufacturers. One of the more dramatic aspects of the past half-decade has been the competition between General Motors (GM) and Toyota for the top spot as the leader in sales in the American auto market. The following figure shows the average fuel economy for GM and Toyota based only on categories of cars in which both had sales in 2002 and 2007 (see Exhibit 11). This graph matches the two automakers by categories of product sold for which they compete head-to-head. It shows both the sales-weighted average fuel economy (mpg) and the unweighted average of the individual models they marketed. For Toyota, both the weighted and unweighted fuel economy averages improved. Toyota's mileage improved both because consumers shifted their purchases to more fuel-efficient categories of vehicles and Toyota offered, on average, significantly more fuel-efficient models. GM's average fuel economy improved because consumers shifted their sales between categories, but GM did not offer, on average, a significantly more fuel-efficient slate of models.

Exhibit 11:



Source: Mark Cooper, *Ending America's Oil Addiction* (Washington, D.C.: Consumer Federation of America, April 2008). **http://www.consumerfed.org/pdfs/First_Quarterly_Gas_Report_2008.pdf**

We were able to test the proposition that fuel economy became more important to consumers over the period since 2002 with an econometric model of fuel economy (see Exhibit 12). After controlling for the key vehicle characteristics that affect fuel economy (vehicle weight, engine traits like horsepower, displacement, number of cylinders, transmission type, drive ratio, dynamometer setting, wheel base, interior volume), each year after 2002, there was a statistically significant, though small, improvement in the fuel economy of cars. For cars, the effect became steadily larger over time. A car sold in 2006 got 2.377 more miles per gallon than one built in 2002, controlling for all the other factors included; for trucks, the increase was .879 miles per gallon.

Exhibit 12: Linear Regressions to Examine Factors Affecting Fuel Economy
(Unit of Analysis is the Sales Weighted Model)
(Regression Coefficients, All Statistically Significant at the .001 level)

Variable	Cars		Trucks	
	Fuel Economy	Product Sales	Fuel Economy	Product Sales
2003	.0662	15456	.982	10120
2004	1.084	-148	.482	-5090
2005	1.758	16763	.869	-16488
2006	2.377	3936	.879	-24092
Fuel Economy	na	945	na	.823
R^2	.56	.32	.24	.12

Control variables: engine (horse power, displacement, cylinders), body (weight, wheel base, interior volume); transmission type, drive ratio, dynamometer setting;
all coefficients are significant at the .05 level or higher

Truck sales were down 24,092 in 2006, compared to 2002; controlling for all the other factors, car sales were up 3,936. For trucks, the effect was large in 2003, declined in 2004 and rebounded in 2005 and 2006. We also find that fuel economy was positively related to product sales. We find the negative effect on truck/SUV sales in 2004, 2005, and 2006, with the effect growing larger over time. This is consistent with the CBO findings. In addition to the shift from trucks to cars and after controlling for all the other factors, a one mile per gallon increase in fuel economy resulted in an additional sale of just under 1,000 more cars and trucks for each model.

CONCLUSION

Over the past three or four years there has been a dramatic shift in the auto market, a shift that is not but should be reflected in NHTSA's approach to setting fuel economy standards. The automakers and NHTSA are looking backward, but consumers are looking forward. If the desire and willingness of consumers to purchase more fuel efficient vehicles were fully recognized in NHTSA's analysis, it would have proposed a much higher standard because erroneous assumptions about consumer attitudes constrain the extent to which fuel savings technologies influence the standard. Correcting underlying economic assumptions of the proposed fleet wide fuel economy rules for 2011-2015 would result in a higher range of alternatives examined in the DEIS, and greater environmental benefits as a result.

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ENDING AMERICA'S OIL ADDICTION:

A QUARTERLY REPORT ON CONSUMPTION, PRICES AND IMPORTS FIRST QUARTER, 2008

MARK COOPER,
DIRECTOR OF RESEARCH

APRIL 2008

D-1412

PURPOSE OF THE QUARTERLY REPORT

For the past several years, the Consumer Federation of America (CFA) has actively supported increased fuel economy standards. Our analysis shows that higher fuel economy is good for consumers, the nation, and the environment.[1] The enactment of the Energy Independence and Security Act of 2007 (EISA), which set the goal of increasing the fuel economy of new cars and light trucks by approximately 40 percent to 35 miles per gallon (mpg) by 2020, is a necessary step in the right direction. But it is only the first of many steps required to achieve the reductions in gasoline consumption necessary to protect consumers' pocketbooks, reduce the impacts of global warming, and alleviate risks to national security posed by our addiction to oil.

While EISA sets an important goal, it does not guarantee we will achieve it. First, the National Highway Traffic Safety Administration (NHTSA),[2] which is responsible for setting the incremental standards between now and 2020, must do so in a manner that ensures steady progress toward the goal. Second, consumers have to buy the more fuel-efficient cars that actually get better mileage. If the agency sets lax goals and consumers do not migrate toward more fuel-efficient cars, then the auto manufacturers will put pressure on the Congress to lower the standards. This has happened before, in the 1990s.

Thus, the public mobilization that drove Congress to enact this landmark legislation must be maintained as the new rules are written and new vehicles roll off the assembly line. To help sustain that vigilance, CFA is launching this quarterly report on what President Bush called our national "oil addiction." The goal is to both remind the public and policy makers what is at stake and to measure whether or not progress is truly being made.

Gasoline consumption imposes huge economic, environmental, and national security costs on the nation. Our quarterly report provides key indicators of these costs:[3]

- Expenditures on gasoline is an indicator of consumer costs;
- Quantity of gasoline consumed is an indicator of greenhouse gas emissions;
- Oil imports are a measure of national security vulnerability.

---

[1] Mark Cooper, *50 by 2030 Why $3.00 Gasoline Makes the 50 MPG Car Feasible, Affordable and Economic* (May 2006), available at http://www.consumerfed.org/pdfs/50_by_2030.pdf; A *Blueprint for Energy Security: Addressing Consumer Concerns About Gasoline Prices and Supplies by Reducing Consumption and Import* (May 2006) available at http://www.consumerfed.org/pdfs/Energy_Blueprint.pdf; Mark Cooper, *Too Little, Too Late: Why The Auto Industry Proposal To Go Low And Slow On Fuel Economy Improvements Is Not In The Consumer Or National Interest* (Consumer Federation of America, July 2007) available at http://www.consumerfed.org/pdfs/Auto_Industry_Proposal.pdf; Mark Cooper, *Technology, Cost and Timing: An Analysis of Competing Congressional Proposals to Raise Fuel Economy Standards) Washington, D.C.: Consumer Federation of America, July 2007) available at* http://www.consumerfed.org/pdfs/Technology_Cost_Timing.pdf;

[2] See Mark Cooper, *A Consumer Pocketbook and National Cost Benefit Analysis of "10-in-10,"* (June 2007), for analysis of some of NHTSA's problems, available at http://www.consumerfed.org/pdfs/CFA_Cost-Benefit_Analysis_of_10_in_10,_June_07.pdf; *A Step Toward A Brighter Future: Policymakers Break the log Jam, But Vigorous Implementation is Crucial* (December 2007, available at http://www.consumerfed.org/pdfs/Brighter_Energy_Future_12-18-07.pdf.

[3] Data for these analyses are from the Energy Information Administration database, available at www.eia.doe.gov. Where monthly numbers are not yet available, four-week averages are used.

This inaugural quarterly report provides historical context by examining long term trends for each major indicator, presented as quarterly results over long periods (20 to 50 years). The long term trends are clear despite strong seasonal patterns of gasoline consumption and expenditures. These trends provide lessons about past behavior that are important to understand in order to achieve the goal of 35 mpg by 2020.

This quarterly report also presents the results for the first quarter of 2008, and future reports will focus on each quarter separately. Comparing same quarter results over time eliminates seasonal variation. Thus, the following exhibits show the first quarter for each year going back to 1990.[4] The winter/spring quarter has traditionally been a period of slack demand for gasoline and moderating prices, although the latter is not the case this year.[5]

The analysis of trends in consumption and price reflects a complex set of factors that affect consumption patterns. A key determinant of the future effectiveness of policies to reduce gasoline consumption is consumer attitudes. What consumers believe about the energy situation and how it affects them strongly influences their behaviors. Over the past several years, CFA has charted consumer responses to critical questions, such as their perception of future gasoline prices, concern about the impact of oil consumption on national security and the environment, and their response or intended response to gas price and fuel economy changes.[6] CFA will continue to survey and chart consumer attitudes about these issues across time.

This report also examines the factors that affect the fuel economy of the vehicle fleet and the influence of fuel economy on consumer vehicle purchases. This is an obvious place to start as the critical challenge is, ultimately, to get automakers to make and consumers to buy more fuel-efficient vehicles.

[4] This report uses 1990 as the starting date for current analysis because that was the year in which Clean Air Act Amendments affecting the refining industry were enacted. Although the Amendments did not take effect until 1995, the refining industry began its strategic response to the new law in the early 1990s.

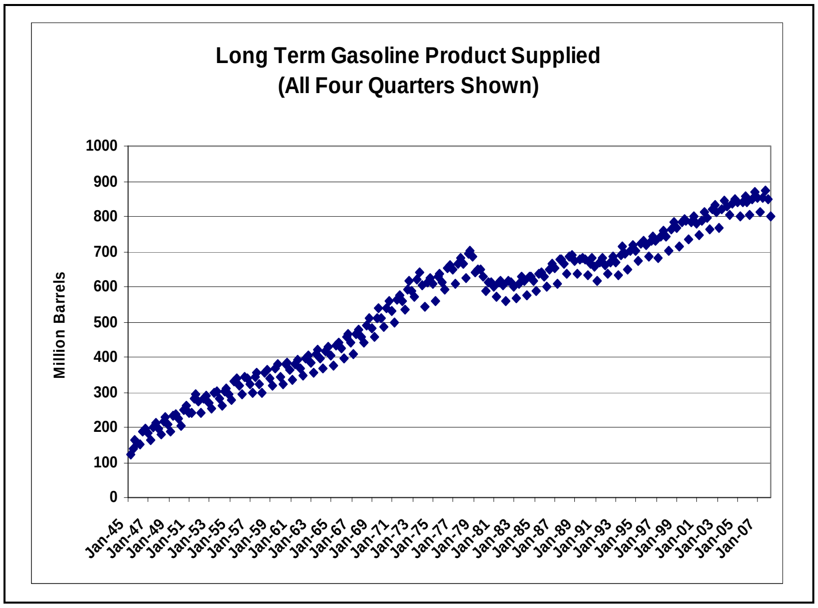
[5] Mark Cooper, *Rising Gasoline Prices: Why Can't Consumers Catch a Break*, March 2008, available at http://www.consumerfed.org/pdfs/2008gasolineprices.pdf; Mark Cooper, "The Failure of Federal Authorities to Protect American Energy Consumers from Market Power and Other Abusive Practices," *Loyola Consumer Law Review,* 19:4 (2007) available at http://www.luc.edu/law/activities/publications/clrdocs/vol19issue4/mark_cooper.pdf.

[6] Consumer Federation of America, *Americans Alarmed About Dependence on Oil Imports and Resulting High Gas Prices and Funding Terrorism*, May 1, 2007 available at http://www.consumerfed.org/pdfs/CFA_For_Immediate_Release052107.pdf.; Consumer Federation of America, *Consumers Still Greatly Concerned About Better Gas Mileage and Oil Imports Despite Falling Gas Prices*, November 13, 2006, available at http://www.consumerfed.org/pdfs/Gas_Mileage_Consumer_Attitudes_Manu_Performance_Press_Release111306.pdf; Consumer Federation of America, available at http://www.consumerfed.org/pdfs/GasPricesRelease090105.pdf

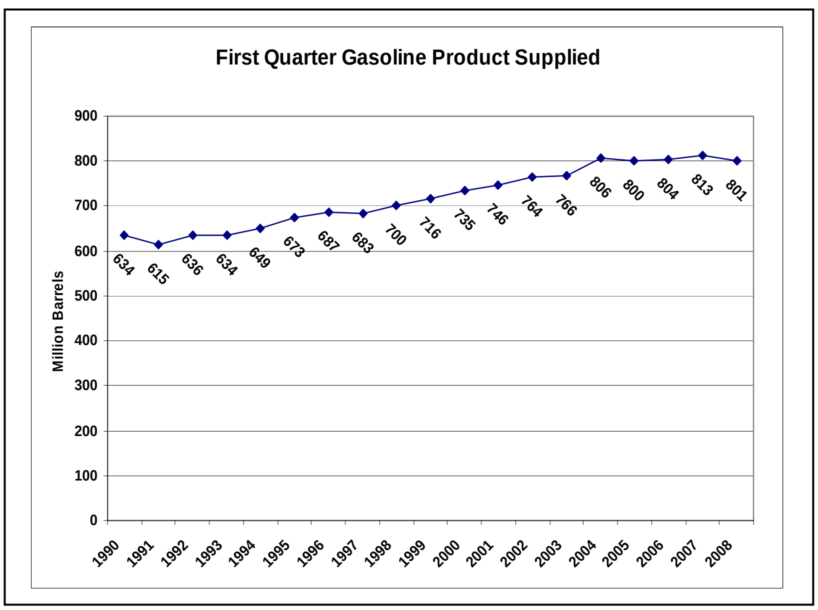
TRENDS IN CONSUMPTION, EXPENDITURES AND IMPORTS

GASOLINE PRODUCT SUPPLIED[7]

The long term trend in gasoline consumption has four dates of interest: 1973, 1979, 1992, and 2004. After 1973, there is a slight shift downward when the Arab oil embargo occurred. The Iranian revolution in 1979 shows a much larger shift downward. And, while growth in consumption occurred after this one-time adjustment, it was much slower than before, even though gas prices declined somewhat. We suggest that this trend in consumption reflects the passage of Corporate Average Fuel Economy standards (CAFE) in 1975, which required automakers to double t he fuel economy of their cars. When CAFE requirements stopped increasing, consumption of gasoline took off again as is evident in the upward trend after 1992. Since gasoline prices were stable and relatively low, auto manufacturers had no incentive to improve fuel economy on their own.



The fourth point of interest is the trend since 2004 when the growth rate of gasoline consumption has flattened and begun to decrease. This is most apparent in the “First Quarter Gasoline Product Supplied” graph. The quantity of gasoline supplied in the first quarter has been just about flat since 2004. And in the first quarter of this year, we have seen an actual decline in the level of

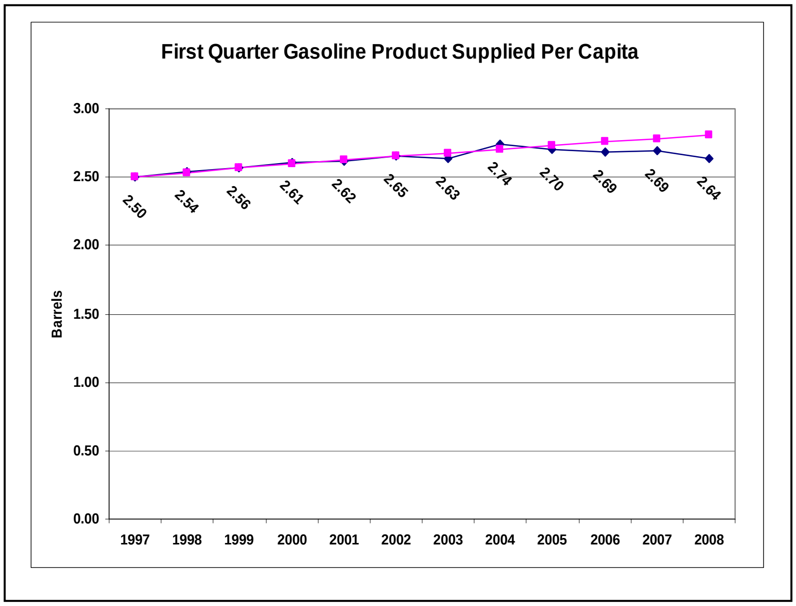


[7] The product supplied is generally equal to the amount consumed (plus minor adjustments in inventories).

gasoline supplied, which generated considerable interest and analysis.

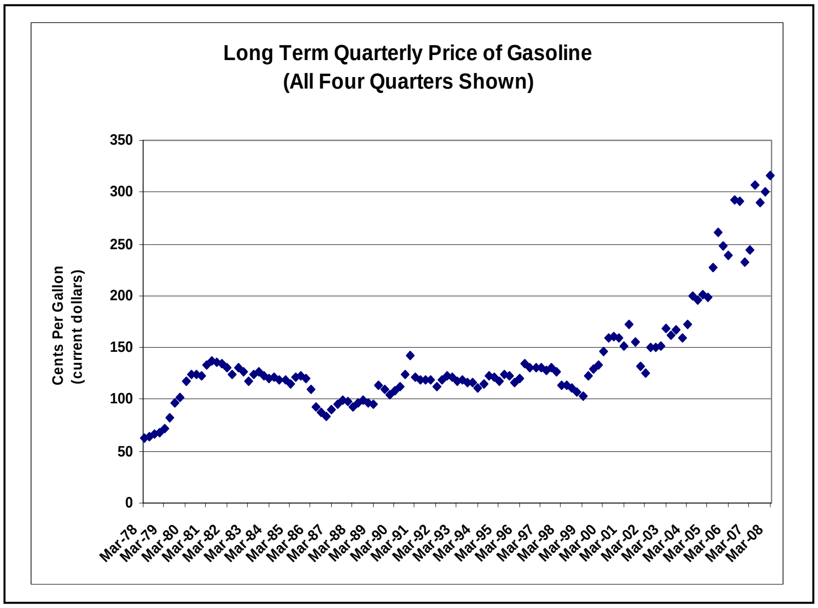
The change in trends since 2004 becomes quite apparent if we look at the past decade and add in the factor of population growth. Calculating gasoline consumption per capita, gasoline consumption is down by 6 percent, compared to what would have been predicted based on the growth of consumption in 1997-2004.

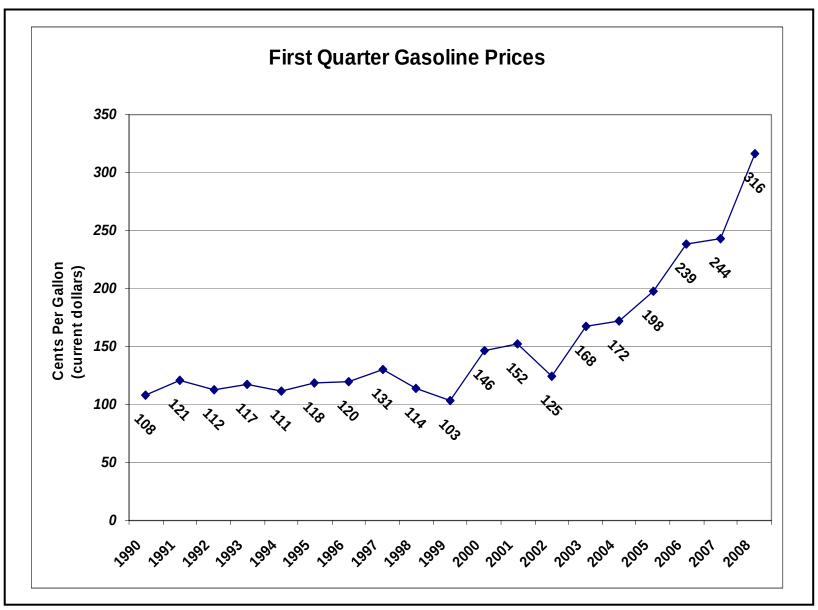
The product supplied or gasoline consumed is a critical indicator of greenhouse gas emissions. Carbon dioxide (CO2) is the most significant greenhouse gas, accounting for about 85 percent of total U.S. emissions. Automobiles emit approximately 19.4 pounds of CO2 for every gallon of gasoline consumed. Moreover, the extraction, refining, and distribution of gasoline cause additional emissions, so the total amount of CO2 emitted per gallon consumed is about 23.9 pounds. Thus, in the first quarter of 2007, U.S. consumption of gasoline, which was more than 800 million barrels, or 34 billion gallons, resulted in about 400 million tons of CO2 emitted into the atmosphere. The reduction in the growth of consumption that began in 2005 indicates a substantial lowering – as much as five percent -- of consumption by 2008, which equals a reduction of more than 25 million tons of CO2 in the first quarter that otherwise would have been released into the atmosphere.



GASOLINE PRICES

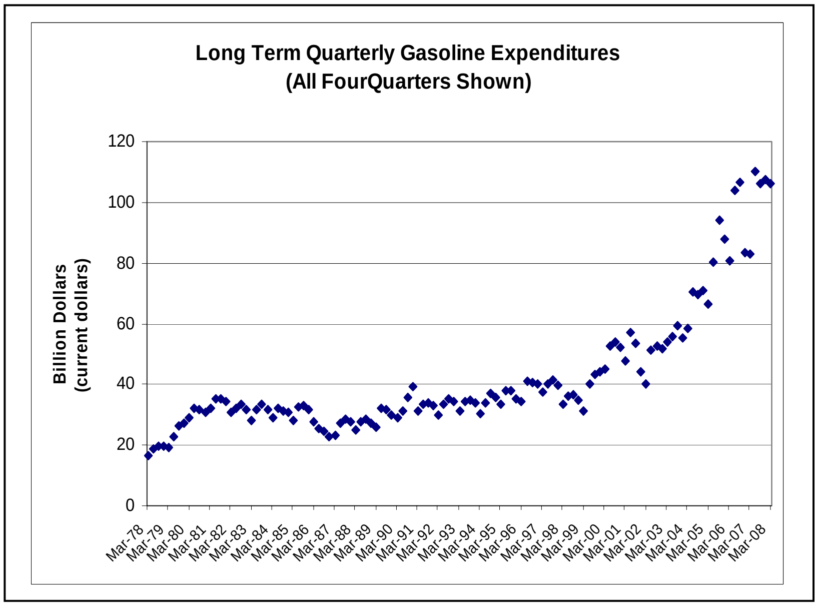
The sharp run-up in gasoline prices over the last six years is in part responsible for the recent downturn in gasoline consumption. The price shock associated with the Iranian revolution in 1979 was about $.75 per gallon, or almost 120 percent. Prices remained stable for several years and then declined a few years later. (Yet, as explained above, the rate of growth of gasoline consumption moderated. Recall that the lower rate of growth of gasoline consumption persisted, which we contend demonstrates the impact of CAFE.) The increase in gasoline prices since 2002 rivals the Iranian Revolution price shock, though this time, prices have continued to rise over a longer period of time. The price today is over 150 percent higher than in 2002, with an increase of almost $2.00 per gallon.

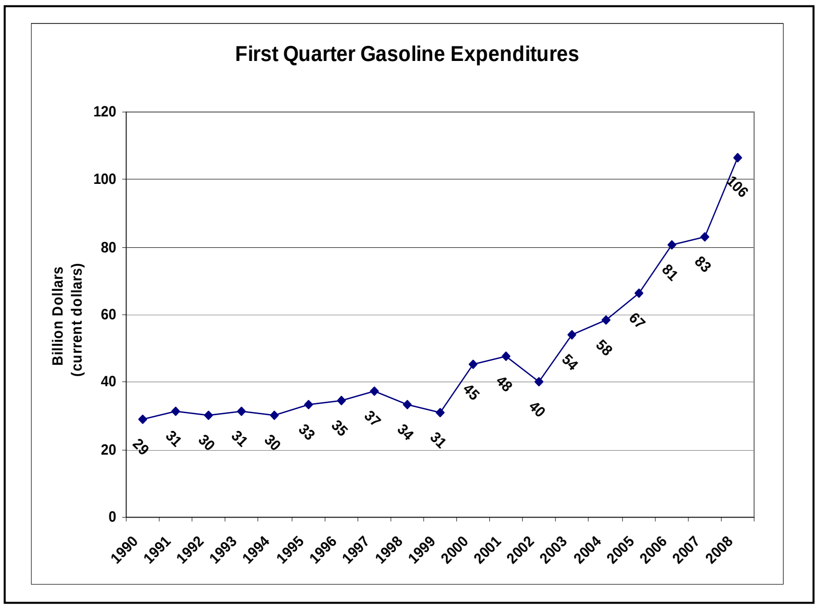




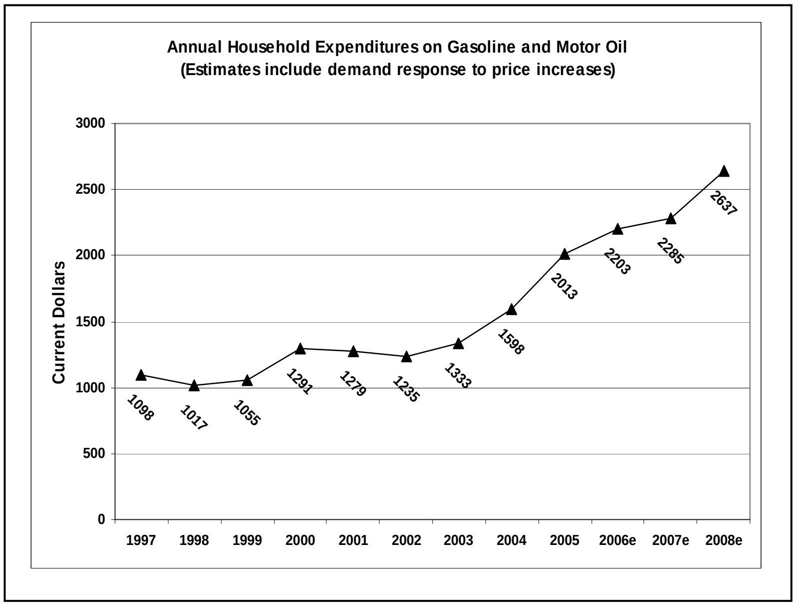
GASOLINE EXPENDITURES

Rising prices have driven total annual gasoline expenditures through the roof, climbing from $40 billion in the first quarter of 2002 to more than $100 billion in the first quarter of 2008. This increase in expenditures averages almost $350 per household in direct gasoline expenditures per quarter and the equivalent of another $250 per household of indirect expenditures. Consumers are unable to cut back on gasoline expenditures even though prices are rising sharply for a number of reasons, e. g. residential housing patterns that create long commutes and frequent auto trips for shopping and daily activities; lack of fuel-efficient vehicles, and scarcity of alternative transportation. Because consumers cannot easily cut back on their consumption, the increase in price causes expenditures on gasoline to take a larger and larger share of household budgets.



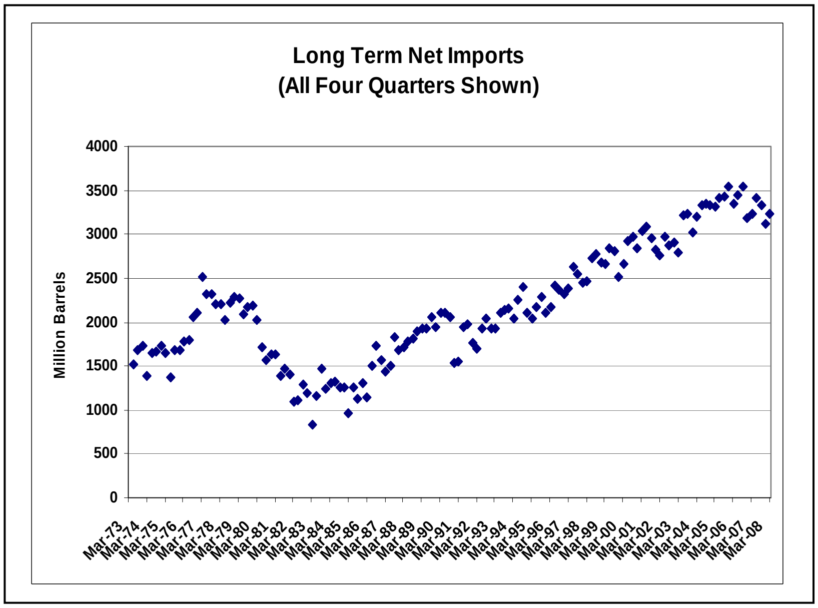


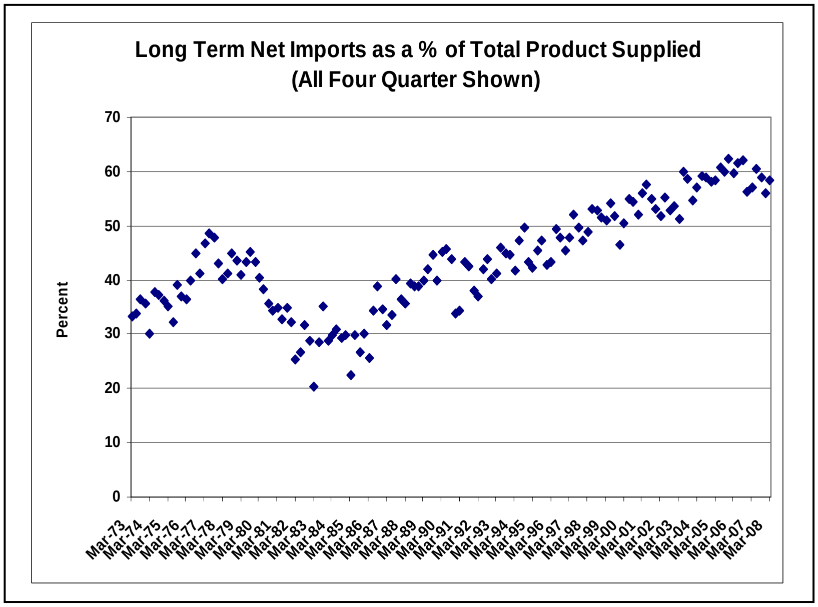
Data on household expenditures is available from the Bureau of Labor Statistics for 1997 through 2005. As the figure on the following page shows, since the late 1990s household expenditures on gasoline and motor increased by 2.5 times. Since 2002 alone, household expenditures have more than doubled. The estimates of household expenditures include the response to price increases described later in this report.


Annual Household Expenditures on Gasoline and Motor Oil
(Estimates include demand response to price increases)
Current Dollars
3000
2500
2000
1500
1000
500
0
1098
1017
1055
1291
1279
1235
1333
1598
2013
2203
2285
2637
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006e
2007e
2008e

NET IMPORTS

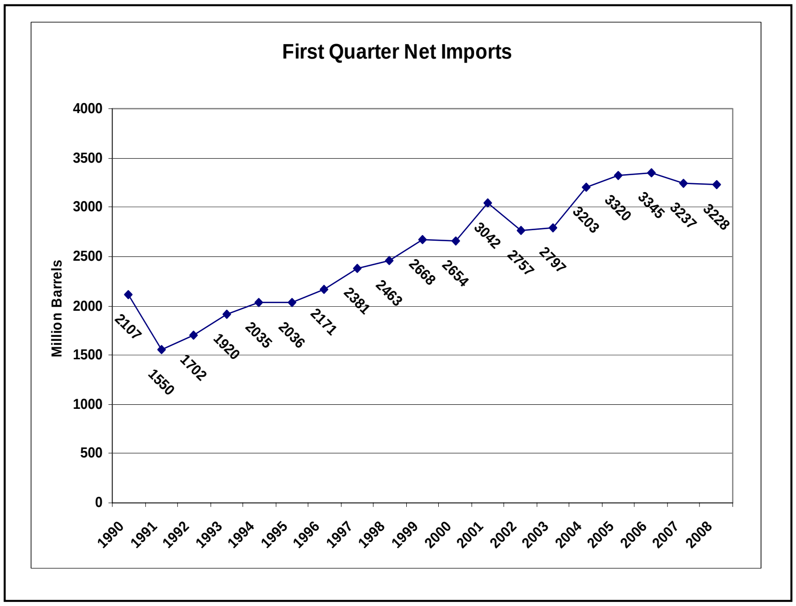
Only 3 percent of the world oil reserves are located in the United States, but the U.S. consumes more than 25 percent of the world's petroleum products. Because the U.S. simply does not have the crude oil resources to keep up with rising gasoline consumption, oil imports have skyrocketed. Gasoline accounts for about 40 percent of all petroleum products supplied to U.S. consumers, and when all vehicle fuels are included, that share increases to about 50 percent. This consumption drives the demand for imported crude oil and refined products. In fact, in recent years, the import of gasoline has more than doubled.





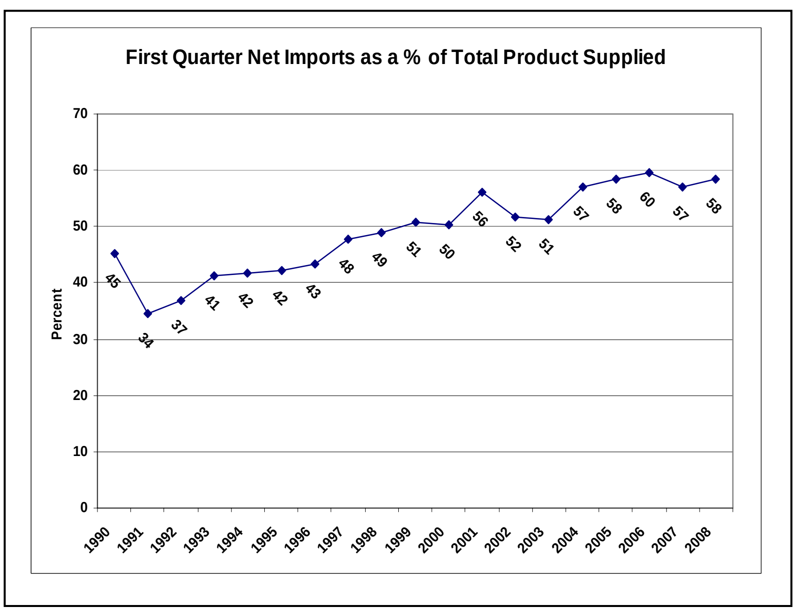
There are two important ways to look at imports– the absolute level of imports and imports as a percentage of total product supplied. The trend in imports tells a story similar to the gasoline consumption patterns described earlier. Imports declined in response to the Iranian price shock (as a result of both production increases and easing demand growth). Imports held steady through the 1980s but began a relentless march upward in the 1990s. The huge increase in imports creates a drag on the economy, as hundreds of billions of dollars are exported, and a threat to security as nations that are hostile to our national interests are enriched.

The increase in our dependence on imports can be seen in the calculation of the percentage of total product supplied that is imported, either as crude oil or as refined product. From an average of about 25 percent in the 1980s, imports grew to about 60 percent of our total product supplied at the start of the 21st century. We are utterly dependent on imports to meet our needs, which is quite apparent in the first quarter statistics.



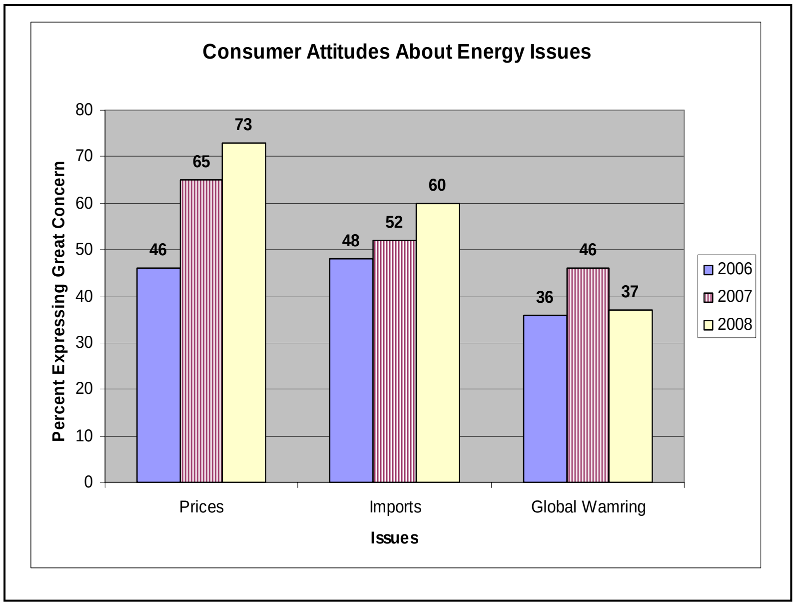
There is an indication that import growth has moderated in the last few quarters. This likely reflects a combination of easing demand growth and increasing supply, except that unlike in the 1980s when the increase in supply was domestic crude, this time, biofuels appear to be playing a role on the supply-side.

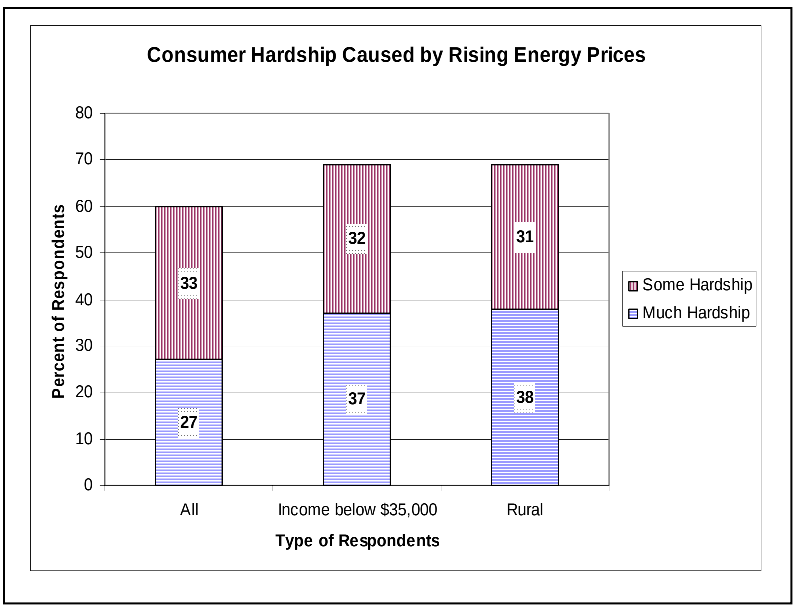
In analyzing both the overall gasoline consumption and the historical trends for imports, we observe a troubling pattern that should inform efforts to achieve the long-term goal of reducing national oil consumption. In both cases, history reveals short-term consumption shifts after price shocks that then return to higher growth rates. It will be critically important to avoid this pattern in the future if we are to achieve the ultimate goal of 35 mpg by 2020. In the 1980s, strong CAFE standards ensured improving fuel economy and moderating growth of gasoline consumption despite steady gasoline prices. In the coming decade, stringent CAFE rules can help ensure the same result.



CONSUMER ATTITUDES

Over the past 18 months, on three occasions CFA commissioned surveys by the Opinion Research Corporation (ORC) of a representative sample of more than 1000 adult Americans on energy issues.[8] During this period, the surveys revealed that Americans' concerns about gas prices and oil import dependency dramatically increased. In response to the question – "Thinking about the next five years, how concerned personally are you about gasoline prices, U.S. dependency on Mid Eastern oil, and global warming?" -- the proportion expressing "great concern" (5 on a 5-point scale) about gas prices rose 27 percentage points to 73 percent, and the proportion expressing great concern about oil import dependency rose 12 percentage points to 60 percent.

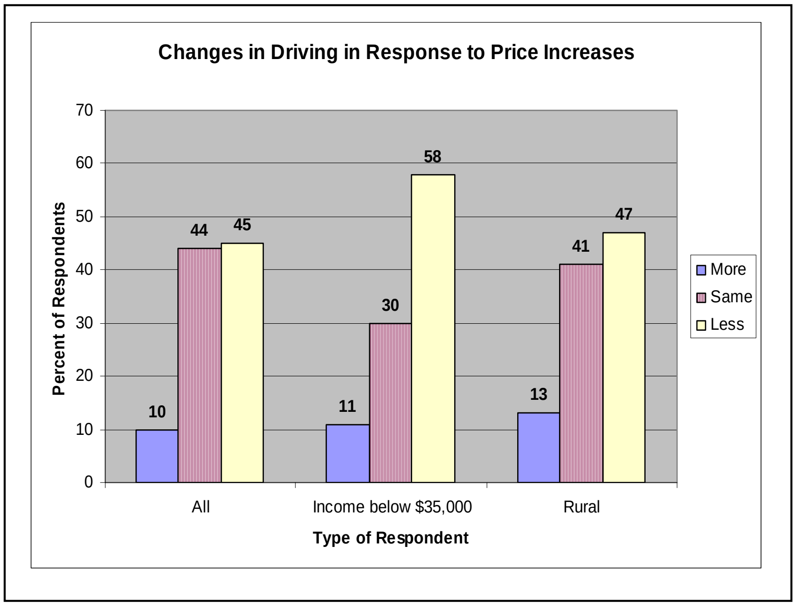




Thus, it is not surprising that most Americans surveyed recently said that gasoline costs have imposed financial hardship on them or their families. Earlier this month, in response to the ORC survey, three-fifths of respondents (60 percent) indicated that rising gasoline prices had caused them much or some hardship, with 27 percent reporting much hardship. Sixty-nine percent of those with incomes below

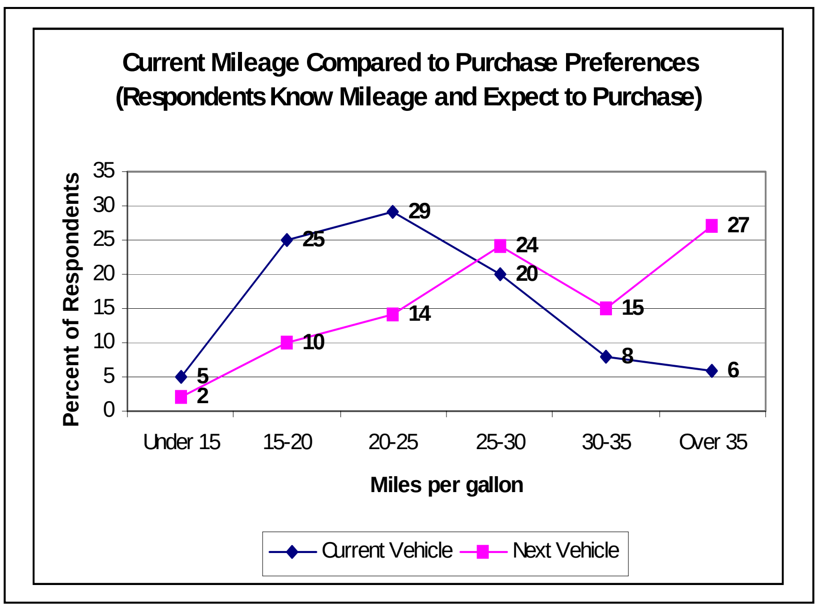
[8] The recent CFA survey of 1,004 representative Americans was conducted by Opinion Research Corporation (ORC) during the first week of April. Earlier CFA surveys were conducted by ORC in July 2007 and October 2006. The margin of error in all surveys is plus or minus three percentage points.

$35,000 reported much or some hardship, with 37 percent indicating much hardship. And 69 percent of those outside metropolitan areas reported much or some hardship, with 38 percent indicating much hardship.



The most recent survey also helped reveal how Americans are responding to this hardship. When asked earlier this month whether they were driving more or less than a year ago, 45 percent of respondents said less, and only 10 percent said more. Lower income households were more likely to say that they were driving less (58 percent compared to 45 percent for all respondents).

But even more significant is a comparison between the mileage of the vehicles consumers currently own and the mileage they would like to get from their next vehicle. Americans said they planned to increase the gas mileage of the next vehicles they purchase, compared to those they currently drive, by nearly 7 miles per gallon (from a median for current vehicles of 23.6 to 30.4). Forty-two percent say they intend to purchase vehicles with an average mileage over thirty miles per gallon, but only 14 percent say that is the mileage that their current vehicles get. Twenty-seven percent said they intend to purchase a vehicle that gets more than 35 mpg, whereas only 6 percent say they currently own a vehicle that gets that level of mileage.



CHANGES IN CONSUMER BEHAVIOR IN GASOLINE AND AUTO MARKETS

A recent Congressional Budget Office Study[9] (CBO) explores a question posed by and confirms the findings of our quarterly reports. What are the effects of high prices on consumption patterns? After four years of rising prices (2002-06), CBO found that when gasoline prices rise significantly, people will:

- Use less gasoline;
- Drive less if they can;
- Drive more slowly;
- Use mass transit where it is available, and
- Buy more fuel-efficient cars, if they can find them.

Much of our analysis of consumption, prices, and expenditures is consistent with the CBO findings. We saw very large increases in prices and expenditures and recently, very modest declines in consumption.

The formal expression of this relationship in economic analysis is the price elasticity of demand. How much does a particular behavior change in response to a price change? The price elasticity of demand is usually calculated in percentages. A one percentage point increase in prices that results in a one percentage decline in the behavior is said to be an elasticity of -1 (-.01/+.01 = -1). CBO studied a variety of behaviors and calculated the elasticity of demand – the percentage change in a particular behavior in response to a change in gasoline prices.

In one sense, these results are encouraging from the point of view of ending the nation's oil dependence. People behave rationally in response to rising gasoline prices. Unfortunately, all of the effects are quite small. As the following exhibit shows, the short-run elasticities are considerably less than -.1. A one percent increase in price leads to a reduction in consumption or changes in behavior that reduce consumption of less than one-tenth of one percent. In the long run, the elasticities are somewhat higher -.2 to -.4, but still quite low compared to other commodities. Moreover, the elasticity of demand has declined over time and is likely to continue to do so.

> *For a variety of reasons, consumers are currently only about one-fifth as responsive to short-run changes in gasoline prices as they were several decades ago. That decline in sensitivity has been attributed to growth in real income, which has rendered gasoline a smaller share of consumers' purchases from disposable income. Price sensitivity has also declined because a gallon of gasoline takes a car farther than it did in the past, in part because of fuel economy standards. The development of distant suburbs also has contributed by making consumers more reliant on the automobile. The longer commutes are balanced by lower housing costs.*[10]

[9] Congressional Budget Office, *Effects of Gasoline Prices on Driving Behavior and Vehicle Markets*, January 2008.
[10] CBO, Effects of Gasoline Prices, pp. x-xi.

Another factor in consumer response to gas prices is the pattern of price run-up, which must be sustained to induce change. The latest run-up of gas prices has far exceeded any previous price spike, but it has unfolded over a longer period of time. The impact on vehicle sales is beginning to be seen.

PRICE ELASTICITIES OF DEMAND FOR VARIOUS GASOLINE CONSUMPTION-RELATED BEHAVIORS COMPARED TO SELECTED OTHER PRODUCTS

Product	Study Trait	Period of Impact Short-terms	Long-term
Gasoline Related[a]			
Consumption	CFA (1997-2005 Expenditures)		-.28
	Recent	-.06	-.40
	1994-2006	-.02 to -.04	
	Higher prices	-.066 to -.074	
	1974-1989	-.05 to -.08	
	Older		-.38 to -.43
Travel Speed	CBO	-.06	
	Recent	-.05	
	Older		-.35
Miles Traveled	CBO	-.035	
	Recent	-.02 to -.03	-.11 to -.15
	Older	-.1 to -.16	-.26 to -.31
New Vehicle	CBO truck-car		
Fuel Economy	Switch to cars	.28	
(improvement)	CFA Implicit mpg	.1	
	CFA	.1	
Other Commodities[b]			
Eggs			- .1
Gasoline			- .2
Shoes			- .9
Foreign Travel			-1.2
Alcoholic Beverages			-1.5
Jewelry			-2.6

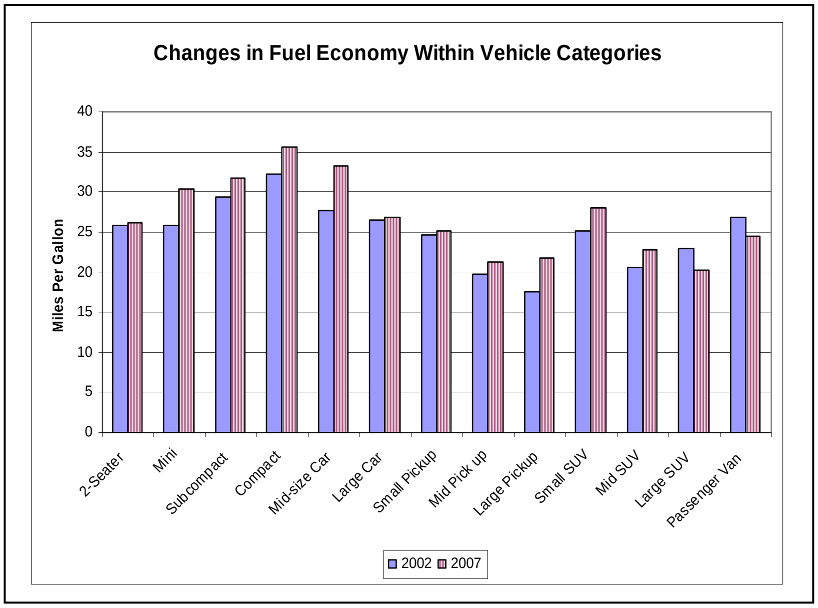
a) Congressional Budget Office, *Effects of Gasoline Prices on Driving Behavior and Vehicle Markets* (Washington, D.C.: January 2008).
b) Jon B. Taylor, *Economics* (Boston: Houghton Mifflin, 1998), p. 99.

To track the trends in vehicle fuel economy, the CBO relied on Environmental Protection Agency (EPA) mileage estimates and auto sales from *Automotive News.* CFA compiled a database on fuel economy and sales using NHTSA data.[11] Our analysis includes more recent data than was used by the CBO, allowing us to extend some analyses to 2007 with preliminary sales data. We find similar patterns of shifts to more fuel-efficient vehicles in consumer purchasing behavior, and with these data, we can explore some important aspects of the automotive market in greater detail.

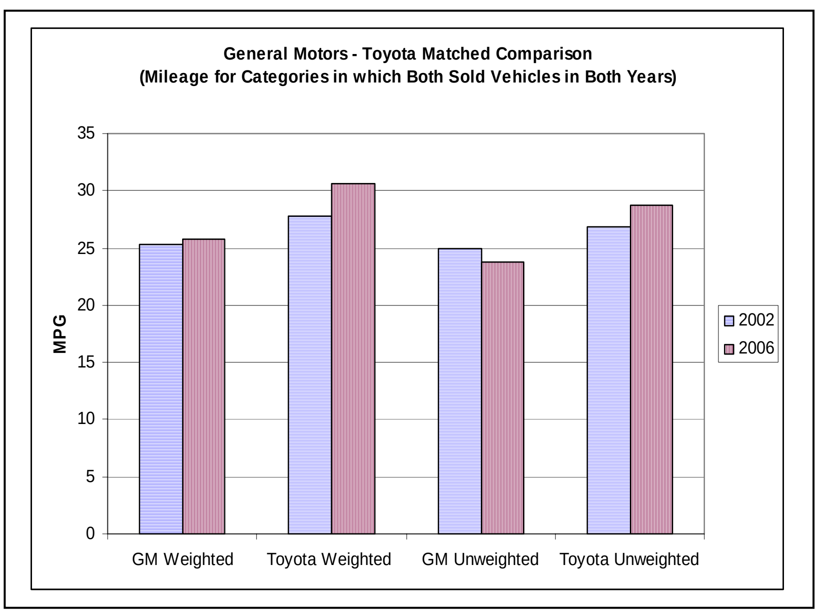
As gasoline prices rise, people switch from less fuel-efficient trucks to cars. As the CBO noted, "Price spikes in the spring of 2005, in October 2005 (after Hurricane Katrina), and in the spring of 2006 all coincided with sharp increases in the new-car market share. Market shares for leading categories of light trucks – especially SUVs – went the opposite way, dipping as gasoline prices rose."[12] In our data, with annual sales, the shift is 2.3 percent. Applying the shift coefficient calculated by CBO to the average difference between cars and trucks in our data, we find that the switch results in an improvement of fuel economy of about .1 percent for every 1 percent increase in gasoline prices. We arrive at a similar estimate by calculating the change in the fleet average fuel economy compared to the average real price of gasoline.

[11] Jack Gillis and Mark Cooper, *Still Stuck in Neutral: America's Continued Failure to Improve Motor Vehicle Fuel Efficiency: 1996:2005,* July, 2007, available at http://www.consumerfed.org/pdfs/Still_Stuck.pdf; Jack Gillis, *Stuck in Neutral: America's Failure to Improve Motor Vehicle Fuel Efficiency,:1996-2005,* November 2006;.; available at http://www.consumerfed.org/pdfs/Stuck_in_Neutral.pdf.
[12] CBO, Effects of Gasoline Prices, p. 16.

One of the key findings of the CBO study is that fuel economy improved both because consumers shifted their purchases away from less fuel-efficient types of vehicles (trucks and large SUVs) and because "the average fuel economy of cars and light trucks alike have been increasing since 2002."[13] Our data shows that the overall improvement in fuel economy was just under one mile per gallon (for 2002-2006) and 2 miler per gallon for 2002-2007; much less than consumers now say they want (7 mpg). And, the improvement in the fuel economy within the individual categories of cars and light trucks is uneven. The largest improvements came in minis, compacts, and mid-sized cars. Passenger vans and large SUVs did not improve. While many consumers shifted to smaller more fuel-efficient vehicles, those who required larger vehicles could not find the fuel- efficiency they needed and wanted.



Fuel economy improvement was also very uneven across auto manufacturers. One of the more dramatic aspects of the past half-decade has been the competition between General Motors (GM) and Toyota for the top spot as the leader in sales in the American auto market. The following figure shows the average fuel economy for GM and Toyota based only on categories of cars in which both had sales in 2002 and 2007. This graph matches the two automakers by categories of product sold for which



[13]CBO, Effects of Gasoline Prices, p. 20.

they compete head-to-head. It shows both the sales-weighted average fuel economy (mpg) and the unweighted average of the individual models they marketed. For Toyota, both the weighted and unweighted fuel economy averages improved. Toyota's mileage improved both because consumers shifted their purchases to more fuel-efficient categories of vehicles and Toyota offered, on average, significantly more fuel-efficient models. GM's average fuel economy improved because consumers shifted their sales between categories, but GM did not offer, on average, a significantly more fuel-efficient slate of models.

LINEAR REGRESSIONS TO EXAMINE FACTORS AFFECTING FUEL ECONOMY UNIT OF ANALYSIS IS THE SALES WEIGHTED MODEL (Regression Coefficients, All Statistically Significant at the .001 level)

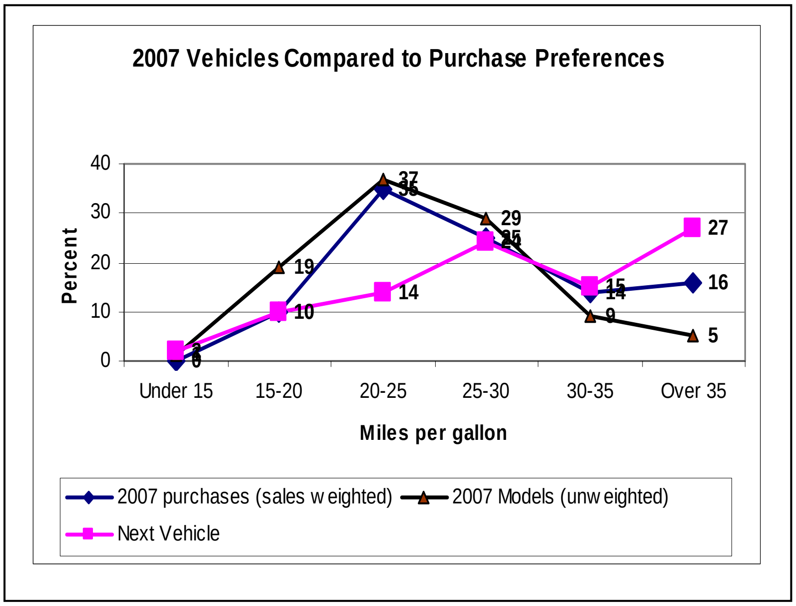
Variable	Cars Fuel Economy	Cars Product Sales	Trucks Fuel Economy	Trucks Product Sales
2003	.0662	15456	.982	10120
2004	1.084	-148	.482	-5090
2005	1.758	16763	.869	-16488
2006	2.377	3936	.879	-24092
Fuel Economy	na	945	na	823
R^2	.56	.32	.24	.12

Control variables: Engine (Horse Power, Displacement, Cylinders), Body (weight, Wheel base, interior volume); Transmission type, Drive Ratio, Dynamometer Setting; all coefficients are significant at the .05 level or higher

We were able to test the proposition that fuel economy became more important to consumers over the period since 2002 with an econometric model of fuel economy. After controlling for the key vehicle characteristics that affect fuel economy (vehicle weight, engine traits like horsepower, displacement, number of cylinders, transmission type, drive ratio, dynamometer setting, wheel base, interior volume), each year after 2002, there was a statistically significant, though small, improvement in the fuel economy of cars. For cars, the effect became steadily larger over time. A car sold in 2006 got 2.377 more miles per gallon than one built in 2002, controlling for all the other factors included; for trucks, the increase was .879 miles per gallon.

Truck sales were down 24,092 in 2006, compared to 2002; controlling for all the other factors, car sales were up 3,936. For trucks, the effect was large in 2003, declined in 2004 and rebounded in 2005 and 2006. We also find that fuel economy was positively related to product sales. We find the negative effect on truck/SUV sales in 2004, 2005, and 2006, with the effect growing larger over time. This is consistent with the CBO findings. In addition to the shift from trucks to cars and after controlling for all the other factors, a one mile per gallon increase in fuel economy resulted in an additional sale of just under 1000 more cars and trucks for each model.

If we contrast the purchase intentions of consumers with the actual purchases made in 2007, we find that the gap between where consumers are headed and where the market has been is large for the high mileage vehicles. Only five percent of the models offered in 2007 got 35 miles per gallon or more. However, 16 percent of the vehicles sold had mileage rating above 35 mpg. This is in contrast to the next purchase preferences of 27 percent of respondents who intend to buy vehicles that get over 35 miles per gallon. Consumer purchases are the result of a combination of what they want and what they are offered. This analysis suggests that the automakers need to offer them a broader set of higher fuel economy options.



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CONCLUSION

This first quarterly report on gasoline consumption, expenditures, oil imports, and consumer attitudes contains both good and bad news about progress toward rapidly reducing our nation's addiction to oil. People care greatly about gasoline price increases and the national security implications of our oil dependency. And, they respond to the extent they can. But thus far, the impact on gasoline consumption has been small, in part, because consumers have not had enough fuel-efficient choices. They are and will be looking for cars that get much better gas mileage than their current vehicle, and than most auto makers are supplying. We see evidence of this in the aggregate measures of consumption, responses to national opinion polls, and detailed analysis of vehicle purchasing patterns.

Our nation has experienced three serious gasoline price shocks since 1973. The only spike that caused a sharp and long decline in gasoline consumption occurred after Congress mandated more fuel-efficient vehicles. Without a strong policy signal that requires automakers to continue to increase the fuel economy of their fleets, consumers can do little to moderate their gasoline consumption, even as the price skyrockets.

We are at a critical moment in national history. The combined threats of oil dependency and global warming require serious and sustained improvement of vehicle fuel economy. Margo Oge, EPA Director of Transportation and Air Quality said recently that vehicles may have to reach 75 mpg by 2030 if we are to prevent the worst impacts of climate change. National policies that push automakers, consumers, and the market in the direction of greater fuel economy are necessary to move society toward the goal of reduced oil consumption. Rapidly and significantly increasing fleet-wide fuel economy is essential for our economy, the environment, and our national security.

Acc. No. 0587 *Uncertainty in Climate Model Projections of Arctic Sea Ice Decline: An Evaluation Relevant to Polar Bears* can be viewed on the docket:
http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0588

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August 18, 2008

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Ground Floor, Room W12-140
1200 New Jersey Avenue, SE
Washington, DC 20590

Reference Docket No. NHTSA-2008-0060

To Whom It May Concern:

The New York State Department of Transportation (NYSDOT) has reviewed the National Highway Traffic Safety Administration (NHTSA) Draft Environmental Impact Statement (DEIS) on Corporate Average Fuel Economy (CAFE) Standards for Passenger Cars and Light Trucks for Model Years 2011-2015, issued June 2008, and offers the comments below.

Based on the extensive materials included in the DEIS on climate change impacts, NYSDOT believes that it is necessary to reiterate its comments originally provided in response to NHTSA's scoping notice.

The transportation sector currently contributes nearly a third of the national carbon dioxide (CO2) and other greenhouse gas (GHG) emissions, both byproducts of petroleum fuel combustion. There is a need to reduce these emissions to slow the rate of anthropogenic-induced climate change, which is having serious impacts on the global and regional environment. Due to the global urgency associated with reducing the nation's reliance on imported petroleum and to reduce GHG emissions, the preferred alternative should increase the fuel economy standards beyond 35.7 mpg and 28.6 mpg for MY 2015 passenger cars and light trucks, respectively.

NYSDOT recommends that NHTSA establish a more aggressive standard and achievement timetable for the new CAFE standards. At a minimum, NHTSA should consider a hybrid alternative that is equivalent to the "Technology Exhaustion" alternative for light-duty trucks and "Total Costs Equal Total Benefits" alternative for passenger cars. NYSDOT believes that this approach would provide significantly greater GHG emissions reductions than the proposed preferred alternative, yet would consider the diminishing returns of technology exhaustion for passenger cars as indicated in Tables 3.2-2 and 3.2-3. It is important for environmental, energy and economic reasons to increase the national fuel economy from the proposed rate of increase to a much more rapid yet technologically achievable rate.

NHTSA should also correct several errors in its analysis that artificially reduce the stringency of the proposed CAFE standards by underestimating benefits and overestimating costs. In particular, NHTSA inflates costs relative to benefits by failing to apply a discount rate to future costs. NHTSA also uses an arbitrary low value for the benefits of avoided greenhouse gas emissions, reducing estimated benefits. In addition, NHTSA uses unrealistically low predictions of motor fuel prices, thereby underestimating economic benefits, and overestimates the rebound effect, which underestimates fuel savings and underestimates vehicle-related criteria and toxic pollutant emissions.

In its analysis, NHTSA discounts economic benefits, but not costs. In any cost-benefit analysis, both future benefits and costs should be discounted using the same discount rate, or time-value of money, to correct for the difference in the value of money in hand today versus money in the future, based on the interest rate and inflation. The Office of Management and Budget specifically instructs NHTSA to discount both costs and benefits, and provides recommended interest rates for that purpose.

As global warming trends continue, NYSDOT encourages NHTSA to work with the industry to expedite the production of more fuel efficient vehicles, as well as those capable of using alternative fuels, such as compressed natural gas (CNG), liquefied natural gas (LNG), and advanced biofuels. NHTSA should also promote hybrid-electric, battery electric, cleaner diesel, and fuel cell technology.

NYSDOT also has the following specific comments on the content of the DEIS:

- The DEIS (page 3-59) states that the Preliminary Regulatory Impact Analysis (PRIA) uses the Energy Information Administration reference price estimate for gasoline in the *AEO 2008 Early Release Forecast*. Please note that the EIA International Energy Outlook Highlights, June 2008 states, "Given current market conditions, it appears that world oil prices are on a path that more closely resembles the projection in the high price case than in the reference case." Therefore, NYSDOT believes that the analysis of alternatives analysis should use EIA's "high price case" scenarios. In addition, the Final Environmental Impact Statement should specifically explain why *current* market prices are excluded from the factoring process for economic practicability.

- Under NHTSA's cost-benefit based standard setting methodology, the values assigned to benefits are critical. Higher value benefits justify more stringent standards. NHTSA arbitrarily chose $7.00 per metric ton of carbon dioxide avoided as the benefit of reduced fuel consumption, rather than $13.60 per metric ton of carbon dioxide ($50 per metric ton of carbon) recommended by the National Academy of Sciences Committee on which NHTSA says it relies for this analysis.

- Tables 3.2-2 and 3.2-3 indicate that the technology exhaustion alternative will yield more incremental benefits for light trucks than it yields for passenger vehicles. Figure 4.2-2 also indicates that the technology exhaustion alternative will yield a significant incremental benefit for light trucks. Certain sections of the DEIS suggest that if the CAFE standards are set too stringent, manufacturers may opt to pay noncompliance penalties rather than meet or exceed the standard. If this is the case, wouldn't the more aggressive alternatives (3-7) yield less benefit than the preferred alternative? The FEIS should explain this in more detail and clearly describe how the Volpe model and other models treat this issue for alternatives 3-7.

- The rebound effect is defined as an increase in Vehicle Miles Traveled (VMT) in response to decreased operating costs. Such an effect may occur as a result of higher fuel economy. Additional driving uses more fuel; thus, the rebound effect reduces the net fuel savings that accrue to vehicle owners, for a given increase in fuel economy. In chapter VIII of the PRIA, NHTSA summarizes the results of studies done on the rebound effect across the country, and chooses the study performed in 2005 by Dr. Kenneth Small at the University of California, Irvine. That study concluded that California would experience a dynamic rebound effect of 3 percent. NHTSA claims that updating this study for the country as a whole and for the period covered by this rulemaking would yield a rebound effect of at least 15 percent. It seems counterintuitive that the nation as a whole would see a rebound effect that is five times that of California, particularly in the face of significantly higher fuel costs. In a 2003 report, the Congressional Budget Office notes that the U.S is a "mature market" and that as such, the rebound effect is small. The report also points out that even though the real cost of fuel per kilometer decreased in the U.S by about 65 percent between 1982 and 1995, that decrease was not accompanied by a strong rebound in VMT. NHTSA's 15 percent downward adjustment to the economic benefits resulting from this fuel economy rulemaking is not warranted by economic research literature, or actual consumer behavior.

- NHTSA confuses the discussion of emissions impacts (particularly Figure 3.3-1) by including the effects of increased vehicle emission regulation stringency. NHTSA should revise its presentation to ensure that the effects of proposed CAFE standards are clearly differentiated from the effects of vehicle emissions standards and general VMT growth.

- Figures 3.3-3, 3.3-4, and 3.3-5 should show the effects of the proposed alternatives on light duty cars and light duty trucks separately. This would help to distinguish the differential effect that the various alternatives will have on the various components of the nation's light duty fleet.

Thank you for providing the opportunity to comment on the DEIS for this vitally important rulemaking action.

Sincerely,

Stanley Gee
Executive Deputy Commissioner

recently, in agreement with earlier results (e.g., Schubert et al., 1998), is a tendency for a poleward shift of several degrees latitude in mid-latitude storm tracks in both hemispheres (Geng and Sugi, 2003; Fischer-Bruns et al., 2005; Yin, 2005; Bengtsson et al., 2006). Consistent with these shifts in storm track activity, Cassano et al. (2006), using a 10-member multi-model ensemble, show a future change to a more cyclonically dominated circulation pattern in winter and summer over the Arctic, and increasing cyclonicity and stronger westerlies in the same multi-model ensemble for the Antarctic (Lynch et al., 2006).

Some studies have shown little change in extratropical cyclone characteristics (Kharin and Zwiers, 2005; Watterson, 2005). But a regional study showed a tendency towards more intense systems, particularly in the A2 scenario in another global coupled climate model analysis (Leckebusch and Ulbrich, 2004), with more extreme wind events in association with those deepened cyclones for several regions of Western Europe, with similar changes in the B2 simulation although less pronounced in amplitude. Geng and Sugi (2003) use a higher-resolution (about 100 km resolution) atmospheric GCM (AGCM) with time-slice experiments and find a decrease in cyclone density (number of cyclones in a 4.5° by 4.5° area per season) in the mid-latitudes of both hemispheres in a warmer climate in both the DJF and JJA seasons, associated with the changes in the baroclinicity in the lower troposphere, in general agreement with earlier results and coarser GCM results (e.g., Dai et al., 2001b). They also find that the density of strong cyclones increases while the density of weak and medium-strength cyclones decreases. Several studies have shown a possible reduction in mid-latitude storms in the NH but a decrease in central pressures in these storms (Lambert and Fyfe, 2006, for a 15-member multi-model ensemble) and in the SH (Fyfe, 2003, with a possible 30% reduction in sub-antarctic cyclones). The latter two studies did not definitively identify a poleward shift of storm tracks, but their methodologies used a relatively coarse grid that may not have been able to detect shifts of several degrees latitude and they used only identification of central pressures which could imply an identification of semi-permanent features like the sub-antarctic trough. More regional aspects of these changes were addressed for the NH in a single model study by Inatsu and Kimoto (2005), who show a more active storm track in the western Pacific in the future but weaker elsewhere. Fischer-Bruns et al. (2005) document storm activity increasing over the North Atlantic and Southern Ocean and decreasing over the Pacific Ocean.

By analysing stratosphere-troposphere exchanges using time-slice experiments with the middle atmosphere version of ECHAM4, Land and Feichter (2003) suggest that cyclonic and blocking activity becomes weaker poleward of 30°N in a warmer climate at least in part due to decreased baroclinicity below 400 hPa, while cyclonic activity becomes stronger in the SH associated with increased baroclinicity above 400 hPa. The atmospheric circulation variability on inter-decadal time scales may also change due to increasing greenhouse gases and aerosols. One model result (Hu et al., 2001) showed that inter-decadal variability of the SLP and 500 hPa height fields increased over the tropics and decreased at high latitudes due to global warming.

In summary, the most consistent results from the majority of the current generation of models show, for a future warmer climate, a poleward shift of storm tracks in both hemispheres that is particularly evident in the SH, with greater storm activity at higher latitudes.

A new feature that has been studied related to extreme conditions over the oceans is wave height. Studies by Wang et al. (2004), Wang and Swail (2006a,b) and Caires et al. (2006) have shown that for many regions of the mid-latitude oceans, an increase in extreme wave height is likely to occur in a future warmer climate. This is related to increased wind speed associated with mid-latitude storms, resulting in higher waves produced by these storms, and is consistent with the studies noted above that showed decreased numbers of mid-latitude storms but more intense storms.

10.4 Changes Associated with Biogeochemical Feedbacks and Ocean Acidification

10.4.1 Carbon Cycle/Vegetation Feedbacks

As a parallel activity to the standard IPCC AR4 climate projection simulations described in this chapter, the Coupled Climate-Carbon Cycle Model Intercomparison Project (C^4MIP) supported by WCRP and the International Geosphere-Biosphere Programme (IGBP) was initiated. Eleven climate models with a representation of the land and ocean carbon cycle (see Chapter 7) performed simulations where the model was driven by an anthropogenic CO_2 emissions scenario for the 1860 to 2100 time period (instead of an atmospheric CO_2 concentration scenario as in the standard IPCC AR4 simulations). Each C^4MIP model performed two simulations, a 'coupled' simulation where the growth of atmospheric CO_2 induces a climate change which affects the carbon cycle, and an 'uncoupled' simulation, where atmospheric CO_2 radiative forcing is held fixed at pre-industrial levels, in order to estimate the atmospheric CO_2 growth rate that would occur if the carbon cycle was unperturbed by the climate. Emissions were taken from the observations for the historical period (Houghton and Hackler, 2000; Marland et al., 2005) and from the SRES A2 scenario for the future (Leemans et al., 1998).

Chapter 7 describes the major results of the C^4MIP models in terms of climate impact on the carbon cycle. This section starts from these impacts to infer the feedback effect on atmospheric CO_2 and therefore on the climate system. There is unanimous agreement among the models that future climate change will reduce the efficiency of the land and ocean carbon cycle to absorb anthropogenic CO_2, essentially owing to a reduction in land carbon uptake. The latter is driven by a combination of reduced net primary productivity and increased soil respiration of CO_2 under a warmer climate. As a result, a larger fraction of anthropogenic CO_2 will stay airborne if climate change controls the carbon cycle. By the end of the 21st century, this additional CO_2 varies between 20 and 220 ppm for the two extreme models, with most of the models lying between 50 and 100 ppm (Friedlingstein et al., 2006). This additional CO_2 leads to an additional radiative forcing of between 0.1 and 1.3 W m^{-2} and hence an additional warming of between 0.1°C and 1.5°C.

All of the C^4MIP models simulate a higher atmospheric CO_2 growth rate in the coupled runs than in the uncoupled runs. For the A2 emission scenario, this positive feedback leads to a greater atmospheric CO_2 concentration (Friedlingstein et al., 2006) as noted above, which is in addition to the concentrations in the standard coupled models assessed in the AR4 (e.g., Meehl et al., 2005b). By 2100, atmospheric CO_2 varies between 730 and 1,020 ppm for the C^4MIP models, compared with 836 ppm for the standard SRES A2 concentration in the multi-model data set (e.g., Meehl et al., 2005b). This uncertainty due to future changes in the carbon cycle is illustrated in Figure 10.20a where the CO_2 concentration envelope of the C^4MIP uncoupled simulations is centred on the standard SRES A2 concentration value. The range reflects the uncertainty in the carbon cycle. It should be noted that the standard SRES A2 concentration value of 836 ppm was calculated in the TAR with the Bern carbon cycle-climate model (BERN-CC; Joos et al., 2001) that accounted for the climate-carbon cycle feedback. Parameter sensitivity studies were performed with the BERN-CC model at that time and gave a range of 735 ppm to 1,080 ppm, comparable to the range of the C^4MIP study. The effects of climate feedback uncertainties on the carbon cycle have also been considered probabilistically by Wigley and Raper (2001). A later paper (Wigley, 2004) considers individual emissions scenarios, accounting for carbon cycle feedbacks in the same way as Wigley and Raper (2001). The results of these studies are consistent with the more recent C^4MIP results. For the A2 scenario considered in C^4MIP, the CO_2 concentration range in 2100 using the Wigley and Raper model is 769 to 1,088 ppm, compared with 730 to 1,020 ppm in the C^4MIP study (which ignored the additional warming effect due to non-CO_2 gases). Similarly, using neural networks, Knutti et al. (2003) show that the climate-carbon cycle feedback leads to an increase of about 0.6°C over the central estimate for the SRES A2 scenario and an increase of about 1.5°C for the upper bound of the uncertainty range.

Further uncertainties regarding carbon uptake were addressed with a 14-member multi-model ensemble using the CMIP2 models to quantify contributions to uncertainty from inter-model variability as opposed to internal variability (Berthelot et al., 2002). They found that the AOGCMs with the largest climate sensitivity also had the largest drying of soils in the tropics and thus the largest reduction in carbon uptake.

The C^4MIP protocol did not account for the evolution of non-CO_2 greenhouse gases and aerosols. In order to compare the C^4MIP simulated warming with the IPCC AR4 climate models, the SRES A2 radiative forcings of CO_2 alone and total forcing (CO_2 plus non-CO_2 greenhouse gases and aerosols) as given

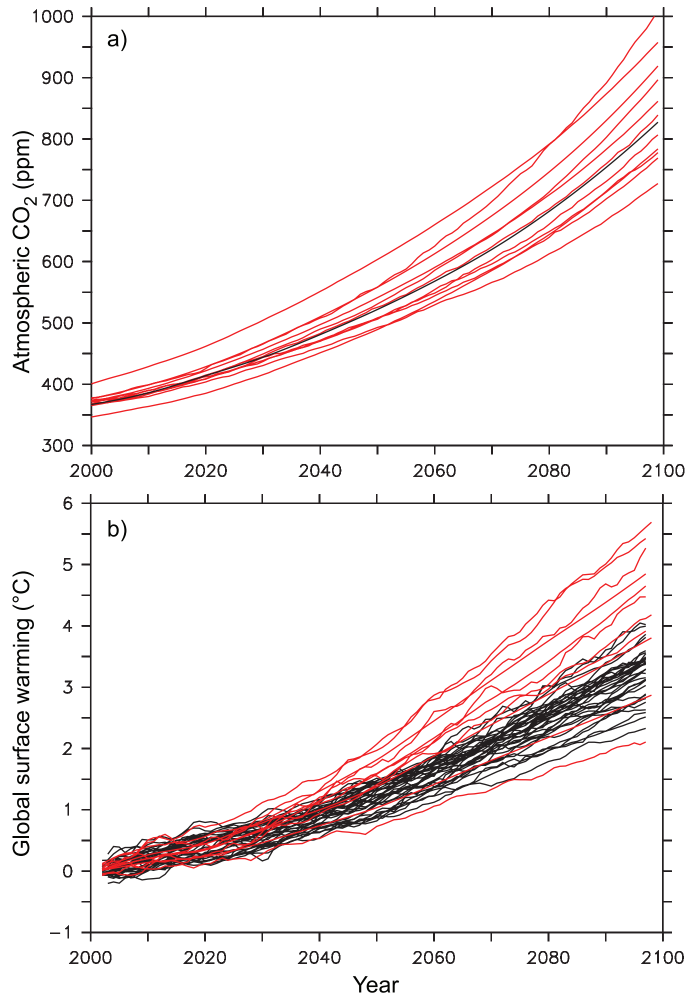

Figure 10.20. *(a) 21st-century atmospheric CO_2 concentration as simulated by the 11 C^4MIP models for the SRES A2 emission scenario (red) compared with the standard atmospheric CO_2 concentration used as a forcing for many IPCC AR4 climate models (black). The standard CO_2 concentration values were calculated by the BERN-CC model and are identical to those used in the TAR. For some IPCC-AR4 models, different carbon cycle models were used to convert carbon emissions to atmospheric concentrations. (b) Globally averaged surface temperature change (relative to 2000) simulated by the C^4MIP models forced by CO_2 emissions (red) compared to global warming simulated by the IPCC AR4 models forced by CO_2 concentration (black). The C^4MIP global temperature change has been corrected to account for the non-CO_2 radiative forcing used by the standard IPCC AR4 climate models.*

in Appendix II of the TAR were used. Using these numbers and knowing the climate sensitivity of each C^4MIP model, the warming that would have been simulated by the C^4MIP models if they had included the non-CO_2 greenhouse gases and aerosols can be estimated. For the SRES A2 scenario, these estimates show that the C^4MIP range of global temperature increase by the end of the 21st century would be 2.4°C to 5.6°C, compared with 2.6°C to 4.1°C for standard IPCC-AR4 climate models (Figure 10.20b). As a result of a much larger CO_2 concentration by 2100 in most of the C^4MIP models, the upper estimate of the global warming by 2100 is up to 1.5°C higher than for the standard SRES A2 simulations.

The C^4MIP results highlight the importance of coupling the climate system and the carbon cycle in order to simulate, for a given scenario of CO_2 emissions, a climate change that takes into account the dynamic evolution of the Earth's capacity to absorb the CO_2 perturbation.

Conversely, the climate-carbon cycle feedback will have an impact on the estimate of the projected CO_2 emissions leading to stabilisation of atmospheric CO_2 at a given level. The TAR showed the range of future emissions for the Wigley, Richels and Edmonds (WRE; Wigley et al., 1996) stabilisation concentration scenarios, using different model parametrizations (including the climate-carbon feedback, Joos et al., 2001; Kheshgi and Jain,

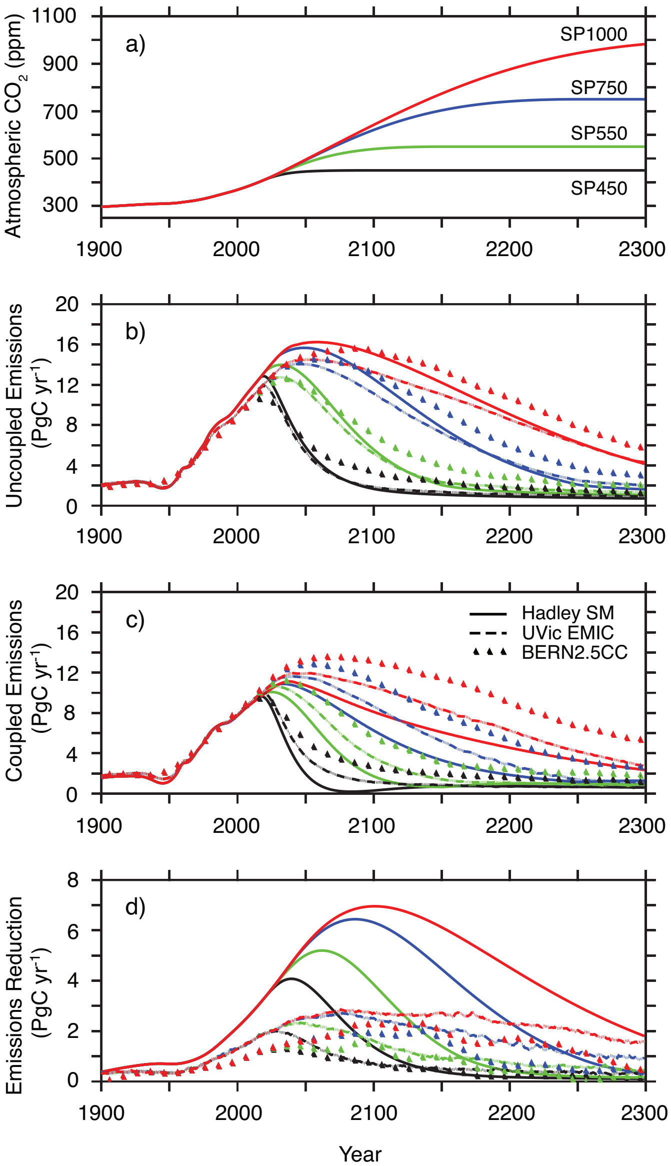

Figure 10.21. *(a) Atmospheric CO_2 stabilisation scenarios SP1000 (red), SP750 (blue), SP550 (green) and SP450 (black). (b) Compatible annual emissions calculated by three models, the Hadley simple model (Jones et al., 2006; solid), the UVic EMIC (Matthews, 2005; dashed) and the BERN2.5CC EMIC (Joos et al., 2001; Plattner et al., 2001; triangles) for the three stabilisation scenarios without accounting for the impact of climate on the carbon cycle (see Table 8.3 for details of the latter two models). (c) As for (b) but with the climate impact on the carbon cycle accounted for. (d) The difference between (b) and (c) showing the impact of the climate-carbon cycle feedback on the calculation of compatible emissions.*

2003). However, the emission reduction due to this feedback was not quantified. Similar to the C[4]MIP protocol, coupled and uncoupled simulations have been recently performed in order to specifically evaluate the impact of climate change on the future CO_2 emissions required to achieve stabilisation (Matthews, 2005; Jones et al., 2006). Figure 10.21 shows the emissions required to achieve CO_2 stabilisation for the stabilisation profiles SP450, SP550, SP750 and SP1000 (SP450 refers to stabilisation at a CO_2 concentration of 450 ppm, etc.) as simulated by three climate-carbon cycle models. As detailed above, the climate-carbon cycle feedback reduces the land and ocean uptake of CO_2, leading to a reduction in the emissions compatible with a given atmospheric CO_2 stabilisation pathway. The higher the stabilisation scenario, the larger the climate change, the larger the impact on the carbon cycle, and hence the larger the emission reduction relative to the case without climate-carbon cycle feedback. For example, stabilising atmospheric CO_2 at 450 ppm, which will likely result in a global equilibrium warming of 1.4°C to 3.1°C, with a best guess of about 2.1°C, would require a reduction of current annual greenhouse gas emissions by 52 to 90% by 2100. Positive carbon cycle feedbacks (i.e., reduced ocean and terrestrial carbon uptake caused by the warming) reduce the total (cumulative) emissions over the 21st century compatible with a stabilisation of CO_2 concentration at 450 ppm by 105 to 300 GtC relative to a hypothetical case where the carbon cycle does not respond to temperature. The uncertainty regarding the strength of the climate-carbon cycle feedback highlighted in the C[4]MIP analysis is also evident in Figure 10.21. For higher stabilisation scenarios such as SP550, SP750 and SP1000, the larger warming (2.9°C, 4.3°C and 5.5°C, respectively) requires an increasingly larger reduction (130 to 425 GtC, 160 to 500 GtC and 165 to 510 GtC, respectively) in the cumulated compatible emissions.

The current uncertainty involving processes driving the land and ocean carbon uptake will translate into an uncertainty in the future emissions of CO_2 required to achieve stabilisation. In Figure 10.22, the carbon-cycle related uncertainty is addressed using the BERN2.5CC carbon cycle EMIC (Joos et al., 2001; Plattner et al., 2001; see Table 8.3 for model details) and the series of S450 to SP1000 CO_2 stabilisation scenarios. The range of emission uncertainty was derived using identical assumptions as made in the TAR, varying ocean transport parameters and parametrizations describing the cycling of carbon through the terrestrial biosphere. Results are thus very closely comparable, and the small differences can be largely explained by the different CO_2 trajectories and the use of a dynamic ocean model here compared to the TAR.

The model results confirm that for stabilisation of atmospheric CO_2, emissions need to be reduced well below year 2000 values in all scenarios. This is true for the full range of simulations covering carbon cycle uncertainty, even including the upper bound, which is based on rather extreme assumptions of terrestrial carbon cycle processes.

Cumulative emissions for the period from 2000 to 2100 (to 2300) range between 596 GtC (933 GtC) for SP450, and 1,236 GtC (3,052 GtC) for SP1000. The emission uncertainty varies between –26 and +28% about the reference cases in year 2100 and between –26 and +34% in year 2300, increasing with time. The range of uncertainty thus depends on the magnitude of the CO_2 stabilisation level and the induced climate change. The additional uncertainty in projected emissions due to uncertainty in climate sensitivity is illustrated by two additional simulations with 1.5°C and 4.5°C climate sensitivities (see Box 10.2). The resulting emissions for this range of climate sensitivities lie within the range covered by the uncertainty in processes driving the carbon cycle.

Both the standard IPCC-AR4 and the C[4]MIP models ignore the effect of land cover change in future projections. However, as described in Chapters 2 and 7, past and future changes in land cover may affect the climate through several processes. First, they may change surface characteristics such as albedo. Second, they may affect the ratio of latent to sensible heat and therefore affect surface temperature. Third, they may induce additional CO_2 emissions from the land. Fourth, they can affect the capacity of the land to take up atmospheric CO_2. So far, no comprehensive coupled AOGCM has addressed these four components all together. Using AGCMs, DeFries et al. (2004) studied the impact of future land cover change on the climate, while Maynard and Royer (2004) performed a similar experiment on Africa only. DeFries et al. (2002) forced the Colorado State University GCM (Randall et al., 1996) with Atmospheric Model Intercomparison Project (AMIP) climatological sea surface temperatures and with either the present-day vegetation cover or a 2050 vegetation map adapted from a low-growth scenario of the Integrated Model to Assess the Global Environment (IMAGE-2; Leemans et al., 1998). The study finds that in the tropics and subtropics, replacement of forests by grassland or cropland leads to a reduction in carbon assimilation, and therefore in latent heat flux. The latter reduction leads to a surface warming of up to 1.5°C in deforested tropical regions. Using the ARPEGE-Climat AGCM (Déqué et al., 1994) with a higher resolution over Africa, Maynard et al. (2002) performed two experiments, one simulation with 2 × atmospheric CO_2 SSTs taken from a previous ARPEGE transient SRES B2 simulation and present-day vegetation, and one with the same SSTs but the vegetation taken from a SRES B2 simulation of the IMAGE-2 model (Leemans et al., 1998). Similar to DeFries et al. (2002), they find that future deforestation in tropical Africa leads to a redistribution of latent and sensible heat that leads to a warming of the surface. However, this warming is relatively small (0.4°C) and represents about 20% of the warming due to the atmospheric CO_2 doubling.

Two recent studies further investigated the relative roles of future changes in greenhouse gases compared with future changes in land cover. Using a similar model design as Maynard and Royer (2004), Voldoire (2006) compared the climate change simulated under a 2050 SRES B2 greenhouse gases scenario to the one under a 2050 SRES B2 land cover change scenario. They show that the relative impact of vegetation change compared to greenhouse gas concentration increase is of the order of 10%, and can reach 30% over localised tropical regions. In a more comprehensive study, Feddema et al. (2005) applied the same

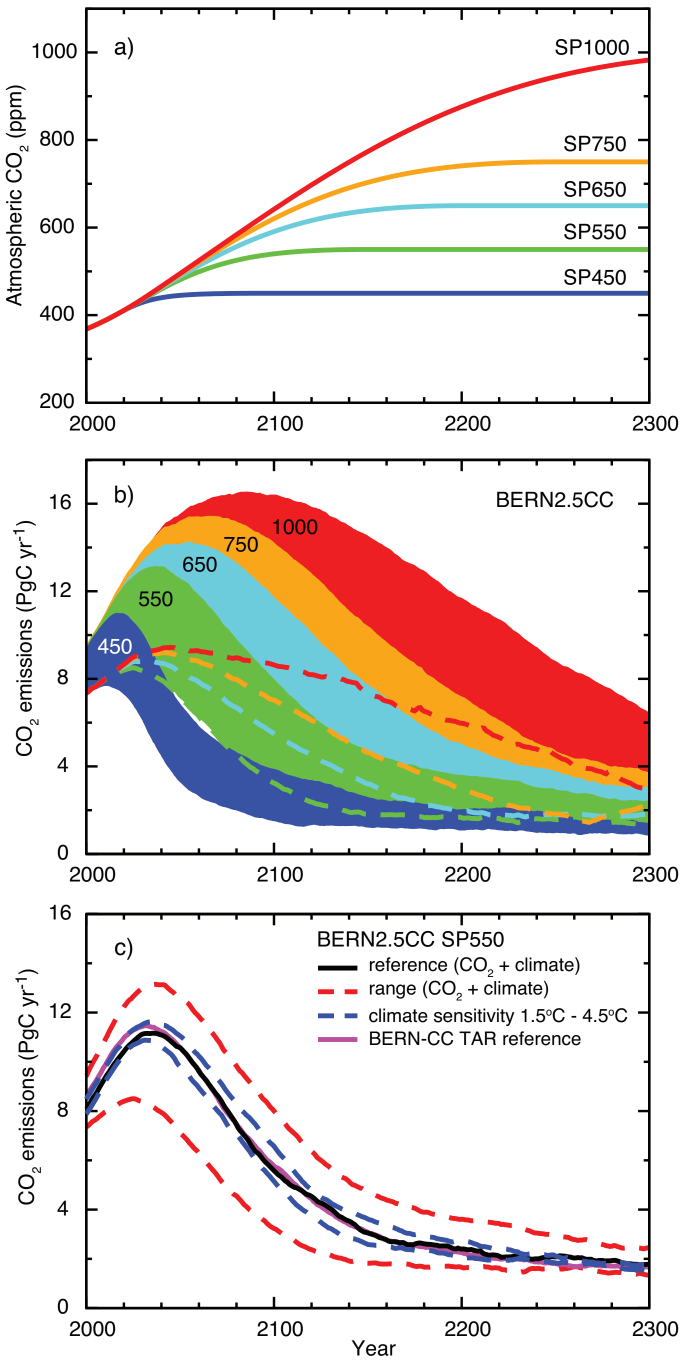

Figure 10.22. *Projected CO_2 emissions leading to stabilisation of atmospheric CO_2 concentrations at different levels and the effect of uncertainty in carbon cycle processes on calculated emissions. Panel (a) shows the assumed trajectories of CO_2 concentration (SP scenarios)(Knutti et al., 2005); (b) and (c) show the implied CO_2 emissions, as projected with the Bern2.5CC EMIC (Joos et al., 2001; Plattner et al., 2001). The ranges given in (b) for each of the SP scenarios represent effects of different model parametrizations and assumptions illustrated for scenario SP550 in panel (c) (range for 'CO_2 + climate'). The upper and lower bounds in (b) are indicated by the top and bottom of the shaded areas. Alternatively, the lower bound (where hidden) is indicated by a dashed line. Panel (c) illustrates emission ranges and sensitivities for scenario SP550.*

methodology for the SRES A2 and B1 scenario over the 2000 to 2100 period. Similarly, they find no significant effect at the global scale, but a potentially large effect at the regional scale, such as a warming of 2°C by 2100 over the Amazon for the A2 land cover change scenario, associated with a reduction in the DTR. The general finding of these studies is that the climate change due to land cover changes may be important relative to greenhouse gases at the regional level, where intense land cover change occurs. Globally, the impact of greenhouse gas concentrations dominates over the impact of land cover change.

10.4.2 Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide

Increasing atmospheric CO_2 concentrations lower oceanic pH and carbonate ion concentrations, thereby decreasing the saturation state with respect to calcium carbonate (Feely et al., 2004). The main driver of these changes is the direct geochemical effect due to the addition of anthropogenic CO_2 to the surface ocean (see Box 7.3). Surface ocean pH today is already 0.1 unit lower than pre-industrial values (Section 5.4.2.3). In the multi-model median shown in Figure 10.23, pH is projected to decrease by another 0.3 to 0.4 units under the IS92a scenario by 2100. This translates into a 100 to 150% increase in the concentration of H^+ ions (Orr et al., 2005). Simultaneously, carbonate ion concentrations will decrease. When water is undersaturated with respect to calcium carbonate, marine organisms can no longer form calcium carbonate shells (Raven et al., 2005).

Under scenario IS92a, the multi-model projection shows large decreases in pH and carbonate ion concentrations throughout the world oceans (Orr et al., 2005; Figures 10.23 and 10.24). The decrease in surface carbonate ion concentrations is found to be largest at low and mid-latitudes, although undersaturation is projected to occur at high southern latitudes first (Figure 10.24). The present-day surface saturation state is strongly influenced by temperature and is lowest at high latitudes, with minima in the Southern Ocean. The model simulations project that undersaturation will be reached in a few decades. Therefore, conditions detrimental to high-latitude ecosystems could develop within decades, not centuries as suggested previously (Orr et al., 2005).

While the projected changes are largest at the ocean surface, the penetration of anthropogenic CO_2 into the ocean interior will alter the chemical composition over the 21st century down to several thousand metres, albeit with substantial regional differences (Figure 10.23). The total volume of water in the ocean that is undersaturated with regard to calcite (not shown) or aragonite, a meta-stable form of calcium carbonate, increases substantially as atmospheric CO_2 concentrations continue to rise (Figure 10.23). In the multi-model projections, the aragonite saturation horizon (i.e., the 100% line separating over- and undersaturated regions) reaches the surface in the Southern Ocean by about 2050 and substantially shoals by 2100 in the South Pacific (by >1,000 m) and throughout the Atlantic (between 800 m and 2,200 m).

Ocean acidification could thus conceivably lead to undersaturation and dissolution of calcium carbonate in parts of the surface ocean during the 21st century, depending on the evolution of atmospheric CO_2 (Orr et al., 2005). Southern Ocean surface water is projected to become undersaturated with respect to aragonite at a CO_2 concentration of approximately 600 ppm. This concentration threshold is largely independent of emission scenarios.

Uncertainty in these projections due to potential future climate change effects on the ocean carbon cycle (mainly through changes in temperature, ocean stratification and marine biological production and re-mineralization; see Box 7.3) are small compared to the direct effect of rising atmospheric CO_2 from anthropogenic emissions. Orr et al. (2005) estimate that 21st century climate change could possibly counteract less than 10% of the projected direct geochemical changes. By far the largest uncertainty in the future evolution of these ocean interior changes is thus associated with the future pathway of atmospheric CO_2.

10.4.3 Simulations of Future Evolution of Methane, Ozone and Oxidants

Simulations using coupled chemistry-climate models indicate that the trend in upper-stratospheric ozone changes sign sometime between 2000 and 2005 due to the gradual reduction in halocarbons. While ozone concentrations in the upper stratosphere decreased at a rate of 400 ppb (–6%) per decade during 1980 to 2000, they are projected to increase at a rate of 100 ppb (1 to 2%) per decade from 2000 to 2020 (Austin and Butchart, 2003). On longer time scales, simulations show significant changes in ozone and CH_4 relative to current concentrations. The changes are related to a variety of factors, including increased emissions of chemical precursors, changes in gas-phase and heterogeneous chemistry, altered climate conditions due to global warming and greater transport and mixing across the tropopause. The impacts on CH_4 and ozone from increased emissions are a direct effect of anthropogenic activity, while the impacts of different climate conditions and stratosphere-troposphere exchange represent indirect effects of these emissions (Grewe et al., 2001).

The projections for ozone based upon scenarios with high emissions (IS92a; Leggett et al., 1992) and SRES A2 (Nakićenović and Swart, 2000) indicate that concentrations of tropospheric ozone might increase throughout the 21st century, primarily as a result of these emissions. Simulations for the period 2015 through 2050 project increases in ozone of 20 to 25% (Grewe et al., 2001; Hauglustaine and Brasseur, 2001), and simulations through 2100 indicate that ozone below 250 mb may grow by 40 to 60% (Stevenson et al., 2000; Grenfell et al., 2003; Zeng and Pyle, 2003; Hauglustaine et al., 2005; Yoshimura et al., 2006). The primary species contributing to the increase in tropospheric ozone are anthropogenic emissions of NO_x, CH_4, CO and compounds from fossil fuel combustion. The photochemical reactions that produce smog are accelerated by increases of 2.6 times the present flux of NO_x, 2.5 times the

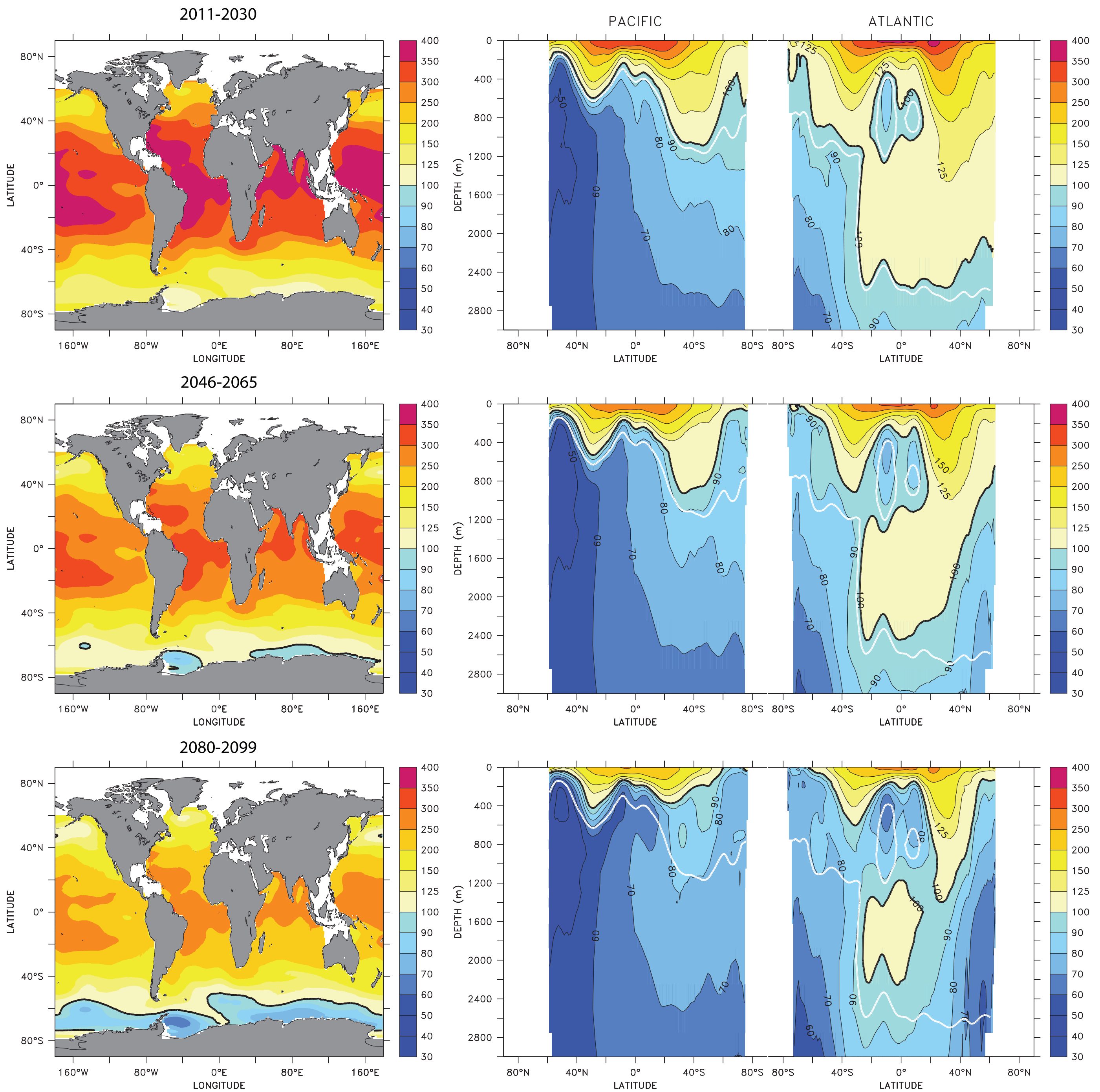

Figure 10.23. *Multi-model median for projected levels of saturation (%) with respect to aragonite, a meta-stable form of calcium carbonate, over the 21st century from the Ocean Carbon-Cycle Model Intercomparison Project (OCMIP-2) models (adapted from Orr et al., 2005). Calcium carbonate dissolves at levels below 100%. Surface maps (left) and combined Pacific/Atlantic zonal mean sections (right) are given for scenario IS92a as averages over three time periods: 2011 to 2030 (top), 2045 to 2065 (middle) and 2080 to 2099 (bottom). Atmospheric CO_2 concentrations for these three periods average 440, 570 and 730 ppm, respectively. Latitude-depth sections start in the North Pacific (at the left border), extend to the Southern Ocean Pacific section and return through the Southern Ocean Atlantic section to the North Atlantic (right border). At 100%, waters are saturated (solid black line - the aragonite saturation horizon); values larger than 100% indicate super-saturation; values lower than 100% indicate undersaturation. The observation-based (Global Ocean Data Analysis Project; GLODAP) 1994 saturation horizon (solid white line) is also shown to illustrate the projected changes in the saturation horizon compared to the present.*

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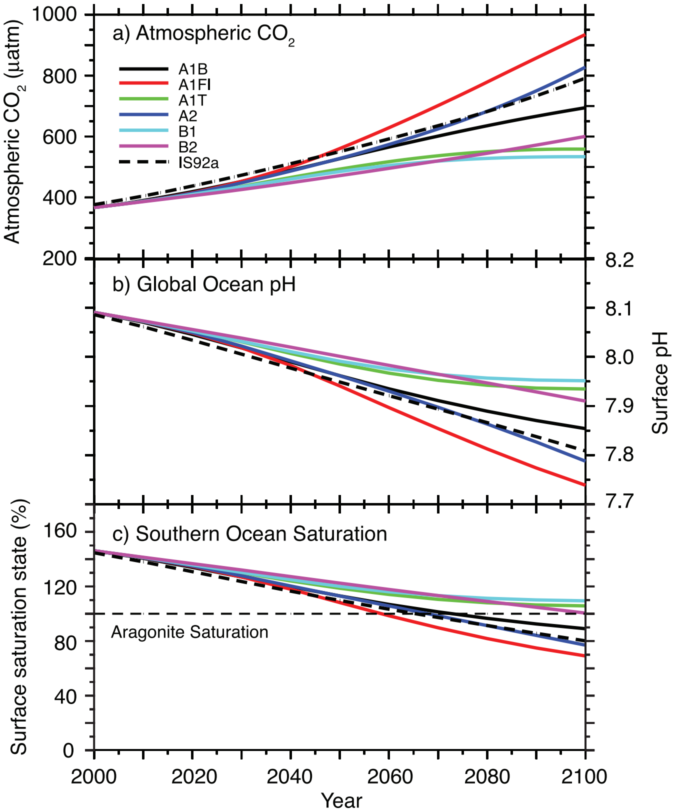


Figure 10.24. *Changes in global average surface pH and saturation state with respect to aragonite in the Southern Ocean under various SRES scenarios. Time series of (a) atmospheric CO_2 for the six illustrative SRES scenarios, (b) projected global average surface pH and (c) projected average saturation state in the Southern Ocean from the BERN2.5D EMIC (Plattner et al., 2001). The results for the SRES scenarios A1T and A2 are similar to those for the non-SRES scenarios S650 and IS92a, respectively. Modified from Orr et al. (2005).*

present flux of CH_4 and 1.8 times the present flux of CO in the A2 scenario. Between 91 and 92% of the higher concentrations in ozone are related to direct effects of these emissions, with the remainder of the increase attributable to secondary effects of climate change (Zeng and Pyle, 2003) combined with biogenic precursor emissions (Hauglustaine et al., 2005). These emissions may also lead to higher concentrations of oxidants including the hydroxyl radical (OH), possibly leading to an 8% reduction in the lifetime of tropospheric CH_4 (Grewe et al., 2001).

Since the projected growth in emissions occurs primarily in low latitudes, the ozone increases are largest in the tropics and subtropics (Grenfell et al., 2003). In particular, the concentrations in Southeast Asia, India and Central America increase by 60 to 80% by 2050 under the A2 scenario. However, the effects of tropical emissions are not highly localised, since the ozone spreads throughout the lower atmosphere in plumes emanating from these regions. As a result, the ozone in remote marine regions in the SH may grow by 10 to 20% over present-day levels by 2050. The ozone may also be distributed through vertical transport in tropical convection followed by lateral transport on isentropic surfaces. Ozone concentrations can also be increased by emissions of biogenic hydrocarbons (e.g., Hauglustaine et al., 2005), in particular isoprene emitted by broadleaf forests. Under the A2 scenario, biogenic hydrocarbons are projected to increase by between 27% (Sanderson et al., 2003) and 59% (Hauglustaine et al., 2005) contributing to a 30 to 50% increase in ozone formation over northern continental regions.

Developing countries have begun reducing emissions from mobile sources through stricter standards. New projections of the evolution of ozone precursors that account for these reductions have been developed with the Regional Air Pollution Information and Simulation (RAINS) model (Amann et al., 2004). One set of projections is consistent with source strengths permitted under the Current Legislation (CLE) scenario. A second set of projections is consistent with lower emissions under a Maximum Feasible Reduction (MFR) scenario. The concentrations of ozone and CH_4 have been simulated for the MFR, CLE and A2 scenarios for the period 2000 through 2030 using an ensemble of 26 chemical transport models (Dentener et al., 2006; Stevenson et al., 2006). The changes in NO_x emissions for these three scenarios are –27%, +12% and +55%, respectively, relative to year 2000. The corresponding changes in ensemble-mean burdens in tropospheric ozone are –5%, +6% and +18% for the MFR, CLE and A2 scenarios, respectively. There are substantial inter-model differences of order ±25% in these results. The ozone decreases throughout the troposphere in the MFR scenario, but the zonal annual mean concentrations increase by up to 6 ppb in the CLE scenario and by typically 6 to 10 ppb in the A2 scenario (Supplementary Material, Figure S10.2).

The radiative forcing by the combination of ozone and CH_4 changes by –0.05, 0.18, and 0.30 W m^{-2} for the MFR, CLE and A2 scenarios, respectively. These projections indicate that the growth in tropospheric ozone between 2000 and 2030 could be reduced or reversed depending on emission controls.

The major issues in the fidelity of these simulations for future tropospheric ozone are the sensitivities to the representation of the stratospheric production, destruction and transport of ozone and the exchange of species between the stratosphere and troposphere. Few of the models include the effects of non-methane hydrocarbons (NMHCs), and the sign of the effects of NMHCs on ozone are not consistent among the models that do (Hauglustaine and Brasseur, 2001; Grenfell et al., 2003).

The effect of more stratosphere-troposphere exchange (STE) in response to climate change is projected to increase the concentrations of ozone in the upper troposphere due to the much greater concentrations of ozone in the lower stratosphere than in the upper troposphere. While the sign of the effect is consistent in recent simulations, the magnitude of the change in STE and its effects on ozone are very model dependent. In a simulation forced by the SRES A1FI scenario, Collins et al. (2003) project that the downward flux of ozone increases by 37% from the 1990s to the 2090s. As a result, the concentration of ozone in the upper troposphere at mid-latitudes increases by 5 to 15%. For the A2 scenarios, projections of the increase in ozone by 2100 due to STE range from 35% (Hauglustaine et al., 2005) to 80% (Sudo et al., 2003; Zeng and Pyle, 2003). The increase in STE is driven by increases in the descending branches of the Brewer-Dobson Circulation at mid-latitudes and is caused by changes in meridional temperature gradients in the upper troposphere and lower stratosphere (Rind et al., 2001). The effects of the enhanced STE are sensitive to the simulation of processes in the stratosphere, including the effects of lower temperatures and the evolution of chlorine, bromine and NO_x concentrations. Since the greenhouse effect of ozone is largest in the upper troposphere, the treatment of STE remains a significant source of uncertainty in the calculation of the total greenhouse effect of tropospheric ozone.

The effects of climate change, in particular increased tropospheric temperatures and water vapour, tend to offset some of the increase in ozone driven by emissions. The higher water vapour is projected to offset the increase in ozone by between 10% (Hauglustaine et al., 2005) and 17% (Stevenson et al., 2000). The water vapour both decelerates the chemical production and accelerates the chemical destruction of ozone. The photochemical production depends on the concentrations of NO_y (reactive odd nitrogen), and the additional water vapour causes a larger fraction of NO_y to be converted to nitric acid, which can be efficiently removed from the atmosphere in precipitation (Grewe et al., 2001). The water vapour also increases the concentrations of OH through reaction with the oxygen radical in the 1D excited state ($O(^1D)$), and the removal of $O(^1D)$ from the atmosphere slows the formation of ozone. The increased concentrations of OH and the increased rates of CH_4 oxidation with higher temperature further reduce the lifetime of tropospheric CH_4 by 12% by 2100 (Stevenson et al., 2000; Johnson et al., 2001). Decreases in CH_4 concentrations also tend to reduce tropospheric ozone (Stevenson et al., 2000).

Recent measurements show that CH_4 growth rates have declined and were negative for several years in the early 21st century (see Section 2.3.2). The observed rate of increase of 0.8 ppb yr^{-1} for the period 1999 to 2004 is considerably less than the rate of 6 ppb yr^{-1} assumed in all the SRES scenarios for the period 1990 to 2000 (Nakićenović and Swart, 2000; TAR Appendix II). Recent studies (Dentener et al., 2005) have considered lower emission scenarios (see above) that take account of new pollution control techniques adopted in major developing countries. In the CLE scenario, emissions of CH_4 are comparable to the B2 scenario and increase from 340 Tg yr^{-1} in 2000 to 450 Tg yr^{-1} in 2030. The CH_4 concentrations increase from 1,750 ppb in 2000 to between 2,090 and 2,200 ppb in 2030 under this scenario. In the MFR scenario, the emissions are sufficiently low that the concentrations in 2030 are unchanged at 1,750 ppb. Under these conditions, the changes in radiative forcing due to CH_4 between the 1990s and 2020s are less than 0.01 W m^{-2}.

Current understanding of the magnitude and variation of CH_4 sources and sinks is covered in Section 7.4, where it is noted that there are substantial uncertainties although the modelling has progressed. There is some evidence for a coupling between climate and wetland emissions. For example, calculations using atmospheric concentrations and small-scale emission measurements as input differ by 60% (Shindell and Schmidt, 2004). Concurrent changes in natural sources of CH_4 are now being estimated to first order using simple models of the biosphere coupled to AOGCMs. Simulations of the response of wetlands to climate change from doubling atmospheric CO_2 show that wetland emissions increase by 78% (Shindell and Schmidt, 2004). Most of this effect is caused by growth in the flux of CH_4 from existing tropical wetlands. The increase would be equivalent to approximately 20% of current inventories and would contribute an additional 430 ppb to atmospheric concentrations. Global radiative forcing would increase by approximately 4 to 5% from the effects of wetland emissions by 2100 (Gedney et al., 2004).

10.4.4 Simulations of Future Evolution of Major Aerosol Species

The time-dependent evolution of major aerosol species and the interaction of these species with climate represent some of the major sources of uncertainty in projections of climate change. An increasing number of AOGCMs have included multiple types of tropospheric aerosols including sulphates, nitrates, black and organic carbon, sea salt and soil dust. Of the 23 models represented in the multi-model ensemble of climate-change simulations for IPCC AR4, 13 include other tropospheric species besides sulphates. Of these, seven have the non-sulphate species represented with parametrizations that interact with the remainder of the model physics. Nitrates are treated in just two of the models in the ensemble. Recent projections of nitrate and sulphate loading under the SRES A2 scenario suggest that forcing by nitrates may exceed forcing by sulphates by the end of the 21st century (Adams et al., 2001). This result is of course strongly dependent upon the evolution of precursor emissions for these aerosol species.

The black and organic carbon aerosols in the atmosphere include a very complex system of primary organic aerosols (POA) and secondary organic aerosols (SOA), which are formed by oxidation of biogenic VOCs. The models used for climate projections typically use highly simplified bulk parametrizations for POA and SOA. More detailed parametrizations for the formation of SOA that trace oxidation pathways have only recently been developed and used to estimate the direct radiative forcing by SOA for present-day conditions (Chung and Seinfeld, 2002). The forcing by SOA is an emerging issue for simulations of present-day and future climate since the rate of chemical formation of SOA may be 60% or more of the emissions rate for primary carbonaceous aerosols (Kanakidou et al., 2005). In addition, two-way coupling between reactive chemistry and tropospheric aerosols has not been explored comprehensively in climate change simulations. Unified models that treat tropospheric ozone-NO_x-hydrocarbon chemistry, aerosol formation, heterogeneous processes in clouds and on aerosols, and gas-phase photolysis have been developed and applied to the current climate (Liao et al., 2003). However, these unified models have not yet been used extensively to study the evolution of the chemical state of the atmosphere under future scenarios.

The interaction of soil dust with climate is under active investigation. Whether emissions of soil dust aerosols increase or decrease in response to changes in atmospheric state and circulation is still unresolved (Tegen et al., 2004a). Several recent studies have suggested that the total surface area where dust can be mobilised will decrease in a warmer climate with higher concentrations of CO_2 (e.g., Harrison et al., 2001). The net effects of reductions in dust emissions from natural sources combined with land use change could potentially be significant but have not been systematically modelled as part of climate change assessment.

Uncertainty regarding the scenario simulations is compounded by inherently unpredictable natural forcings from future volcanic eruptions and solar variability. The eruptions that produce climatologically significant forcing represent just the extremes of global volcanic activity (Naveau and Ammann, 2005). Global simulations can account for the effects of future natural forcings using stochastic representations based upon prior eruptions and variations in solar luminosity. The relative contribution of these forcings to the projections of global mean temperature anomalies are largest in the period up to 2030 (Stott and Kettleborough, 2002).

10.5 Quantifying the Range of Climate Change Projections

10.5.1 Sources of Uncertainty and Hierarchy of Models

Uncertainty in predictions of anthropogenic climate change arises at all stages of the modelling process described in Section 10.1. The specification of future emissions of greenhouse gases, aerosols and their precursors is uncertain (e.g., Nakićenović and Swart, 2000). It is then necessary to convert these emissions into concentrations of radiatively active species, calculate the associated forcing and predict the response of climate system variables such as surface temperature and precipitation (Figure 10.1). At each step, uncertainty in the true signal of climate change is introduced both by errors in the representation of Earth system processes in models (e.g., Palmer et al., 2005) and by internal climate variability (e.g., Selten et al., 2004). The effects of internal variability can be quantified by running models many times from different initial conditions, provided that simulated variability is consistent with observations. The effects of uncertainty in the knowledge of Earth system processes can be partially quantified by constructing ensembles of models that sample different parametrizations of these processes. However, some processes may be missing from the set of available models, and alternative parametrizations of other processes may share common systematic biases. Such limitations imply that distributions of future climate responses from ensemble simulations are themselves subject to uncertainty (Smith, 2002), and would be wider were uncertainty due to structural model errors accounted for. These distributions may be modified to reflect observational constraints expressed through metrics of the agreement between the observed historical climate and the simulations of individual ensemble members, for example through Bayesian methods (see Chapter 9 Supplementary Material, Appendix 9.B). In this case, the choice of observations and their associated errors introduce further sources of uncertainty. In addition, some sources of future radiative forcing are yet to be accounted for in the ensemble projections, including those from land use change, variations in solar and volcanic activity (Kettleborough et al., 2007), and CH_4 release from permafrost or ocean hydrates (see Section 8.7).

A spectrum or hierarchy of models of varying complexity has been developed (Claussen et al., 2002; Stocker and Knutti, 2003) to assess the range of future changes consistent with the understanding of known uncertainties. Simple climate models (SCMs) typically represent the ocean-atmosphere system as a set of global or hemispheric boxes, predicting global surface temperature using an energy balance equation, a prescribed value of climate sensitivity and a basic representation of ocean heat uptake (see Section 8.8.2). Their role is to perform comprehensive analyses of the interactions between global variables, based on prior estimates of uncertainty in their controlling parameters obtained from observations, expert judgement and from tuning to complex models. By coupling SCMs to simple models of biogeochemical cycles they can be used to extrapolate the results of AOGCM simulations to a wide range of alternative forcing scenarios (e.g., Wigley and Raper, 2001; see Section 10.5.3).

Compared to SCMs, EMICs include more of the processes simulated in AOGCMs, but in a less detailed, more highly parametrized form (see Section 8.8.3), and at coarser resolution. Consequently, EMICs are not suitable for quantifying uncertainties in regional climate change or extreme events, however they can be used to investigate the large-scale effects of coupling between multiple Earth system components in large ensembles or long simulations (e.g., Forest et al., 2002; Knutti et al., 2002), which is not yet possible with AOGCMs due to their greater computational expense. Some EMICs therefore include modules such as vegetation dynamics, the terrestrial and ocean carbon cycles and atmospheric chemistry (Plattner et al., 2001; Claussen et al., 2002), filling a gap in the spectrum of models between AOGCMs and SCMs. Thorough sampling of parameter space is computationally feasible for some EMICs (e.g., Stocker and Schmittner, 1997; Forest et al., 2002; Knutti et al., 2002), as for SCMs (Wigley and Raper, 2001), and is used to obtain probabilistic projections (see Section 10.5.4.5). In some EMICs, climate sensitivity is an adjustable parameter, as in SCMs. In other EMICs, climate sensitivity is dependent on multiple model parameters, as in AOGCMs. Probabilistic estimates of climate sensitivity and TCR from SCMs and EMICs are assessed in Section 9.6 and compared with estimates from AOGCMs in Box 10.2.

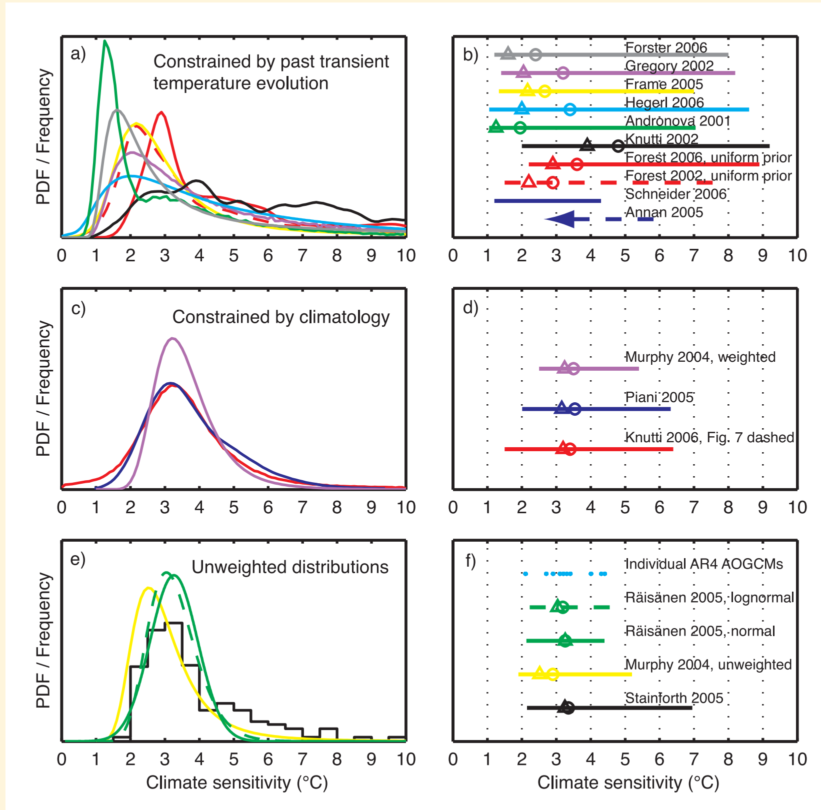
The high resolution and detailed parametrizations in AOGCMs enable them to simulate more comprehensively the

Box 10.2: Equilibrium Climate Sensitivity

The likely range[1] for equilibrium climate sensitivity was estimated in the TAR (Technical Summary, Section F.3; Cubasch et al., 2001) to be 1.5°C to 4.5°C. The range was the same as in an early report of the National Research Council (Charney, 1979), and the two previous IPCC assessment reports (Mitchell et al., 1990; Kattenberg et al., 1996). These estimates were expert assessments largely based on equilibrium climate sensitivities simulated by atmospheric GCMs coupled to non-dynamic slab oceans. The mean ±1 standard deviation values from these models were 3.8°C ± 0.78°C in the SAR (17 models), 3.5°C ± 0.92°C in the TAR (15 models) and in this assessment 3.26°C ± 0.69°C (18 models).

Considerable work has been done since the TAR (IPCC, 2001) to estimate climate sensitivity and to provide a better quantification of relative probabilities, including a most likely value, rather than just a subjective range of uncertainty. Since climate sensitivity of the real climate system cannot be measured directly, new methods have been used since the TAR to establish a relationship between sensitivity and some observable quantity (either directly or through a model), and to estimate a range or probability density function (PDF) of climate sensitivity consistent with observations. These methods are summarised separately in Chapters 9 and 10, and here we synthesize that information into an assessment. The information comes from two main categories: constraints from past climate change on various time scales, and the spread of results for climate sensitivity from ensembles of models.

The first category of methods (see Section 9.6) uses the historical transient evolution of surface temperature, upper air temperature, ocean temperature, estimates of the radiative forcing, satellite data, proxy data over the last millennium, or a subset thereof to calculate ranges or PDFs for sensitivity (e.g., Wigley et al., 1997b; Tol and De Vos, 1998; Andronova and Schlesinger, 2001; Forest et al., 2002; Gregory et al., 2002a; Harvey and Kaufmann, 2002; Knutti et al., 2002, 2003; Frame et al., 2005; Forest et al., 2006; Forster and Gregory, 2006; Hegerl et al., 2006). A summary of all PDFs of climate sensitivity from those methods is shown in Figure 9.20 and in Box 10.2, Figure 1a. Median values, most likely values (modes) and 5 to 95% uncertainty ranges are shown in Box 10.2, Figure 1b for each PDF. Most of the results confirm that climate sensitivity is very unlikely below 1.5°C. The upper bound is more difficult to constrain because of a nonlinear relationship between climate sensitivity and the observed transient response, and is further hampered by the limited length of the observational record and uncertainties in the observations, which are particularly large for ocean heat uptake and for the magnitude of the aerosol radiative forcing. Studies that take all the important known uncertainties in observed historical trends into account cannot rule out the possibility that the climate sensitivity exceeds 4.5°C, although such high values are consistently found to be less likely than values of around 2.0°C to 3.5°C. Observations of transient climate change provide better constraints for the TCR (see Section 9.6.1.3).



Box 10.2, Figure 1. *(a) PDFs or frequency distributions constrained by the transient evolution of the atmospheric temperature, radiative forcing and ocean heat uptake, (b) as in (a) and (b) but 5 to 95% ranges, medians (circles) and maximum probabilities (triangles), (c) and (d) as in (a) but using constraints from present-day climatology, and (e) and (f) unweighted or fitted distributions from different models or from perturbing parameters in a single model. Distributions in (e) and (f) should not be strictly interpreted as PDFs. See Chapter 9 text, Figure 9.20 and Table 9.3 for details. Note that Annan et al. (2005b) only provide an upper but no lower bound. All PDFs are truncated at 10°C for consistency, some are shown for different prior distributions than in the original studies, and ranges may differ from numbers reported in individual studies.*

Two recent studies use a modelled relation between climate sensitivity and tropical SSTs in the Last Glacial Maximum (LGM) and proxy records of the latter to estimate ranges of climate sensitivity (Annan et al., 2005b; Schneider von Deimling et al., 2006; see

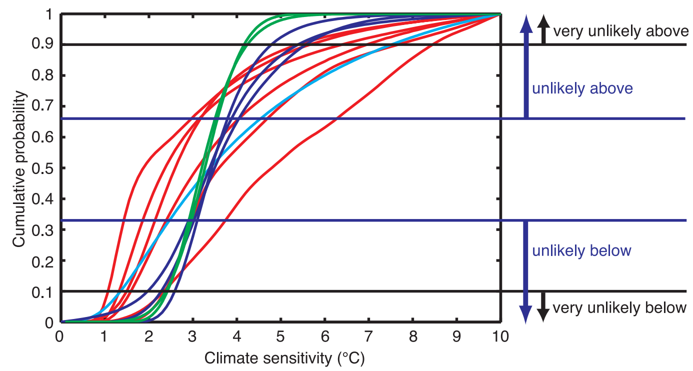
(continued)

[1] Though the TAR Technical Summary attached 'likely' to the 1.5°C - 4.5°C range, the word 'likely' was used there in a general sense rather than in a specific calibrated sense. No calibrated confidence assessment was given in either the Summary for Policymakers or in Chapter 9 of the TAR, and no probabilistic studies on climate sensitivity were cited in Chapter 9 where the range was assessed.

Section 9.6). While both of these estimates overlap with results from the instrumental period and results from other AOGCMS, the results differ substantially due to different forcings and the different relationships between LGM SSTs and sensitivity in the models used. Therefore, LGM proxy data provide support for the range of climate sensitivity based on other lines of evidence.

Studies comparing the observed transient response of surface temperature after large volcanic eruptions with results obtained from models with different climate sensitivities (see Section. 9.6) do not provide PDFs, but find best agreement with sensitivities around 3°C, and reasonable agreement within the 1.5°C to 4.5°C range (Wigley et al., 2005). They are not able to exclude sensitivities above 4.5°C.

The second category of methods examines climate sensitivity in GCMs. Climate sensitivity is not a single tuneable parameter in these models, but depends on many processes and feedbacks. Three PDFs of climate sensitivity were obtained by comparing different variables of the simulated present-day climatology and variability against observations in a perturbed physics ensemble (Murphy et al., 2004; Piani et al., 2005; Knutti et al., 2006, Box 10.2, Figure 1c,d; see Section 10.5.4.2). Equilibrium climate sensitivity is found to be most likely around 3.2°C, and very unlikely to be below about 2°C. The upper bound is sensitive to how model parameters are sampled and to the method used to compare with observations.



Box 10.2, Figure 2. *Individual cumulative distributions of climate sensitivity from the observed 20th-century warming (red), model climatology (blue) and proxy evidence (cyan), taken from Box 10.2, Figure 1a, c (except LGM studies and Forest et al. (2002), which is superseded by Forest et al. (2006)) and cumulative distributions fitted to the AOGCMs' climate sensitivities (green) from Box 10.2, Figure 1e. Horizontal lines and arrows mark the edges of the likelihood estimates according to IPCC guidelines.*

Box 10.2, Figure 1e,f show the frequency distributions obtained by different methods when perturbing parameters in the Hadley Centre Atmospheric Model (HadAM3) but before weighting with observations (Section10.5.4). Murphy et al. (2004; unweighted) sampled 29 parameters and assumed individual effects to combine linearly. Stainforth et al. (2005) found nonlinearities when simulating multiple combinations of a subset of key parameters. The most frequently occurring climate sensitivity values are grouped around 3°C, but this could reflect the sensitivity of the unperturbed model. Some, but not all, of the simulations by high-sensitivity models have been found to agree poorly with observations and are therefore unlikely, hence even very high values are not excluded. This inability to rule out very high values is common to many methods, since for well-understood physical reasons, the rate of change (against sensitivity) of most quantities that can be observed tends to zero as the sensitivity increases (Hansen et al., 1985; Knutti et al., 2005; Allen et al., 2006b).

There is no well-established formal way of estimating a single PDF from the individual results, taking account of the different assumptions in each study. Most studies do not account for structural uncertainty, and thus probably tend to underestimate the uncertainty. On the other hand, since several largely independent lines of evidence indicate similar most likely values and ranges, climate sensitivity values are likely to be better constrained than those found by methods based on single data sets (Annan and Hargreaves, 2006; Hegerl et al., 2006).

The equilibrium climate sensitivity values for the AR4 AOGCMs coupled to non-dynamic slab ocean models are given for comparison (Box 10.2, Figure 1e,f; see also Table 8.2). These estimates come from models that represent the current best efforts from the international global climate modelling community at simulating climate. A normal fit yields a 5 to 95% range of about 2.1°C to 4.4°C with a mean value of equilibrium climate sensitivity of about 3.3°C (2.2°C to 4.6°C for a lognormal distribution, median 3.2°C) (Räisänen, 2005b). A probabilistic interpretation of the results is problematic, because each model is assumed to be equally credible and the results depend upon the assumed shape of the fitted distribution. Although the AOGCMs used in IPCC reports are an 'ensemble of opportunity' not designed to sample modelling uncertainties systematically or randomly, the range of sensitivities covered has been rather stable over many years. This occurs in spite of substantial model developments, considerable progress in simulating many aspects of the large-scale climate, and evaluation of those models against observations. Progress has been made since the TAR in diagnosing and understanding inter-model differences in climate feedbacks and equilibrium climate sensitivity. Confidence has increased in the strength of water vapour-lapse rate feedbacks, whereas cloud feedbacks (particularly from low-level clouds) have been confirmed as the primary source of climate sensitivity differences (see Section 8.6).

Since the TAR, the levels of scientific understanding and confidence in quantitative estimates of equilibrium climate sensitivity have increased substantially. Basing our assessment on a combination of several independent lines of evidence, as summarised in Box 10.2 Figures 1 and 2, including observed climate change and the strength of known feedbacks simulated in GCMs, we conclude that the global mean equilibrium warming for doubling CO_2, or 'equilibrium climate sensitivity', is likely to lie in the range 2°C to 4.5°C, with a most likely value of about 3°C. Equilibrium climate sensitivity is very likely larger than 1.5°C.

For fundamental physical reasons as well as data limitations, values substantially higher than 4.5°C still cannot be excluded, but agreement with observations and proxy data is generally worse for those high values than for values in the 2°C to 4.5°C range.

processes giving rise to internal variability (see Section 8.4), extreme events (see Section 8.5) and climate change feedbacks, particularly at the regional scale (Boer and Yu, 2003a; Bony and Dufresne, 2005; Bony et al., 2006; Soden and Held, 2006). Given that ocean dynamics influence regional feedbacks (Boer and Yu, 2003b), quantification of regional uncertainties in time-dependent climate change requires multi-model ensemble simulations with AOGCMs containing a full, three-dimensional dynamic ocean component. However, downscaling methods (see Chapter 11) are required to obtain credible information at spatial scales near or below the AOGCM grid scale (125 to 400 km in the AR4 AOGCMs, see Table 8.1).

10.5.2 Range of Responses from Different Models

10.5.2.1 Comprehensive AOGCMs

The way a climate model responds to changes in external forcing, such as an increase in anthropogenic greenhouse gases, is characterised by two standard measures: (1) 'equilibrium climate sensitivity' (the equilibrium change in global surface temperature following a doubling of the atmospheric equivalent CO_2 concentration; see Glossary), and (2) 'transient climate response' (the change in global surface temperature in a global coupled climate model in a 1% yr^{-1} CO_2 increase experiment at the time of atmospheric CO_2 doubling; see Glossary). The first measure provides an indication of feedbacks mainly residing in the atmospheric model but also in the land surface and sea ice components, and the latter quantifies the response of the fully coupled climate system including aspects of transient ocean heat uptake (e.g., Sokolov et al., 2003). These two measures have become standard for quantifying how an AOGCM will react to more complicated forcings in scenario simulations.

Historically, the equilibrium climate sensitivity has been given in the range from 1.5°C to 4.5°C. This range was reported in the TAR with no indication of a probability distribution within this range. However, considerable recent work has addressed the range of equilibrium climate sensitivity, and attempted to assign probabilities to climate sensitivity.

Equilibrium climate sensitivity and TCR are not independent (Figure 10.25a). For a given AOGCM, the TCR is smaller than the equilibrium climate sensitivity because ocean heat uptake delays the atmospheric warming. A large ensemble of the BERN2.5D EMIC has been used to explore the relationship of TCR and equilibrium sensitivity over a wide range of ocean heat uptake parametrizations (Knutti et al., 2005). Good agreement with the available results from AOGCMs is found, and the BERN2.5D EMIC covers almost the entire range of structurally different models. The percent change in precipitation is closely related to the equilibrium climate sensitivity for the current generation of AOGCMs (Figure 10.25b), with values from the current models falling within the range of the models from the TAR. Figure 10.25c shows the percent change in globally averaged precipitation as a function of TCR at the time of atmospheric CO_2 doubling, as simulated by 1% yr^{-1} transient CO_2 increase experiments with AOGCMs. The figure suggests

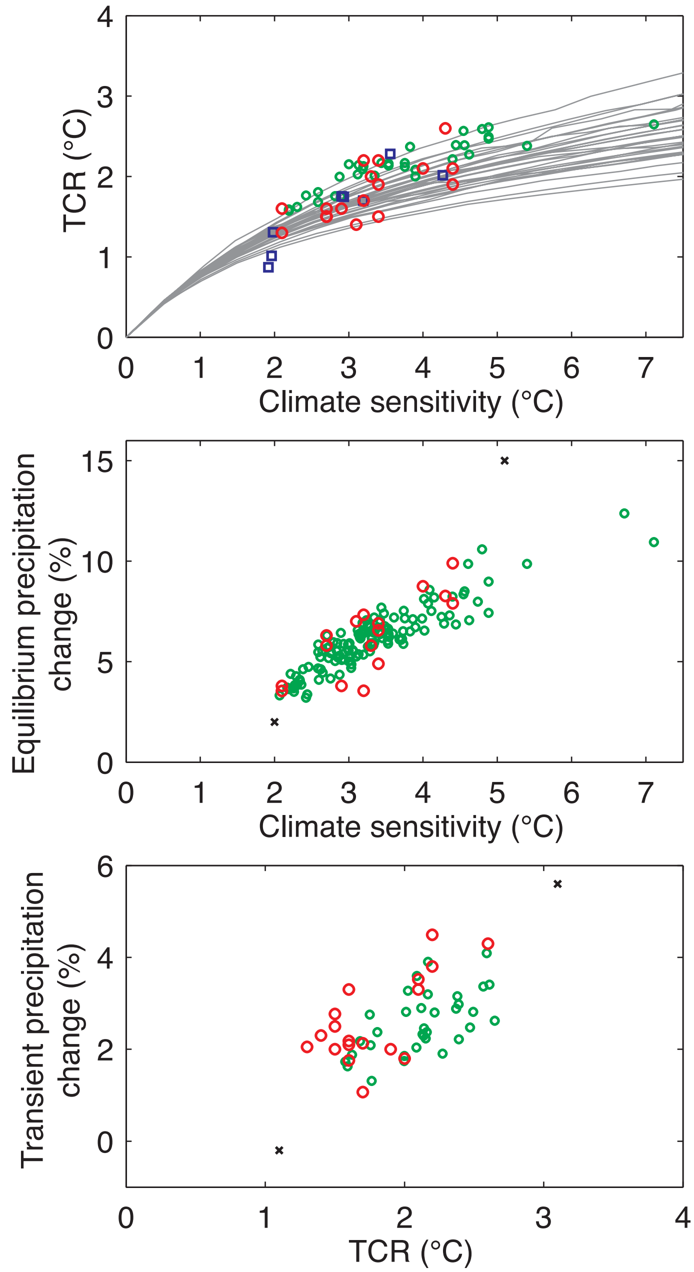


Figure 10.25. *(a) TCR versus equilibrium climate sensitivity for all AOGCMs (red), EMICs (blue), a perturbed physics ensemble of the UKMO-HadCM3 AOGCM (green; an updated ensemble based on M. Collins et al., 2006) and from a large ensemble of the Bern2.5D EMIC (Knutti et al., 2005) using different ocean vertical diffusivities and mixing parametrizations (grey lines). (b) Global mean precipitation change (%) as a function of global mean temperature change at equilibrium for doubled CO_2 in atmospheric GCMs coupled to a non-dynamic slab ocean (red all AOGCMS, green from a perturbed physics ensemble of the atmosphere-slab ocean version of UKMO-HadCM3 (Webb et al., 2006)). (c) Global mean precipitation change (%) as a function of global mean temperature change (TCR) at the time of CO_2 doubling in a transient 1% yr^{-1} CO_2 increase scenario, simulated by coupled AOGCMs (red) and the UKMO-HadCM3 perturbed physics ensemble (green). Black crosses in (b) and (c) mark ranges covered by the TAR AOGCMs (IPCC, 2001) for each quantity.*

a broadly positive correlation between these two quantities similar to that for equilibrium climate sensitivity, with these values from the new models also falling within the range of the previous generation of AOGCMs assessed in the TAR. Note that the apparent relationships may not hold for other forcings or at smaller scales. Values for an ensemble with perturbations made to parameters in the atmospheric component of UKMO-HadCM3 (M. Collins et al., 2006) cover similar ranges and are shown in Figure 10.25 for comparison.

Fitting normal distributions to the results, the 5 to 95% uncertainty range for equilibrium climate sensitivity from the AOGCMs is approximately 2.1°C to 4.4°C and that for TCR is 1.2°C to 2.4°C (using the method of Räisänen, 2005b). The mean for climate sensitivity is 3.26°C and that for TCR is 1.76°C. These numbers are practically the same for both the normal and the lognormal distribution (see Box 10.2). The assumption of a (log) normal fit is not well supported by the limited sample of AOGCM data. In addition, the AOGCMs represent an 'ensemble of opportunity' and are by design not sampled in a random way. However, most studies aiming to constrain climate sensitivity with observations do indeed indicate a similar to lognormal probability distribution of climate sensitivity and an approximately normal distribution of the uncertainty in future warming and thus TCR (see Box 10.2). Those studies also suggest that the current AOGCMs may not cover the full range of uncertainty for climate sensitivity. An assessment of all the evidence on equilibrium climate sensitivity is provided in Box 10.2. The spread of the AOGCM climate sensitivities is discussed in Section 8.6 and the AOGCM values for climate sensitivity and TCR are listed in Table 8.2.

The nonlinear relationship between TCR and equilibrium climate sensitivity shown in Figure 10.25a also indicates that on time scales well short of equilibrium, the model's TCR is not particularly sensitive to the model's climate sensitivity. The implication is that transient climate change is better constrained than the equilibrium climate sensitivity, that is, models with different sensitivity might still show good agreement for projections on decadal time scales. Therefore, in the absence of unusual solar or volcanic activity, climate change is well constrained for the coming few decades, because differences in some feedbacks will only become important on long time scales (see also Section 10.5.4.5) and because over the next few decades, about half of the projected warming would occur as a result of radiative forcing being held constant at year 2000 levels (constant composition commitment, see Section 10.7).

Comparing observed thermal expansion with those AR4 20th-century simulations that have natural forcings indicates that ocean heat uptake in the models may be 25% larger than observed, although both could be consistent within their uncertainties. This difference is possibly due to a combination of overestimated ocean heat uptake in the models, observational uncertainties and limited data coverage in the deep ocean (see Sections 9.5.1.1, 9.5.2, and 9.6.2.1). Assigning this difference solely to overestimated ocean heat uptake, the TCR estimates could increase by 0.6°C at most. This is in line with evidence for a relatively weak dependence of TCR on ocean mixing based on SCMs and EMICS (Allen et al., 2000; Knutti et al., 2005). The range of TCR covered by an ensemble with perturbations made to parameters in the atmospheric component of UKMO-HadCM3 is 1.5 to 2.6°C (M. Collins et al., 2006), similar to the AR4 AOGCM range. Therefore, based on the range covered by AOGCMs, and taking into account structural uncertainties and possible biases in transient heat uptake, TCR is assessed as very likely larger than 1°C and very unlikely greater than 3°C (i.e., 1.0°C to 3.0°C is a 10 to 90% range). Because the dependence of TCR on sensitivity becomes small as sensitivity increases, uncertainties in the upper bound on sensitivity only weakly affect the range of TCR (see Figure 10.25; Chapter 9; Knutti et al., 2005; Allen et al., 2006b). Observational constraints based on detection and attribution studies provide further support for this TCR range (see Section 9.6.2.3).

10.5.2.2 Earth System Models of Intermediate Complexity

Over the last few years, a range of climate models has been developed that are dynamically simpler and of lower resolution than comprehensive AOGCMs, although they might well be more 'complete' in terms of climate system components that are included. The class of such models, usually referred to as EMICs (Claussen et al., 2002), is very heterogeneous, ranging from zonally averaged ocean models coupled to energy balance models (Stocker et al., 1992a) or to statistical-dynamical models of the atmosphere (Petoukhov et al., 2000), to low resolution three-dimensional ocean models, coupled to energy balance or simple dynamical models of the atmosphere (Opsteegh et al., 1998; Edwards and Marsh, 2005; Müller et al., 2006). Some EMICs have a radiation code and prescribe greenhouse gases, while others use simplified equations to project radiative forcing from projected concentrations and abundances (Joos et al., 2001; see Chapter 2 and the TAR, Appendix II, Table II.3.11). Compared to comprehensive models, EMICs have hardly any computational constraints, and therefore many simulations can be performed. This allows for the creation of large ensembles, or the systematic exploration of long-term changes many centuries hence. However, because of the reduced resolution, only results at the largest scales (continental to global) are to be interpreted (Stocker and Knutti, 2003). Table 8.3 lists all EMICs used in this section, including their components and resolution.

A set of simulations is used to compare EMICs with AOGCMs for the SRES A1B scenario with stable atmospheric concentrations after year 2100 (see Section 10.7.2). For global mean temperature and sea level, the EMICs generally reproduce the AOGCM behaviour quite well. Two of the EMICs have values for climate sensitivity and transient response below the AOGCM range. However, climate sensitivity is a tuneable parameter in some EMICs, and no attempt was made here to match the range of response of the AOGCMs. The transient reduction of the MOC in most EMICs is also similar to the AOGCMs (see also Sections 10.3.4 and 10.7.2 and Figure 10.34), providing support that this class of models can be used for both long-term commitment projections (see Section 10.7) and probabilistic projections involving hundreds to thousands of simulations (see Section 10.5.4.5). If the forcing is strong enough, and lasts long enough (e.g., 4 × CO_2), a complete and irreversible collapse of the MOC can be induced in a few models. This is in line with earlier results using EMICs (Stocker and Schmittner, 1997; Rahmstorf and Ganopolski, 1999) or a coupled model (Stouffer and Manabe, 1999).

10.5.3 Global Mean Responses from Different Scenarios

The TAR projections with an SCM presented a range of warming over the 21st century for 35 SRES scenarios. The SRES emission scenarios assume that no climate policies are implemented (Nakićenović and Swart, 2000). The construction of Figure 9.14 of the TAR was pragmatic. It used a simple model tuned to AOGCMs that had a climate sensitivity within the long-standing range of 1.5°C to 4.5°C (e.g., Charney, 1979; and stated in earlier IPCC Assessment Reports). Models with climate sensitivity outside that range were discussed in the text and allowed the statement that the presented range was not the extreme range indicated by AOGCMs. The figure was based on a single anthropogenic-forcing estimate for 1750 to 2000, which is well within the range of values recommended by TAR Chapter 6, and is also consistent with that deduced from model simulations and the observed temperature record (TAR Chapter 12.). To be consistent with TAR Chapter 3, climate feedbacks on the carbon cycle were included. The resulting range of global mean temperature change from 1990 to 2100 given by the full set of SRES scenarios was 1.4°C to 5.8°C.

Since the TAR, several studies have examined the TAR projections and attempted probabilistic assessments. Allen et al. (2000) show that the forcing and simple climate model tunings used in the TAR give projections that are in agreement with the observationally constrained probabilistic forecast, reported in TAR Chapter 12.

As noted by Moss and Schneider (2000), giving only a range of warming results is potentially misleading unless some guidance is given as to what the range means in probabilistic terms. Wigley and Raper (2001) interpret the warming range in probabilistic terms, accounting for uncertainties in emissions, the climate sensitivity, the carbon cycle, ocean mixing and aerosol forcing. They give a 90% probability interval for 1990 to 2100 warming of 1.7°C to 4°C. As pointed out by Wigley and Raper (2001), such results are only as realistic as the assumptions upon which they are based. Key assumptions in this study were that each SRES scenario was equally likely, that 1.5°C to 4.5°C corresponds to the 90% confidence interval for the climate sensitivity, and that carbon cycle feedback uncertainties can be characterised by the full uncertainty range of abundance in 2100 of 490 to 1,260 ppm given in the TAR. The aerosol probability density function (PDF) was based on the uncertainty estimates given in the TAR together with constraints based on fitting the SCM to observed global and hemispheric mean temperatures.

The most controversial assumption in the Wigley and Raper (2001) probabilistic assessment was the assumption that each SRES scenario was equally likely. The *Special Report on Emissions Scenarios* (Nakićenović and Swart, 2000) states that 'No judgment is offered in this report as to the preference for any of the scenarios and they are not assigned probabilities of occurrence, neither must they be interpreted as policy recommendations.'

Webster et al. (2003) use the probabilistic emissions projections of Webster et al. (2002), which consider present uncertainty in SO_2 emissions, and allow the possibility of continuing increases in SO_2 emissions over the 21st century, as well as the declining emissions consistent with SRES scenarios. Since their climate model parameter PDFs were constrained by observations and are mutually dependent, the effect of the lower present-day aerosol forcing on the projections is not easy to separate, but there is no doubt that their projections tend to be lower where they admit higher and increasing SO_2 emissions.

Irrespective of the question of whether it is possible to assign probabilities to specific emissions scenarios, it is important to distinguish different sources of uncertainties in temperature projections up to 2100. Different emission scenarios arise because future greenhouse gas emissions are largely dependent on key socioeconomic drivers, technological development and political decisions. Clearly, one factor leading to different temperature projections is the choice of scenario. On the other hand, the 'response uncertainty' is defined as the range in projections for a particular emission scenario and arises from the limited knowledge of how the climate system will react to the anthropogenic perturbations. In the following, all given uncertainty ranges reflect the response uncertainty of the climate system and should therefore be seen as conditional on a specific emission scenario.

The following paragraphs describe the construction of the AR4 temperature projections for the six illustrative SRES scenarios, using the SCM tuned to 19 models from the MMD (see Section 8.8). These 19 tuned simple model versions have effective climate sensitivities in the range 1.9°C to 5.9°C. The simple model sensitivities are derived from the fully coupled 2 × and 4 × CO_2 1% yr^{-1} CO_2 increase AOGCM simulations and in some cases differ from the equilibrium slab ocean model sensitivities given in Table 8.2.

The SRES emission scenarios used here were designed to represent plausible futures assuming that no climate policies will be implemented. This chapter does not analyse any scenarios with explicit climate change mitigation policies. Still, there is a wide variation across these SRES scenarios in terms of anthropogenic emissions, such as those of fossil CO_2, CH_4 and SO_2 (Nakićenović and Swart, 2000) as shown in the top three panels of Figure 10.26. As a direct consequence of the different emissions, the projected concentrations vary widely for the six illustrative SRES scenarios (see panel rows four to six in Figure 10.26 for the concentrations of the main greenhouse gases, CO_2, CH_4 and N_2O). These results incorporate the effect of carbon cycle uncertainties (see Section 10.4.1), which were not explored with the SCM in the TAR. Projected CH_4 concentrations are influenced by the temperature-dependent water vapour feedback on the lifetime of CH_4.

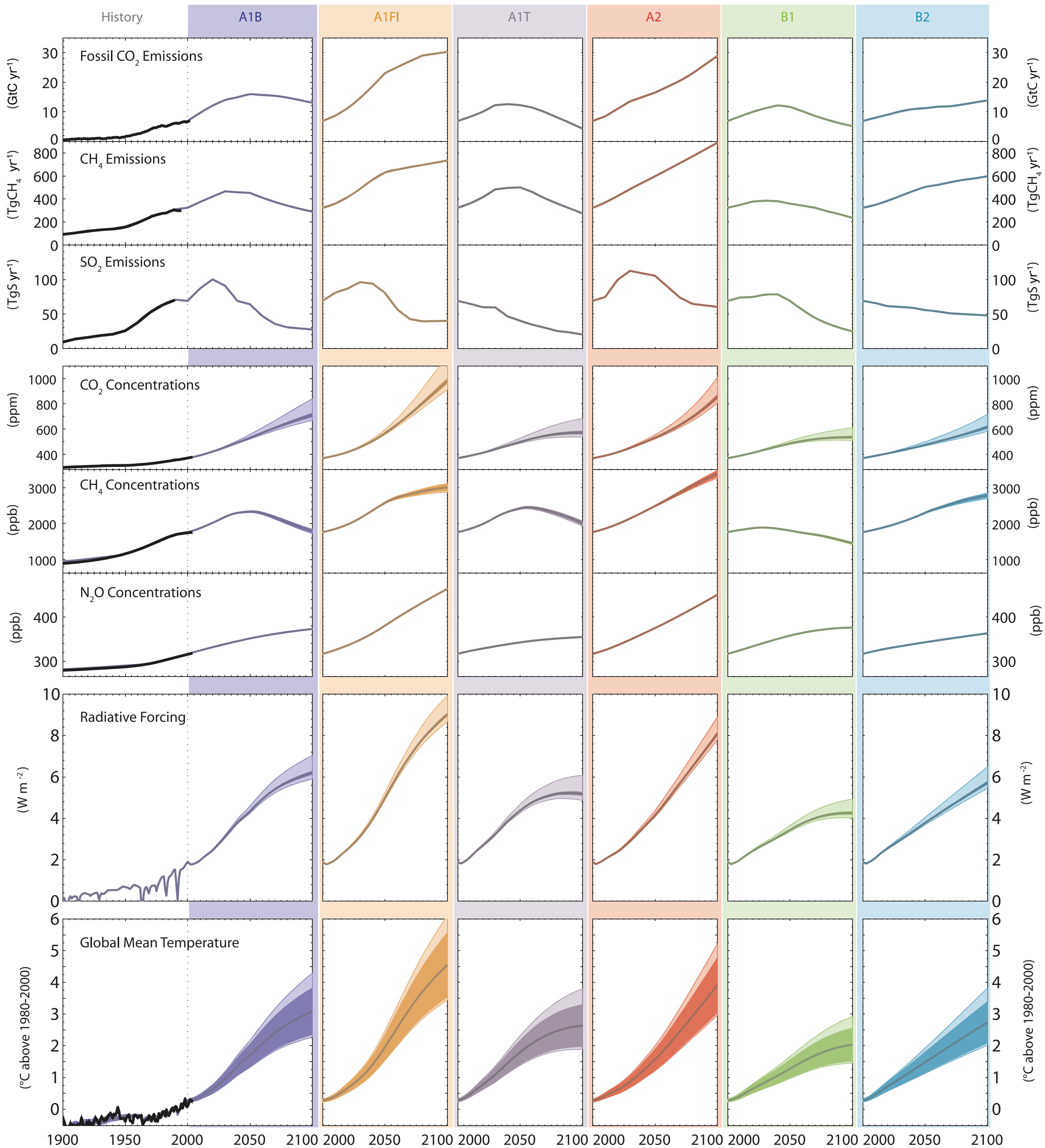


Figure 10.26. *Fossil CO_2, CH_4 and SO_2 emissions for six illustrative SRES non-mitigation emission scenarios, their corresponding CO_2, CH_4 and N_2O concentrations, radiative forcing and global mean temperature projections based on an SCM tuned to 19 AOGCMs. The dark shaded areas in the bottom temperature panel represent the mean ±1 standard deviation for the 19 model tunings. The lighter shaded areas depict the change in this uncertainty range, if carbon cycle feedbacks are assumed to be lower or higher than in the medium setting. Mean projections for mid-range carbon cycle assumptions for the six illustrative SRES scenarios are shown as thick coloured lines. Historical emissions (black lines) are shown for fossil and industrial CO_2 (Marland et al., 2005), for SO_2 (van Aardenne et al., 2001) and for CH_4 (van Aardenne et al., 2001, adjusted to Olivier and Berdowski, 2001). Observed CO_2, CH_4 and N_2O concentrations (black lines) are as presented in Chapter 6. Global mean temperature results from the SCM for anthropogenic and natural forcing compare favourably with 20th-century observations (black line) as shown in the lower left panel (Folland et al., 2001; Jones et al., 2001; Jones and Moberg, 2003).*

In Figure 10.26, the plumes of CO_2 concentration reflect high and low carbon cycle feedback settings of the applied SCM. Their derivation is described as follows. The carbon cycle model in the SCM used here (Model for the Assessment of Greenhouse-gas Induced Climate Change: MAGICC) includes a number of climate-related carbon cycle feedbacks driven by global mean temperature. The parametrization of the overall effect of carbon cycle feedbacks is tuned to the more complex and physically realistic carbon cycle models of the C^4MIP (Friedlingstein et al, 2006; see also Section 10.4) and the results are comparable to the BERN-CC model results across the six illustrative scenarios. This allows the SCM to produce projections of future CO_2 concentration change that are consistent with state-of-the-art carbon cycle model results. Specifically, the C^4MIP range of CO_2 concentrations for the A2 emission scenario in 2100 is 730 to 1,020 ppm, while the SCM results presented here show an uncertainty range of 806 ppm to 1,008 ppm. The lower bound of this SCM uncertainty range is the mean minus one standard deviation for low carbon cycle feedback settings and the 19 AOGCM tunings, while the upper bound represents the mean plus one standard deviation for high carbon cycle settings. For comparison, the 90% confidence interval from Wigley and Raper (2001) is 770 to 1,090 ppm. The simple model CO_2 concentration projections can be slightly higher than under the C^4MIP because the SCM's carbon cycle is driven by the full temperature changes in the A2 scenario, while the C^4MIP values are driven by the component of A2 climate change due to CO_2 alone.

The radiative forcing projections in Figure 10.26 combine anthropogenic and natural (solar and volcanic) forcing. The forcing plumes reflect primarily the sensitivity of the forcing to carbon cycle uncertainties. Results are based on a forcing of 3.71 W m^{-2} for a doubling of the atmospheric CO_2 concentration. The anthropogenic forcing is based on Table 2.12 but uses a value of –0.8 W m^{-2} for the present-day indirect aerosol forcing. Solar forcing for the historical period is prescribed according to Lean et al. (1995) and volcanic forcing according to Ammann et al. (2003). The historical solar forcing series is extended into the future using its average over the most recent 22 years. The volcanic forcing is adjusted to have a zero mean over the past 100 years and the anomaly is assumed to be zero for the future. In the TAR, the anthropogenic forcing was used alone even though the projections started in 1765. There are several advantages of using both natural and anthropogenic forcing for the past. First, this was done by most of the AOGCMs the simple models are emulating. Second, it allows the simulations to be compared with observations. Third, the warming commitments accrued over the instrumental period are reflected in the projections. The disadvantage of including natural forcing is that the warming projections in 2100 are dependent to a few tenths of a degree on the necessary assumptions made about the natural forcing (Bertrand et al., 2002). These assumptions include how the natural forcing is projected into the future and whether to reference the volcanic forcing to a past reference period mean value. In addition, the choice of data set for both solar and volcanic forcing affects the results (see Section 2.7 for discussion about uncertainty in natural forcings).

The temperature projections for the six illustrative scenarios are shown in the bottom panel of Figure 10.26. Model results are shown as anomalies from the mean of observations (Folland et al., 2001; Jones et al., 2001; Jones and Moberg, 2003) over the 1980 to 2000 period and the corresponding observed temperature anomalies are shown for comparison. The inner (darker) plumes show the ±1 standard deviation uncertainty due to the 19 model tunings and the outer (lighter) plumes show results for the corresponding high and low carbon cycle settings. Note that the asymmetry in the carbon cycle uncertainty causes global mean temperature projections to be skewed towards higher warming.

Considering only the mean of the SCM results with mid-range carbon cycle settings, the projected global mean temperature rise above 1980 to 2000 levels for the lower-emission SRES scenario B1 is 2.0°C in 2100. For a higher-emission scenario, for example, the SRES A2 scenario, the global mean temperature is projected to rise by 3.9°C above 1980 to 2000 levels in 2100. This clear difference in projected mean warming highlights the importance of assessing different emission scenarios separately. As mentioned above, the 'response uncertainty' is defined as the range in projections for a particular emission scenario. For the A2 emission scenario, the temperature change projections with the SCM span a ±1 standard deviation range of about 1.8°C, from 3.0°C to 4.8°C above 1980 to 2000 levels in 2100. If carbon cycle feedbacks are considered to be low, the lower end of this range decreases only slightly and is unchanged to one decimal place. For the higher carbon cycle feedback settings, the upper bound of the ±1 standard deviation range increases to 5.2°C. For lower-emission scenarios, this uncertainty range is smaller. For example, the B1 scenario projections span a range of about 1.4°C, from 1.5°C to 2.9°C, including carbon cycle uncertainties. The corresponding results for the medium-emission scenario A1B are 2.3°C to 4.3°C, and for the higher-emission scenario A1FI, they are 3.4°C to 6.1°C. Note that these uncertainty ranges are not the minimum to maximum bounds of the projected warming across all SCM runs, which are higher, namely 2.7°C to 7.1°C for the A2 scenario and 1.3°C to 4.2°C for the B1 scenario (not shown).

The SCM results presented here are a sensitivity study with different model tunings and carbon cycle feedback parameters. Note that forcing uncertainties have not been assessed and that the AOGCM model results available for SCM tuning may not span the full range of possible climate response. For example, studies that constrain forecasts based on model fits to historic or present-day observations generally allow for a somewhat wider 'response uncertainty' (see Section 10.5.4). The concatenation of all such uncertainties would require a probabilistic approach because the extreme ranges have low probability. A synthesis of the uncertainty in global temperature increase by the year 2100 is provided in Section 10.5.4.6.

10.5.4 Sampling Uncertainty and Estimating Probabilities

Uncertainty in the response of an AOGCM arises from the effects of internal variability, which can be sampled in isolation by creating ensembles of simulations of a single model using alternative initial conditions, and from modelling uncertainties, which arise from errors introduced by the discretization of the equations of motion on a finite resolution grid, and the parametrization of sub-grid scale processes (radiative transfer, cloud formation, convection, etc). Modelling uncertainties are manifested in alternative structural choices (for example, choices of resolution and the basic physical assumptions on which parametrizations are based), and in the values of poorly constrained parameters within parametrization schemes. Ensemble approaches are used to quantify the effects of uncertainties arising from variations in model structure and parameter settings. These are assessed in Sections 10.5.4.1 to 10.5.4.3, followed by a discussion of observational constraints in Section 10.5.4.4 and methods used to obtain probabilistic predictions in Sections 10.5.4.5 to 10.5.4.7.

While ensemble projections carried out to date give a wide range of responses, they do not sample all possible sources of modelling uncertainty. For example, the AR4 multi-model ensemble relies on specified concentrations of CO_2, thus neglecting uncertainties in carbon cycle feedbacks (see Section 10.4.1), although this can be partially addressed by using less detailed models to extrapolate the AOGCM results (see Section 10.5.3). More generally, the set of available models may share fundamental inadequacies, the effects of which cannot be quantified (Kennedy and O'Hagan, 2001). For example, climate models currently implement a restricted approach to the parametrization of sub-grid scale processes, using deterministic bulk formulae coupled to the resolved flow exclusively at the grid scale. Palmer et al. (2005) argue that the outputs of parametrization schemes should be sampled from statistical distributions consistent with a range of possible sub-grid scale states, following a stochastic approach that has been tried in numerical weather forecasting (e.g., Buizza et al., 1999; Palmer, 2001). The potential for missing or inadequately parametrized processes to broaden the simulated range of future changes is not clear, however, this is an important caveat for the results discussed below.

10.5.4.1 The Multi-Model Ensemble Approach

The use of ensembles of AOGCMs developed at different modelling centres has become established in climate prediction/projection on both seasonal-to-interannual and centennial time scales. To the extent that simulation errors in different AOGCMs are independent, the mean of the ensemble can be expected to outperform individual ensemble members, thus providing an improved 'best estimate' forecast. Results show this to be the case, both in verification of seasonal forecasts (Palmer et al., 2004; Hagedorn et al., 2005) and of the present-day climate from long term simulations (Lambert and Boer, 2001). By sampling modelling uncertainties, ensembles of AOGCMs should provide an improved basis for probabilistic projections compared with ensembles of a single model sampling only uncertainty in the initial state (Palmer et al., 2005). However, members of a multi-model ensemble share common systematic errors (Lambert and Boer, 2001), and cannot span the full range of possible model configurations due to resource constraints. Verification of future climate change projections is not possible, however, Räisänen and Palmer (2001) used a 'perfect model approach' (treating one member of an ensemble as truth and predicting its response using the other members) to show that the hypothetical economic costs associated with climate events can be reduced by calculating the probability of the event across the ensemble, rather than using a deterministic prediction from an individual ensemble member.

An additional strength of multi-model ensembles is that each member is subjected to careful testing in order to obtain a plausible and stable control simulation, although the process of tuning model parameters to achieve this (Section 8.1.3.1) involves subjective judgement, and is not guaranteed to identify the optimum location in the model parameter space.

10.5.4.2 Perturbed Physics Ensembles

The AOGCMs featured in Section 10.5.2 are built by selecting components from a pool of alternative parametrizations, each based on a given set of physical assumptions and including a number of uncertain parameters. In principle, the range of predictions consistent with these components could be quantified by constructing very large ensembles with systematic sampling of multiple options for parametrization schemes and parameter values, while avoiding combinations likely to double-count the effect of perturbing a given physical process. Such an approach has been taken using simple climate models and EMICs (Wigley and Raper, 2001; Knutti et al., 2002), and Murphy et al. (2004) and Stainforth et al. (2005) describe the first steps in this direction using AOGCMs, constructing large ensembles by perturbing poorly constrained parameters in the atmospheric component of UKMO-HadCM3 coupled to a mixed layer ocean. These experiments quantify the range of equilibrium responses to doubled atmospheric CO_2 consistent with uncertain parameters in a single GCM. Murphy et al. (2004) perturbed 29 parameters one at a time, assuming that effects of individual parameters were additive but making a simple allowance for additional uncertainty introduced by nonlinear interactions. They find a probability distribution for climate sensitivity with a 5 to 95% range of 2.4°C to 5.4°C when weighting the models with a broadly based metric of the agreement between simulated and observed climatology, compared to 1.9°C to 5.3°C when all model versions are assumed equally reliable (Box 10.2, Figure 1c).

Stainforth et al. (2005) deployed a distributed computing approach (Allen, 1999) to run a very large ensemble of 2,578 simulations sampling combinations of high, intermediate and low values of six parameters known to affect climate sensitivity. They find climate sensitivities ranging from 2°C to

11°C, with 4.2% of model versions exceeding 8°C, and show that the high-sensitivity models cannot be ruled out, based on a comparison with surface annual mean climatology. By utilising multivariate linear relationships between climate sensitivity and spatial fields of several present-day observables, the 5 to 95% range of climate sensitivity is estimated at 2.2°C to 6.8°C from the same data set (Piani et al., 2005; Box 10.2 Figure 1c). In this ensemble, Knutti et al. (2006) find a strong relationship between climate sensitivity and the amplitude of the seasonal cycle in surface temperature in the present-day simulations. Most of the simulations with high sensitivities overestimate the observed amplitude. Based on this relationship, the 5 to 95% range of climate sensitivity is estimated at 1.5°C to 6.4°C (Box 10.2, Figure 1c). The differences between the PDFs in Box 10.2, Figure 1c, which are all based on the same climate model, reflect uncertainties in methodology arising from choices of uncertain parameters, their expert-specified prior distributions and alternative applications of observational constraints. They do not account for uncertainties associated with changes in ocean circulation, and do not account for structural model errors (Smith, 2002; Goldstein and Rougier, 2004)

Annan et al. (2005a) use an ensemble Kalman Filter technique to obtain uncertainty ranges for model parameters in an EMIC subject to the constraint of minimising simulation errors with respect to a set of climatological observations. Using this method, Hargreaves and Annan (2006) find that the risk of a collapse in the Atlantic MOC (in response to increasing CO_2) depends on the set of observations to which the EMIC parameters are tuned. Section 9.6.3 assesses perturbed physics studies of the link between climate sensitivity and cooling during the Last Glacial Maximum (Annan et al., 2005b; Schneider von Deimling et al., 2006).

10.5.4.3 Diagnosing Drivers of Uncertainty from Ensemble Results

Figure 10.27a shows the agreement between annual changes simulated by members of the AR4 multi-model ensemble for 2080 to 2099 relative to 1980 to 1999 for the A1B scenario, calculated as in Räisänen (2001). For precipitation, the agreement increases with spatial scale. For surface temperature, the agreement is high even at local scales, indicating the robustness of the simulated warming (see also Figure 10.8, discussed in Section 10.3.2.1). Differences in model formulation are the dominant contributor to ensemble spread, though the role of internal variability increases at smaller scales (Figure 10.27b). The agreement between AR4 ensemble members is slightly higher compared with the earlier CMIP2 ensemble of Räisänen (2001) (also reported in the TAR), and internal variability explains a smaller fraction of the ensemble spread. This is expected, given the larger forcing and responses in the A1B scenario for 2080 to 2099 compared to the transient response to doubled CO_2 considered by Räisänen (2001), although the use of an updated set of models may also contribute. For seasonal changes, internal variability is found to be comparable with model differences as a source of

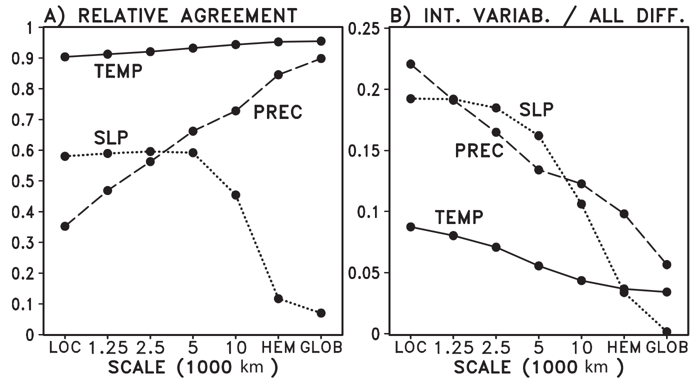


Figure 10.27. *Statistics of annual mean responses to the SRES A1B scenario, for 2080 to 2099 relative to 1980 to 1999, calculated from the 21-member AR4 multi-model ensemble using the methodology of Räisänen (2001). Results are expressed as a function of horizontal scale on the x axis ('Loc': grid box scale; 'Hem': hemispheric scale; 'Glob': global mean) plotted against the y axis showing (a) the relative agreement between ensemble members, a dimensionless quantity defined as the square of the ensemble-mean response (corrected to avoid sampling bias) divided by the mean squared response of individual ensemble members, and (b) the dimensionless fraction of internal variability relative to the ensemble variance of responses. Values are shown for surface air temperature, precipitation and sea level pressure. The low agreement of SLP changes at hemispheric and global scales reflects problems with the conservation of total atmospheric mass in some of the models, however, this has no practical significance because SLP changes at these scales are extremely small.*

uncertainty in local precipitation and SLP changes (although not for surface temperature) in both multi-model and perturbed physics ensembles (Räisänen, 2001; Murphy et al., 2004). Consequently the local seasonal changes for precipitation and SLP are not consistent in the AR4 ensemble over large areas of the globe (i.e., the multi-model mean change does not exceed the ensemble standard deviation; see Figure 10.9), whereas the surface temperature changes are consistent almost everywhere, as discussed in Section 10.3.2.1.

Wang and Swail (2006b) examine the relative importance of internal variability, differences in radiative forcing and model differences in explaining the transient response of ocean wave height using three AOGCMs each run for three plausible forcing scenarios, and find model differences to be the largest source of uncertainty in the simulated changes.

Selten et al. (2004) report a 62-member initial condition ensemble of simulations of 1940 to 2080 including natural and anthropogenic forcings. They find an individual member that reproduces the observed trend in the NAO over the past few decades, but no trend in the ensemble mean, and suggest that the observed change can be explained through internal variability associated with a mode driven by increases in precipitation over the tropical Indian Ocean. Terray et al. (2004) find that the ARPEGE coupled ocean-atmosphere model shows small increases in the residence frequency of the positive phase of the NAO in response to SRES A2 and B2 forcing, whereas larger increases are found when SST changes prescribed from the coupled experiments are used to drive a version of the atmosphere model with enhanced resolution over the North Atlantic and Europe (Gibelin and Déqué, 2003).

Figure 10.25 compares global mean transient and equilibrium changes simulated by the AR4 multi-model ensembles against perturbed physics ensembles (M. Collins et al., 2006; Webb et al., 2006) designed to produce credible present-day simulations while sampling a wide range of multiple parameter perturbations and climate sensitivities. The AR4 ensembles partially sample structural variations in model components, whereas the perturbed physics ensembles sample atmospheric parameter uncertainties for a fixed choice of model structure. The results show similar relationships between TCR, climate sensitivity and precipitation change in both types of ensemble. The perturbed physics ensembles contain several members with sensitivities higher than the multi-model range, while some of the multi-model transient simulations give TCR values slightly below the range found in the perturbed physics ensemble (Figure 10.25a,b).

Soden and Held (2006) find that differences in cloud feedback are the dominant source of uncertainty in the transient response of surface temperature in the AR4 ensemble (see also Section 8.6.3.2), as in previous IPCC assessments. Webb et al. (2006) compare equilibrium radiative feedbacks in a 9-member multi-model ensemble against those simulated in a 128-member perturbed physics ensemble with multiple parameter perturbations. They find that the ranges of climate sensitivity in both ensembles are explained mainly by differences in the response of shortwave cloud forcing in areas where changes in low-level clouds predominate. Bony and Dufresne (2005) find that marine boundary layer clouds in areas of large-scale subsidence provide the largest source of spread in tropical cloud feedbacks in the AR4 ensemble. Narrowing the uncertainty in cloud feedback may require both improved parametrizations of cloud microphysical properties (e.g., Tsushima et al., 2006) and improved representations of cloud macrophysical properties, through improved parametrizations of other physical processes (e.g., Williams et al., 2001) and/or increases in resolution (Palmer, 2005).

10.5.4.4 Observational Constraints

A range of observables has been used since the TAR to explore methods for constraining uncertainties in future climate change in studies using simple climate models, EMICs and AOGCMs. Probabilistic estimates of global climate sensitivity have been obtained from the historical transient evolution of surface temperature, upper-air temperature, ocean temperature, estimates of the radiative forcing, satellite data, proxy data over the last millennium, or a subset thereof (Wigley et al., 1997a; Tol and De Vos, 1998; Andronova and Schlesinger, 2001; Forest et al., 2002; Gregory et al., 2002a; Knutti et al., 2002, 2003; Frame et al., 2005; Forest et al., 2006; Forster and Gregory, 2006; Hegerl et al., 2006; see Section 9.6). Some of these studies also constrain the transient response to projected future emissions (see section 10.5.4.5). For climate sensitivity, further probabilistic estimates have been obtained using statistical measures of the correspondence between simulated and observed fields of present-day climate (Murphy et al., 2004; Piani et al., 2005), the climatological seasonal cycle of surface temperature (Knutti et al., 2006) and the response to palaeoclimatic forcings (Annan et al., 2005b; Schneider von Deimling et al., 2006). For the purpose of constraining regional climate projections, spatial averages or fields of time-averaged regional climate have been used (Giorgi and Mearns, 2003; Tebaldi et al., 2004, 2005; Laurent and Cai, 2007), as have past regional- or continental-scale trends in surface temperature (Greene et al., 2006; Stott et al., 2006a).

Further observables have been suggested as potential constraints on future changes, but are not yet used in formal probabilistic estimates. These include measures of climate variability related to cloud feedbacks (Bony et al., 2004; Bony and Dufresne, 2005; Williams et al., 2005), radiative damping of the seasonal cycle (Tsushima et al., 2005), the relative entropy of simulated and observed surface temperature variations (Shukla et al., 2006), major volcanic eruptions (Wigley et al., 2005; Yokohata et al., 2005; see Section 9.6) and trends in multiple variables derived from reanalysis data sets (Lucarini and Russell, 2002).

Additional constraints could also be found, for example, from evaluation of ensemble climate prediction systems on shorter time scales for which verification data exist. These could include assessment of the reliability of seasonal to interannual probabilistic forecasts (Palmer et al., 2004; Hagedorn et al., 2005) and the evaluation of model parametrizations in short-range weather predictions (Phillips et al., 2004; Palmer, 2005). Annan and Hargreaves (2006) point out the potential for narrowing uncertainty by combining multiple lines of evidence. This will require objective quantification of the impact of different constraints and their degree of independence, estimation of the effects of structural modelling errors and the development of comprehensive probabilistic frameworks in which to combine these elements (e.g., Rougier, 2007).

10.5.4.5 Probabilistic Projections - Global Mean

A number of methods for providing probabilistic climate change projections, both for global means (discussed in this section) and geographical depictions (discussed in the following section) have emerged since the TAR.

Methods of constraining climate sensitivity using observations of present-day climate are discussed in Section 10.5.4.2. Results from both the AR4 multi-model ensemble and from perturbed physics ensembles suggest a very low probability for a climate sensitivity below 2°C, despite exploring the effects of a wide range of alternative modelling assumptions on the global radiative feedbacks arising from lapse rate, water vapour, surface albedo and cloud (Bony et al., 2006; Soden and Held, 2006; Webb et al., 2006; Box 10.2). However, exclusive reliance on AOGCM ensembles can be questioned on the basis that models share components, and therefore errors, and may not sample the full range of possible outcomes (e.g., Allen and Ingram, 2002).

Observationally constrained probability distributions for climate sensitivity have also been derived from physical relationships based on energy balance considerations, and from instrumental observations of historical changes during the past 50 to 150 years or proxy reconstructions of surface temperature during the past millennium (Section 9.6). The results vary according to the choice of verifying observations, the forcings considered and their specified uncertainties, however, all these studies report a high upper limit for climate sensitivity, with the 95th percentile of the distributions invariably exceeding 6°C (Box 10.2). Frame et al. (2005) demonstrate that uncertainty ranges for sensitivity are dependent on the choices made about prior distributions of uncertain quantities before the observations are applied. Frame et al. (2005) and Piani et al. (2005) show that many observable variables are likely to scale inversely with climate sensitivity, implying that projections of quantities that are inversely related to sensitivity will be more strongly constrained by observations than climate sensitivity itself, particularly with respect to the estimated upper limit (Allen et al., 2006b).

In the case of transient climate change, optimal detection techniques have been used to determine factors by which hindcasts of global surface temperature from AOGCMs can be scaled up or down while remaining consistent with past changes, accounting for uncertainty due to internal variability (Section 9.4.1.6). Uncertainty is propagated forward in time by assuming that the fractional error found in model hindcasts of global mean temperature change will remain constant in projections of future changes. Using this approach, Stott and Kettleborough (2002) find that probabilistic projections of global mean temperature derived from UKMO-HadCM3 simulations were insensitive to differences between four representative SRES emissions scenarios over the first few decades of the 21st century, but that much larger differences emerged between the response to different SRES scenarios by the end of the 21st century (see also Section 10.5.3 and Figure 10.28). Stott et al. (2006b) show that scaling the responses of three models with different sensitivities brings their projections into better agreement. Stott et al. (2006a) extend their approach to obtain probabilistic projections of future warming averaged over continental-scale regions under the SRES A2 scenario. Fractional errors in the past continental warming simulated by UKMO-HadCM3 are used to scale future changes, yielding wide uncertainty ranges, notably for North America and Europe where the 5 to 95% ranges for warming during the 21st century are 2°C to 12°C and 2°C to 11°C respectively. These estimates do not account for potential constraints arising from regionally differentiated warming rates. Tighter ranges of 4°C to 8°C for North America and 4°C to 7°C for Europe are obtained if fractional errors in past global mean temperature are used to scale the future continental changes, although this neglects uncertainty in the relationship between global and regional temperature changes.

Allen and Ingram (2002) suggest that probabilistic projections for some variables may be made by searching for 'emergent constraints'. These are relationships between variables that can be directly constrained by observations, such as global surface temperature, and variables that may be indirectly constrained by establishing a consistent, physically

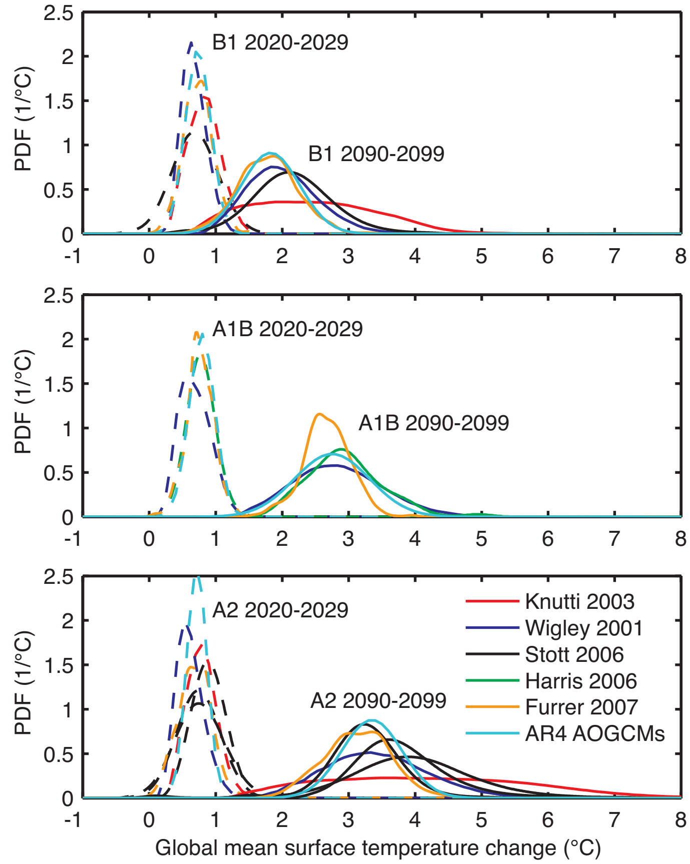


Figure 10.28. *Probability density functions from different studies for global mean temperature change for the SRES scenarios B1, A1B and A2 and for the decades 2020 to 2029 and 2090 to 2099 relative to the 1980 to 1999 average (Wigley and Raper, 2001; Knutti et al., 2002; Furrer et al., 2007; Harris et al., 2006; Stott et al., 2006b). A normal distribution fitted to the multi-model ensemble is shown for comparison.*

based relationship which holds across a wide range of models. They present an example in which future changes in global mean precipitation are constrained using a probability distribution for global temperature obtained from a large EMIC ensemble (Forest et al., 2002) and a relationship between precipitation and temperature obtained from multi-model ensembles of the response to doubled atmospheric CO_2. These methods are designed to produce distributions constrained by observations, and are relatively model independent (Allen and Stainforth, 2002; Allen et al., 2006a). This can be achieved provided the inter-variable relationships are robust to alternative modelling assumptions Piani et al. (2005) and Knutti et al. (2006) (described in Section 10.5.4.2) follow this approach, noting that in these cases the inter-variable relationships are derived from perturbed versions of a single model, and need to be confirmed using other models.

A synthesis of published probabilistic global mean projections for the SRES scenarios B1, A1B and A2 is given in Figure 10.28. Probability density functions are given for short-term projections (2020–2030) and the end of the century (2090–2100). For comparison, normal distributions fitted to results from AOGCMs in the multi-model archive (see Section

10.3.1) are also given, although these curve fits should not be regarded as PDFs. The five methods of producing PDFs are all based on different models and/or techniques, described in Section 10.5. In short, Wigley and Raper (2001) use a large ensemble of a simple model with expert prior distributions for climate sensitivity, ocean heat uptake, sulphate forcing and the carbon cycle, without applying constraints. Knutti et al. (2002, 2003) use a large ensemble of EMIC simulations with non-informative prior distributions, consider uncertainties in climate sensitivity, ocean heat uptake, radiative forcing and the carbon cycle, and apply observational constraints. Neither method considers natural variability explicitly. Stott et al. (2006b) apply the fingerprint scaling method to AOGCM simulations to obtain PDFs which implicitly account for uncertainties in forcing, climate sensitivity and internal unforced as well as forced natural variability. For the A2 scenario, results obtained from three different AOGCMs are shown, illustrating the extent to which the Stott et al. PDFs depend on the model used. Harris et al. (2006) obtain PDFs by boosting a 17-member perturbed physics ensemble of the UKMO-HadCM3 model using scaled equilibrium responses from a larger ensemble of simulations. Furrer et al. (2007) use a Bayesian method described in Section 10.5.4.7 to calculate PDFs from the AR4 multi-model ensemble. The Stott et al. (2006b), Harris et al. (2006) and Furrer et al. (2007) methods neglect carbon cycle uncertainties.

Two key points emerge from Figure 10.28. For the projected short-term warming (i) there is more agreement among models and methods (narrow width of the PDFs) compared to later in the century (wider PDFs), and (ii) the warming is similar across different scenarios, compared to later in the century where the choice of scenario significantly affects the projections. These conclusions are consistent with the results obtained with SCMs (Section 10.5.3).

Additionally, projection uncertainties increase close to linearly with temperature in most studies. The different methods show relatively good agreement in the shape and width of the PDFs, but with some offsets due to different methodological choices. Only Stott et al. (2006b) account for variations in future natural forcing, and hence project a small probability of cooling over the next few decades not seen in the other PDFs. The results of Knutti et al. (2003) show wider PDFs for the end of the century because they sample uniformly in climate sensitivity (see Section 9.6.2 and Box 10.2). Resampling uniformly in observables (Frame et al., 2005) would bring their PDFs closer to the others. In sum, probabilistic estimates of uncertainties for the next few decades seem robust across a variety of models and methods, while results for the end of the century depend on the assumptions made.

10.5.4.6 Synthesis of Projected Global Temperature at Year 2100

All available estimates for projected warming by the end of the 21st century are summarised in Figure 10.29 for the six SRES non-intervention marker scenarios. Among the various techniques, the AR4 AOGCM ensemble provides the most

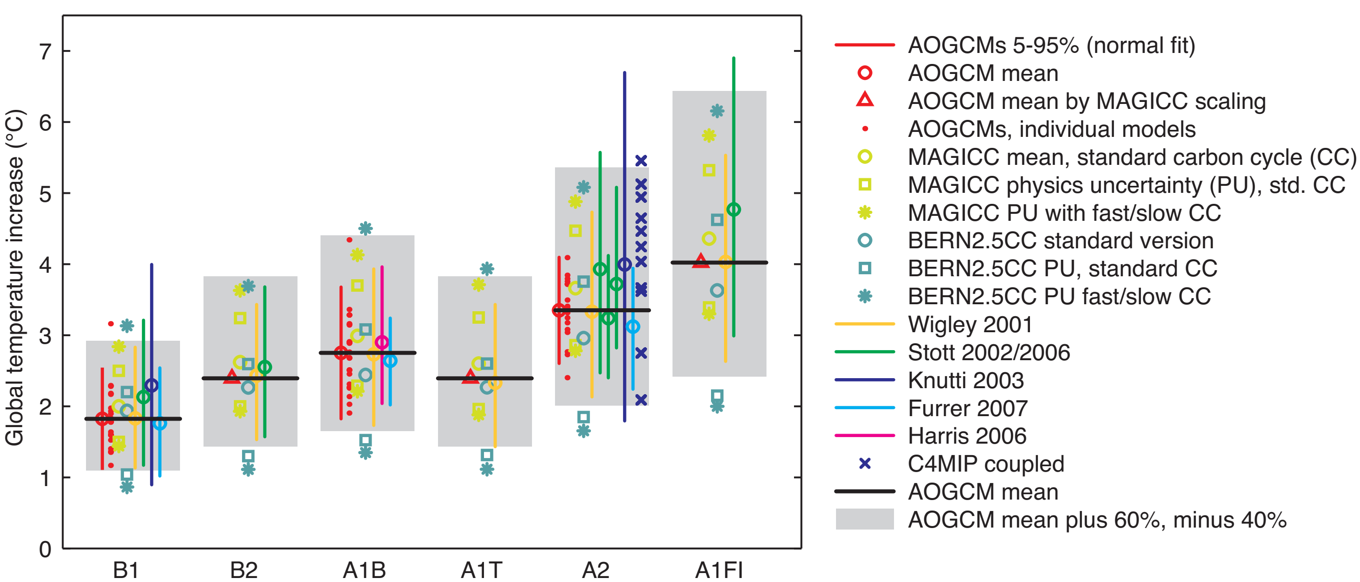


Figure 10.29. *Projections and uncertainties for global mean temperature increase in 2090 to 2099 (relative to the 1980 to 1999 average) for the six SRES marker scenarios. The AOGCM means and the uncertainty ranges of the mean –40% to +60% are shown as black horizontal solid lines and grey bars, respectively. For comparison, results are shown for the individual models (red dots) of the multi-model AOGCM ensemble for B1, A1B and A2, with a mean and 5 to 95% range (red line and circle) from a fitted normal distribution. The AOGCM mean estimates for B2, A1T and A1FI (red triangles) are obtained by scaling the A1B AOGCM mean with ratios obtained from the SCM (see text). The mean (light green circle) and one standard deviation (light green square) of the MAGICC SCM tuned to all AOGCMs (representing the physics uncertainty) are shown for standard carbon cycle settings, as well as for a slow and fast carbon cycle assumption (light green stars). Similarly, results from the BERN2.5CC EMIC are shown for standard carbon cycle settings and for climate sensitivities of 3.2°C (AOGCM average, dark green circle), 1.5°C and 4.5°C (dark green squares). High climate sensitivity/low carbon cycle and low climate sensitivity/high carbon cycle combinations are shown as dark green stars. The 5 to 95% ranges (vertical lines) and medians (circles) are shown from probabilistic methods (Wigley and Raper, 2001; Stott and Kettleborough, 2002; Knutti et al., 2003; Furrer et al., 2007; Harris et al., 2006; Stott et al., 2006b). Individual model results are shown for the C^{4}MIP models (blue crosses, see Figure 10.20).*

sophisticated set of models in terms of the range of processes included and consequent realism of the simulations compared to observations (see Chapters 8 and 9). On average, this ensemble projects an increase in global mean surface air temperature of 1.8°C, 2.8°C and 3.4°C in the B1, A1B and A2 scenarios, respectively, by 2090 to 2099 relative to 1980 to 1999 (note that in Table 10.5, the years 2080 to 2099 were used for those globally averaged values to be consistent with the comparable averaging period for the geographic plots in Section 10.3; this longer averaging period smoothes spatial noise in the geographic plots). A scaling method is used to estimate AOGCM mean results for the three missing scenarios B2, A1T and A1FI. The ratio of the AOGCM mean values for B1 relative to A1B and A2 relative to A1B are almost identical to the ratios obtained with the MAGICC SCM, although the absolute values for the SCM are higher. Thus, the AOGCM mean response for the scenarios B2, A1T and A1FI can be estimated as 2.4°C, 2.4°C and 4.0°C by multiplying the AOGCM A1B mean by the SCM-derived ratios B2/A1B, A1T/A1B and A1FI/A1B, respectively (for details see Appendix 10.A.1).

The AOGCMs cannot sample the full range of possible warming, in particular because they do not include uncertainties in the carbon cycle. In addition to the range derived directly from the AR4 multi-model ensemble, Figure 10.29 depicts additional uncertainty estimates obtained from published probabilistic methods using different types of models and observational constraints: the MAGICC SCM and the BERN2.5CC coupled climate-carbon cycle EMIC tuned to different climate sensitivities and carbon cycle settings, and the C^4MIP coupled climate-carbon cycle models. Based on these results, the future increase in global mean temperature is likely to fall within –40 to +60% of the multi-model AOGCM mean warming simulated for each scenario. This range results from an expert judgement of the multiple lines of evidence presented in Figure 10.29, and assumes that the models approximately capture the range of uncertainties in the carbon cycle. The range is well constrained at the lower bound since climate sensitivity is better constrained at the low end (see Box 10.2), and carbon cycle uncertainty only weakly affects the lower bound. The upper bound is less certain as there is more variation across the different models and methods, partly because carbon cycle feedback uncertainties are greater with larger warming. The uncertainty ranges derived from the above percentages for the warming by 2090 to 2099 relative to 1980 to 1999 are 1.1°C to 2.9°C, 1.4°C to 3.8°C, 1.7°C to 4.4°C, 1.4°C to 3.8°C, 2.0°C to 5.4°C and 2.4°C to 6.4°C for the scenarios B1, B2, A1B, A1T, A2 and A1FI, respectively. It is not appropriate to compare the lowest and highest values across these ranges against the single range given in the TAR, because the TAR range resulted only from projections using an SCM and covered all SRES scenarios, whereas here a number of different and independent modelling approaches are combined to estimate ranges for the six illustrative scenarios separately. Additionally, in contrast to the TAR, carbon cycle uncertainties are now included in these ranges. These uncertainty ranges include only anthropogenically forced changes.

10.5.4.7 Probabilistic Projections - Geographical Depictions

Tebaldi et al. (2005) present a Bayesian approach to regional climate prediction, developed from the ideas of Giorgi and Mearns (2002, 2003). Non-informative prior distributions for regional temperature and precipitation are updated using observations and results from AOGCM ensembles to produce probability distributions of future changes. Key assumptions are that each model and the observations differ randomly and independently from the true climate, and that the weight given to a model prediction should depend on the bias in its present-day simulation and its degree of convergence with the weighted ensemble mean of the predicted future change. Lopez et al. (2006) apply the Tebaldi et al. (2005) method to a 15-member multi-model ensemble to predict future changes in global surface temperature under a 1% yr^{-1} increase in atmospheric CO_2. They compare it with the method developed by Allen et al. (2000) and Stott and Kettleborough (2002) (ASK), which aims to provide relatively model independent probabilities consistent with observed changes (see Section 10.5.4.5). The Bayesian method predicts a much narrower uncertainty range than ASK. However its results depend on choices made in its design, particularly the convergence criterion for up-weighting models close to the ensemble mean, relaxation of which substantially reduces the discrepancy with ASK.

Another method by Furrer et al. (2007) employs a hierarchical Bayesian model to construct PDFs of temperature change at each grid point from a multi-model ensemble. The main assumptions are that the true climate change signal is a common large-scale structure represented to some degree in each of the model simulations, and that the signal unexplained by climate change is AOGCM-specific in terms of small-scale structure, but can be regarded as noise when averaged over all AOGCMs. In this method, spatial fields of future minus present temperature difference from each ensemble member are regressed upon basis functions. One of the basis functions is a map of differences of observed temperatures from late-minus mid-20th century, and others are spherical harmonics. The statistical model then estimates the regression coefficients and their associated errors, which account for the deviation in each AOGCM from the (assumed) true pattern of change. By recombining the coefficients with the basis functions, an estimate is derived of the true climate change field and its associated uncertainty, thus providing joint probabilities for climate change at all grid points around the globe.

Estimates of uncertainty derived from multi-model ensembles of 10 to 20 members are potentially sensitive to outliers (Räisänen, 2001). Harris et al. (2006) therefore augment a 17-member ensemble of AOGCM transient simulations by scaling the equilibrium response patterns of a large perturbed physics ensemble. Transient responses are emulated by scaling equilibrium response patterns according to global temperature (predicted from an energy balance model tuned to the relevant climate sensitivities). For surface temperature, the scaled equilibrium patterns correspond well to the transient response patterns, while scaling errors for precipitation vary more widely with location. A correction field is added to account for ensemble-mean differences between the equilibrium and transient patterns, and uncertainty is allowed for in the emulated result. The correction field and emulation errors are determined by comparing the responses of model versions for which both transient and equilibrium simulations exist. Results are used to obtain frequency distributions of transient regional changes in surface temperature and precipitation in response to increasing atmospheric CO_2, arising from the combined effects of atmospheric parameter perturbations and internal variability in UKMO-HadCM3.

Figure 10.30 shows probabilities of a temperature change larger than 2°C by the end of the 21st century under the A1B scenario, comparing values estimated from the 21-member AR4 multi-model ensemble (Furrer et al., 2007) against values estimated by combining transient and equilibrium perturbed physics ensembles of 17 and 128 members, respectively (Harris et al., 2006). Although the methods use different ensembles and different statistical approaches, the large-scale patterns are similar in many respects. Both methods show larger probabilities (typically 80% or more) over land, and at high latitudes in the winter hemisphere, with relatively low values (typically less than 50%) over the southern oceans. However, the plots also reveal some substantial differences at a regional level, notably over the North Atlantic Ocean, the sub-tropical Atlantic and Pacific Oceans in the SH, and at high northern latitudes during June to August.

10.5.4.8 Summary

Significant progress has been made since the TAR in exploring ensemble approaches to provide uncertainty ranges and probabilities for global and regional climate change. Different methods show consistency in some aspects of their results, but differ significantly in others (see Box 10.2; Figures 10.28 and 10.30), because they depend to varying degrees on the nature and use of observational constraints, the nature and design of model ensembles and the specification of prior distributions for uncertain inputs (see, e.g., Table 11.3). A preferred method cannot yet be recommended, but the assumptions and limitations underlying the various approaches, and the sensitivity of the results to them, should be communicated to users. A good example concerns the treatment of model error in Bayesian methods, the uncertainty in which affects the calculation of the likelihood of different model versions, but is difficult to specify (Rougier, 2007). Awareness of this issue is growing in the field of climate prediction (Annan et al., 2005b; Knutti et al., 2006), however, it is yet to be thoroughly addressed. Probabilistic depictions, particularly at the regional level, are new to climate change science and are being facilitated by the recently available multi-model ensembles. These are discussed further in Section 11.10.2.

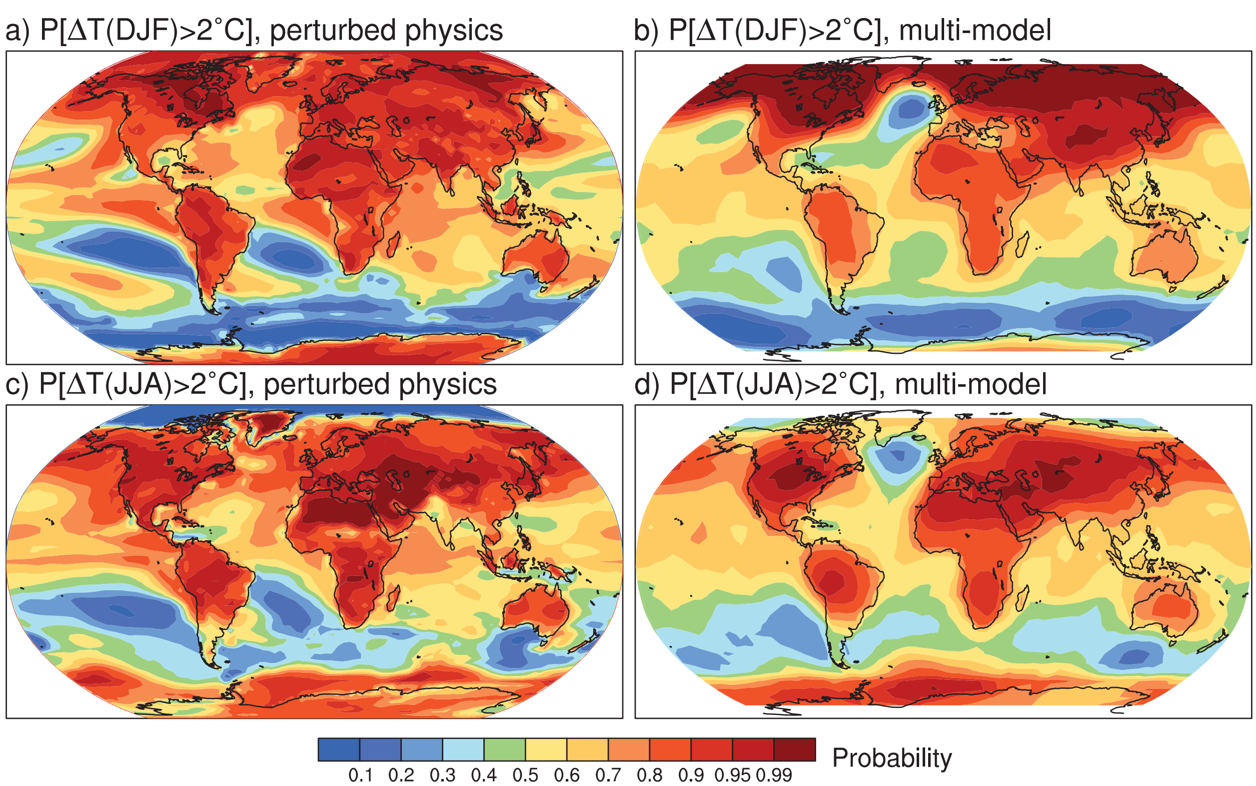


Figure 10.30. *Estimated probabilities for a mean surface temperature change exceeding 2°C in 2080 to 2099 relative to 1980 to 1999 under the SRES A1B scenario. Results obtained from a perturbed physics ensemble of a single model (a, c), based on Harris et al. (2006), are compared with results from the AR4 multi-model ensemble (b, d), based on Furrer et al. (2007), for December to February (DJF, a, b) and June to August (JJA, c, d).*

10.6 Sea Level Change in the 21st Century

10.6.1 Global Average Sea Level Rise Due to Thermal Expansion

As seawater warms up, it expands, increasing the volume of the global ocean and producing thermosteric sea level rise (see Section 5.5.3). Global average thermal expansion can be calculated directly from simulated changes in ocean temperature. Results are available from 17 AOGCMs for the 21st century for SRES scenarios A1B, A2 and B1 (Figure 10.31), continuing from simulations of the 20th century. One ensemble member was used for each model and scenario. The time series are rather smooth compared with global average temperature time series, because thermal expansion reflects heat storage in the entire ocean, being approximately proportional to the time integral of temperature change (Gregory et al., 2001).

During 2000 to 2020 under scenario SRES A1B in the ensemble of AOGCMs, the rate of thermal expansion is 1.3 ± 0.7 mm yr^{-1}, and is not significantly different under A2 or B1. This rate is more than twice the observationally derived rate of 0.42 ± 0.12 mm yr^{-1} during 1961 to 2003. It is similar to the rate of 1.6 ± 0.5 mm yr^{-1} during 1993 to 2003 (see Section 5.5.3), which may be larger than that of previous decades partly because of natural forcing and internal variability (see Sections 5.5.2.4, 5.5.3 and 9.5.2). In particular, many of the AOGCM experiments do not include the influence of Mt. Pinatubo, the omission of which may reduce the projected rate of thermal expansion during the early 21st century.

During 2080 to 2100, the rate of thermal expansion is projected to be 1.9 ± 1.0, 2.9 ± 1.4 and 3.8 ± 1.3 mm yr^{-1} under scenarios SRES B1, A1B and A2 respectively in the AOGCM ensemble (the width of the range is affected by the different numbers of models under each scenario). The acceleration is caused by the increased climatic warming. Results are shown for all SRES marker scenarios in Table 10.7 (see Appendix 10.A for methods). In the AOGCM ensemble, under any given SRES scenario, there is some correlation of the global average temperature change across models with thermal expansion and its rate of change, suggesting that the spread in thermal expansion for that scenario is caused both by the spread in surface warming and by model-dependent ocean heat uptake efficiency (Raper et al., 2002; Table 8.2) and the distribution of added heat within the ocean (Russell et al., 2000).

10.6.2 Local Sea Level Change Due to Change in Ocean Density and Dynamics

The geographical pattern of mean sea level relative to the geoid (the dynamic topography) is an aspect of the dynamical balance relating the ocean's density structure and its circulation, which are maintained by air-sea fluxes of heat, freshwater and momentum. Over much of the ocean on multi-annual time scales, a good approximation to the pattern of dynamic topography change is given by the steric sea level change, which can be calculated straightforwardly from local temperature and salinity change (Gregory et al., 2001; Lowe and Gregory, 2006). In much of the world, salinity changes are as important as temperature changes in determining the pattern of dynamic topography change in the future, and their contributions can be opposed (Landerer et al., 2007; and as in the past, Section 5.5.4.1). Lowe and Gregory (2006) show that in the UKMO-HadCM3 AOGCM, changes in heat fluxes are the cause of many of the large-scale features of sea level change, but freshwater

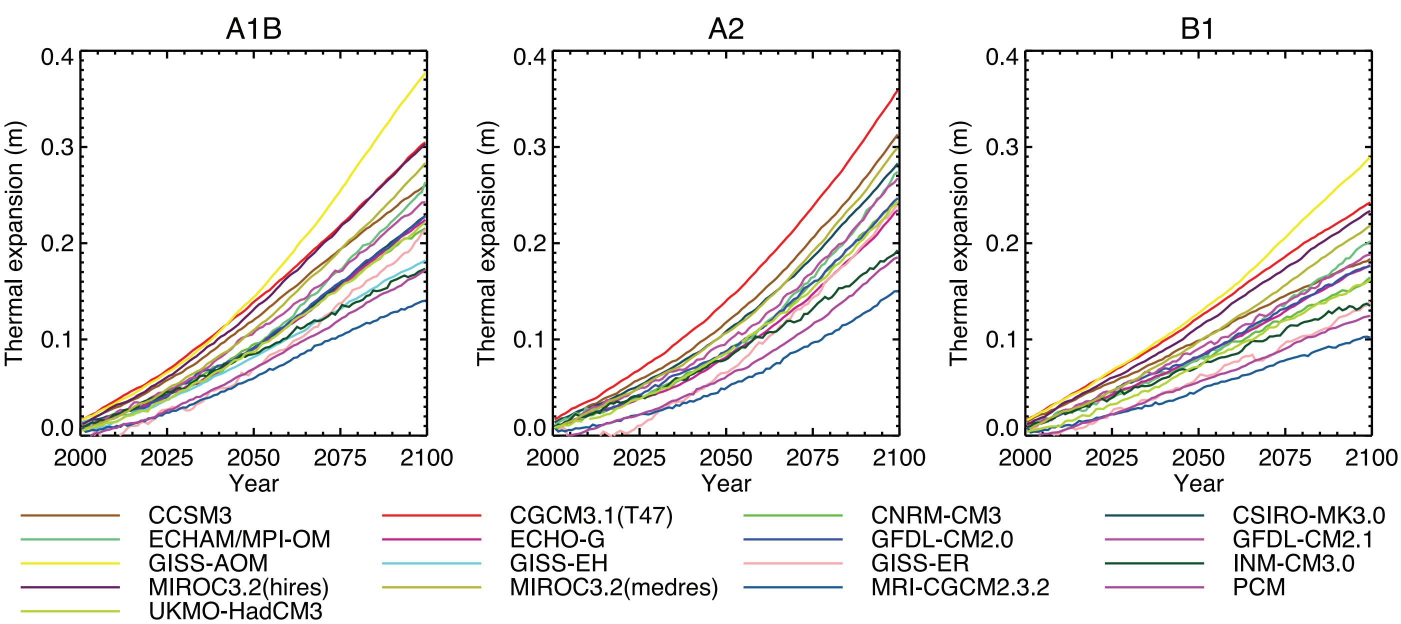


Figure 10.31. *Projected global average sea level rise (m) due to thermal expansion during the 21st century relative to 1980 to 1999 under SRES scenarios A1B, A2 and B1. See Table 8.1 for model descriptions.*

flux change dominates the North Atlantic and momentum flux change has a signature in the north and low-latitude Pacific and the Southern Ocean.

Results are available for local sea level change due to ocean density and circulation change from AOGCMs in the multi-model ensemble for the 20th century and the 21st century. There is substantial spatial variability in all models (i.e., sea level change is not uniform), and as the geographical pattern of climate change intensifies, the spatial standard deviation of local sea level change increases (Church et al., 2001; Gregory et al., 2001). Suzuki et al. (2005) show that, in their high-resolution model, enhanced eddy activity contributes to this increase, but across models there is no significant correlation of the spatial standard deviation with model spatial resolution. This section evaluates sea level change between 1980 to 1999 and 2080 to 2099 projected by 16 models forced with SRES scenario A1B. (Other scenarios are qualitatively similar, but fewer models are available.) The ratio of spatial standard deviation to global average thermal expansion varies among models, but is mostly within the range 0.3 to 0.4. The model median spatial standard deviation of thermal expansion is 0.08 m, which is about 25% of the central estimate of global average sea level rise during the 21st century under A1B (Table 10.7).

The geographical patterns of sea level change from different models are not generally similar in detail, although they have more similarity than those analysed in the TAR by Church et al. (2001). The largest spatial correlation coefficient between any pair is 0.75, but only 25% of correlation coefficients exceed 0.5. To identify common features, an ensemble mean (Figure 10.32) is examined. There are only limited areas where the model ensemble mean change exceeds the inter-model standard deviation, unlike for surface air temperature change (Section 10.3.2.1).

Like Church et al. (2001) and Gregory et al. (2001), Figure 10.32 shows smaller than average sea level rise in the Southern Ocean and larger than average in the Arctic, the former possibly due to wind stress change (Landerer et al., 2007) or low thermal expansivity (Lowe and Gregory, 2006) and the latter due to freshening. Another obvious feature is a narrow band of pronounced sea level rise stretching across the southern Atlantic and Indian Oceans and discernible in the southern Pacific. This could be associated with a southward shift in the circumpolar front (Suzuki et al., 2005) or subduction of warm anomalies in the region of formation of sub antarctic mode water (Banks et al., 2002). In the zonal mean, there are maxima of sea level rise in 30°S to 45°S and 30°N to 45°N. Similar indications are present in the altimetric and thermosteric patterns of sea level change for 1993 to 2003 (Figure 5.15). The model projections do not share other aspects of the observed pattern of sea level rise, such as in the western Pacific, which could be related to interannual variability.

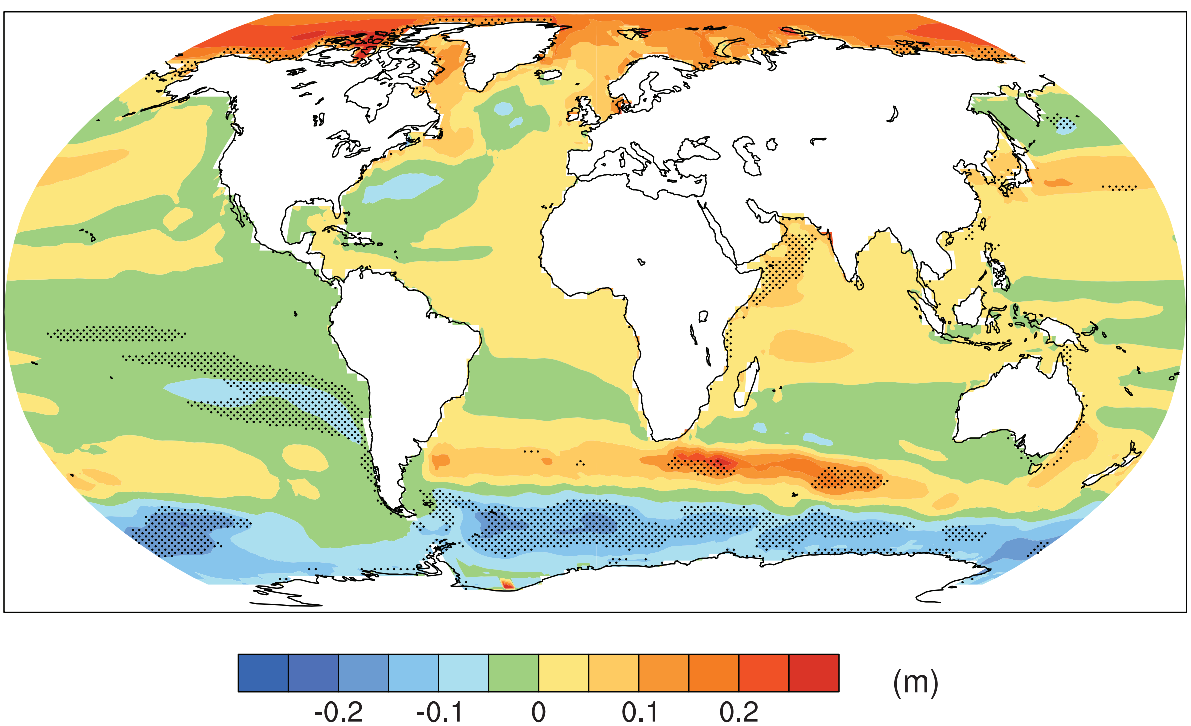


Figure 10.32. *Local sea level change (m) due to ocean density and circulation change relative to the global average (i.e., positive values indicate greater local sea level change than global) during the 21st century, calculated as the difference between averages for 2080 to 2099 and 1980 to 1999, as an ensemble mean over 16 AOGCMs forced with the SRES A1B scenario. Stippling denotes regions where the magnitude of the multi-model ensemble mean divided by the multi-model standard deviation exceeds 1.0.*

The North Atlantic dipole pattern noted by Church et al. (2001), that is, reduced rise to the south of the Gulf Stream extension, enhanced to the north, consistent with a weakening of the circulation, is present in some models; a more complex feature is described by Landerer et al. (2007). The reverse is apparent in the north Pacific, which Suzuki et al. (2005) associate with a wind-driven intensification of the Kuroshio Current. Using simplified models, Hsieh and Bryan (1996) and Johnson and Marshall (2002) show how upper-ocean velocities and sea level would be affected in North Atlantic coastal regions within months of a cessation of sinking in the North Atlantic as a result of propagation by coastal and equatorial Kelvin waves, but would take decades to adjust in the central regions and the south Atlantic. Levermann et al. (2005) show that a sea level rise of several tenths of a metre could be realised in coastal regions of the North Atlantic within a few decades (i.e., tens of millimetres per year) of a collapse of the MOC. Such changes to dynamic topography would be much more rapid than global average sea level change. However, it should be emphasized that these studies are sensitivity tests, not projections; the Atlantic MOC does not collapse in the SRES scenario runs evaluated here (see Section 10.3.4).

The geographical pattern of sea level change is affected also by changes in atmospheric surface pressure, but this is a relatively small effect given the projected pressure changes (Figure 10.9; a pressure increase of 1 hPa causes a drop in local sea level of 0.01 m; see Section 5.5.4.3). Land movements and changes in the gravitational field resulting from the changing loading of the crust by water and ice also have effects which are small over most of the ocean (see Section 5.5.4.4).

10.6.3 Glaciers and Ice Caps

Glaciers and ice caps (G&IC, see also Section 4.5.1) comprise all land ice except for the ice sheets of Greenland and Antarctica (see Sections 4.6.1 and 10.6.4). The mass of G&IC can change because of changes in surface mass balance (Section 10.6.3.1). Changes in mass balance cause changes in area and thickness (Section 10.6.3.2), with feedbacks on surface mass balance.

10.6.3.1 Mass Balance Sensitivity to Temperature and Precipitation

Since G&IC mass balance depends strongly on their altitude and aspect, use of data from climate models to make projections requires a method of downscaling, because individual G&IC are much smaller than typical AOGCM grid boxes. Statistical relations for meteorological quantities can be developed between the GCM and local scales (Reichert et al., 2002), but they may not continue to hold in future climates. Hence, for projections the approach usually adopted is to use GCM simulations of changes in climate parameters to perturb the observed climatology or mass balance (Gregory and Oerlemans, 1998; Schneeberger et al., 2003).

Change in ablation (mostly melting) of a glacier or ice cap is modelled using b_T (in m yr^{-1} °C^{-1}), the sensitivity of the mean specific surface mass balance to temperature (refer to Section 4.5 for a discussion of the relation of mass balance to climate). One approach determines b_T by energy balance modelling, including evolution of albedo and refreezing of melt water within the firn (Zuo and Oerlemans, 1997). Oerlemans and Reichert (2000), Oerlemans (2001) and Oerlemans et al. (2006) refine this approach to include dependence on monthly temperature and precipitation changes. Another approach uses a degree-day method, in which ablation is proportional to the integral of mean daily temperature above the freezing point (Braithwaite et al., 2003). Braithwaite and Raper (2002) show that there is excellent consistency between the two approaches, which indicates a similar relationship between b_T and climatological precipitation. Schneeberger et al. (2000, 2003) use a degree-day method for ablation modified to include incident solar radiation, again obtaining similar results. De Woul and Hock (2006) find somewhat larger sensitivities for arctic G&IC from the degree-day method than the energy balance method. Calculations of b_T are estimated to have an uncertainty of ±15% (standard deviation) (Gregory and Oerlemans, 1998; Raper and Braithwaite, 2006).

The global average sensitivity of G&IC surface mass balance to temperature is estimated by weighting the local sensitivities by land ice area in various regions. For a geographically and seasonally uniform rise in global temperature, Oerlemans and Fortuin (1992) derive a global average G&IC surface mass balance sensitivity of –0.40 m yr^{-1} °C^{-1}, Dyurgerov and Meier (2000) –0.37 m yr^{-1} °C^{-1} (from observations), Braithwaite and Raper (2002) –0.41 m yr^{-1} °C^{-1} and Raper and Braithwaite (2005) –0.35 m yr^{-1} °C^{-1}. Applying the scheme of Oerlemans (2001) and Oerlemans et al. (2006) worldwide gives a smaller value of –0.32 m yr^{-1} °C^{-1}, the reduction being due to the modified treatment of albedo by Oerlemans (2001).

These global average sensitivities for uniform temperature change are given only for scenario-independent comparison of the various methods; they cannot be used for projections, which require regional and seasonal temperature changes (Gregory and Oerlemans, 1998; van de Wal and Wild, 2001). Using monthly temperature changes simulated in G&IC regions by 17 AR4 AOGCMs for scenarios A1B, A2 and B1, the global total surface mass balance sensitivity to global average temperature change for all G&IC outside Greenland and Antarctica is 0.61 ± 0.12 mm yr^{-1} °C^{-1} (sea level equivalent) with the b_T of Zuo and Oerlemans (1997) or 0.49 ± 0.13 mm yr^{-1} °C^{-1} with those of Oerlemans (2001) and Oerlemans et al. (2006), subject to uncertainty in G&IC area (see Section 4.5.2 and Table 4.4).

Hansen and Nazarenko (2004) collate measurements of soot (fossil fuel black carbon) in snow and estimate consequent reductions in snow and ice albedo of between 0.001 for the pristine conditions of Antarctica and over 0.10 for polluted NH land areas. They argue that glacial ablation would be increased by this effect. While it is true that soot has not been explicitly considered in existing sensitivity estimates, it may already be included because the albedo and degree-day parametrizations have been empirically derived from data collected in affected regions.

For seasonally uniform temperature rise, Oerlemans et al. (1998) find that an increase in precipitation of 20 to 50% $°C^{-1}$ is required to balance increased ablation, while Braithwaite et al. (2003) report a required precipitation increase of 29 to 41% $°C^{-1}$, in both cases for a sample of G&IC representing a variety of climatic regimes. Oerlemans et al. (2006) require a precipitation increase of 20 to 43% $°C^{-1}$ to balance ablation increase, and de Woul and Hock (2006) approximately 20% $°C^{-1}$ for Arctic G&IC. Although AOGCMs generally project larger than average precipitation change in northern mid- and high-latitude regions, the global average is 1 to 2% $°C^{-1}$ (Section 10.3.1), so ablation increases would be expected to dominate worldwide. However, precipitation changes may sometimes dominate locally (see Section 4.5.3).

Regressing observed global total mass balance changes of all G&IC outside Greenland and Antarctica against global average surface temperature change gives a global total mass balance sensitivity which is greater than model results (see Appendix 10.A). The current state of knowledge does not permit a satisfactory explanation of the difference. Giving more weight to the observational record but enlarging the uncertainty to allow for systematic error, a value of 0.80 ± 0.33 mm yr^{-1} $°C^{-1}$ (5 to 95% range) is adopted for projections. The regression indicates that the climate of 1865 to 1895 was 0.13°C warmer globally than the climate that gives a steady state for G&IC (cf., Zuo and Oerlemans, 1997; Gregory et al., 2006). Model results for the 20th century are sensitive to this value, but the projected temperature change in the 21st century is large by comparison, making the effect relatively less important for projections (see Appendix 10.A).

10.6.3.2 Dynamic Response and Feedback on Mass Balance

As glacier volume is lost, glacier area declines so the ablation decreases. Oerlemans et al. (1998) calculate that omitting this effect leads to overestimates of ablation of about 25% by 2100. Church et al. (2001), following Bahr et al. (1997) and Van de Wal and Wild (2001), make some allowance for it by diminishing the area A of a glacier of volume V according to $V \propto A^{1.375}$. This is a scaling relation derived for glaciers in a steady state, which may hold only approximately during retreat. For example, thinning in the ablation zone will steepen the surface slope and tend to increase the flow. Comparison with a simple flow model suggests the deviations do not exceed 20% (van de Wal and Wild, 2001). Schneeberger et al. (2003) find that the scaling relation produced a mixture of over- and underestimates of volume loss for their sample of glaciers compared with more detailed dynamic modelling. In some regions where G&IC flow into the sea or lakes there is accelerated dynamic discharge (Rignot et al., 2003) that is not included in currently available glacier models, leading to an underestimate of G&IC mass loss.

The mean specific surface mass balance of the glacier or ice cap will change as volume is lost: lowering the ice surface as the ice thins will tend to make it more negative, but the predominant loss of area at lower altitude in the ablation zone will tend to make it less negative (Braithwaite and Raper, 2002). For rapid thinning rates in the ablation zone, of several metres per year, lowering the surface will give enhanced local warmings comparable to the rate of projected climatic warming. However, those areas of the ablation zone of valley glaciers that thin most rapidly will soon be removed altogether, resulting in retreat of the glacier. The enhancement of ablation by surface lowering can only be sustained in glaciers with a relatively large, thick and flat ablation area. On multi-decadal time scales, for the majority of G&IC, the loss of area is more important than lowering of the surface (Schneeberger et al., 2003).

The dynamical approach (Oerlemans et al., 1998; Schneeberger et al., 2003) cannot be applied to all the world's glaciers individually as the required data are unknown for the vast majority of them. Instead, it might be applied to a representative ensemble derived from statistics of size distributions of G&IC. Raper et al. (2000) developed a geometrical approach, in which the width, thickness and length of a glacier are reduced as its volume and area declines. When applied statistically to the world population of glaciers and individually to ice caps, this approach shows that the reduction of area of glaciers strongly reduces the ablation during the 21st century (Raper and Braithwaite, 2006), by about 45% under scenario SRES A1B for the GFDL-CM2.0 and PCM AOGCMs (see Table 8.1 for model details). For the same cases, using the mass-balance sensitivities to temperature of Oerlemans (2001) and Oerlemans et al. (2006), G&IC mass loss is reduced by about 35% following the area scaling of Van de Wal and Wild (2001), suggesting that the area scaling and the geometrical model have a similar effect in reducing estimated ablation for the 21st century. The effect is greater when using the observationally derived mass balance sensitivity (Section 10.6.3.1), which is larger, implying faster mass loss for fixed area. The uncertainty in present-day glacier volume (Table 4.4) introduces a 5 to 10% uncertainty into the results of area scaling. For projections, the area scaling of Van de Wal and Wild (2001) is applied, using three estimates of world glacier volume (see Table 4.4 and Appendix 10.A). The scaling reduces the projections of the G&IC contribution up to the mid-21st century by 25% and over the whole century by 40 to 50% with respect to fixed G&IC area.

10.6.3.3 Glaciers and Ice Caps on Greenland and Antarctica

The G&IC on Greenland and Antarctica (apart from the ice sheets) have been less studied and projections for them are consequently more uncertain. A model estimate for the G&IC on Greenland indicates an addition of about 6% to the G&IC sea level contribution in the 21st century (van de Wal and Wild, 2001). Using a degree-day scheme, Vaughan (2006) estimates that ablation of glaciers in the Antarctic Peninsula presently amounts to 0.008 to 0.055 mm yr^{-1} of sea level, 1 to 9% of the contribution from G&IC outside Greenland and Antarctica (Table 4.4). Morris and Mulvaney (2004) find that accumulation increases on the Antarctic Peninsula were larger than ablation increases during 1972 to 1998, giving a small net *negative* sea level contribution from the region. However, because ablation increases nonlinearly with temperature, they estimate that for future warming the contribution would become positive, with a sensitivity of 0.07 ± 0.03 mm yr^{-1} $°C^{-1}$ to uniform temperature change in Antarctica, that is, about 10% of the global sensitivity of G&IC outside Greenland and Antarctica (Section 10.6.3.1).

These results suggest that the Antarctic and Greenland G&IC will together give 10 to 20% of the sea level contribution of other G&IC in future decades. In recent decades, the G&IC on Greenland and Antarctica have together made a contribution of about 20% of the total of other G&IC (see Section 4.5.2). On these grounds, the global G&IC sea level contribution is increased by a factor of 1.2 to include those in Greenland and Antarctica in projections for the 21st century (see Section 10.6.5 and Table 10.7). Dynamical acceleration of glaciers in Greenland and Antarctica following removal of ice shelves, as has recently happened on the Antarctic Peninsula (Sections 4.6.2.2 and 10.6.4.2), would add further to this, and is included in projections of that effect (Section 10.6.4.3).

10.6.4 Ice Sheets

The mass of ice grounded on land in the Greenland and Antarctic Ice Sheets (see also Section 4.6.1) can change as a result of changes in surface mass balance (the sum of accumulation and ablation; Section 10.6.4.1) or in the flux of ice crossing the grounding line, which is determined by the dynamics of the ice sheet (Section 10.6.4.2). Surface mass balance and dynamics together both determine and are affected by the change in surface topography.

10.6.4.1 Surface Mass Balance

Surface mass balance (SMB) is immediately influenced by climate change. A good simulation of the ice sheet SMB requires a resolution exceeding that of AGCMs used for long climate experiments, because of the steep slopes at the margins of the ice sheet, where the majority of the precipitation and all of the ablation occur. Precipitation over ice sheets is typically overestimated by AGCMs, because their smooth topography does not present a sufficient barrier to inland penetration (Ohmura et al., 1996; Glover, 1999; Murphy et al., 2002). Ablation also tends to be overestimated because the area at low altitude around the margins of the ice sheet, where melting preferentially occurs, is exaggerated (Glover, 1999; Wild et al., 2003). In addition, AGCMs do not generally have a representation of the refreezing of surface melt water within the snowpack and may not include albedo variations dependent on snow ageing and its conversion to ice.

To address these issues, several groups have computed SMB at resolutions of tens of kilometres or less, with results that compare acceptably well with observations (e.g., van Lipzig et al., 2002; Wild et al., 2003). Ablation is calculated either by schemes based on temperature (degree-day or other temperature index methods) or by energy balance modelling. In the studies listed in Table 10.6, changes in SMB have been calculated from climate change simulations with high-resolution AGCMs or by perturbing a high-resolution observational climatology with climate model output, rather than by direct use of low-resolution GCM results. The models used for projected SMB changes are similar in kind to those used to study recent SMB changes (Section 4.6.3.1).

All the models show an increase in accumulation, but there is considerable uncertainty in its size (Table 10.6; van de Wal et al., 2001; Huybrechts et al., 2004). Precipitation increase could be determined by atmospheric radiative balance, increase in saturation specific humidity with temperature, circulation changes, retreat of sea ice permitting greater evaporation or a combination of these (van Lipzig et al., 2002). Accumulation also depends on change in local temperature, which strongly affects whether precipitation is solid or liquid (Janssens and Huybrechts, 2000), tending to make the accumulation increase smaller than the precipitation increase for a given temperature rise. For Antarctica, accumulation increases by 6 to 9% $°C^{-1}$ in the high-resolution AGCMs. Precipitation increases somewhat less in AR4 AOGCMs (typically of lower resolution), by 3 to 8% $°C^{-1}$. For Greenland, accumulation derived from the high-resolution AGCMs increases by 5 to 9% $°C^{-1}$. Precipitation increases by 4 to 7% $°C^{-1}$ in the AR4 AOGCMs.

Kapsner et al. (1995) do not find a relationship between precipitation and temperature variability inferred from Greenland ice cores for the Holocene, although both show large changes from the Last Glacial Maximum (LGM) to the Holocene. In the UKMO-HadCM3 AOGCM, the relationship is strong for climate change forced by greenhouse gases and the glacial-interglacial transition, but weaker for naturally forced variability (Gregory et al., 2006). Increasing precipitation in conjunction with warming has been observed in recent years in Greenland (Section 4.6.3.1).

All studies for the 21st century project that antarctic SMB changes will contribute negatively to sea level, owing to increasing accumulation exceeding any ablation increase (see Table 10.6). This tendency has not been observed in the average over Antarctica in reanalysis products for the last two decades (see Section 4.6.3.1), but during this period Antarctica as a whole has not warmed; on the other hand, precipitation has increased on the Antarctic Peninsula, where there has been strong warming.

In projections for Greenland, ablation increase is important but uncertain, being particularly sensitive to temperature change around the margins. Climate models project less warming in these low-altitude regions than the Greenland average, and less warming in summer (when ablation occurs) than the annual average, but greater warming in Greenland than the global average (Church et al., 2001; Huybrechts et al., 2004; Chylek and Lohmann, 2005; Gregory and Huybrechts, 2006). In most studies, Greenland SMB changes represent a net positive contribution to sea level in the 21st century (Table 10.6; Kiilsholm et al., 2003) because the ablation increase is larger than the precipitation increase. Only Wild et al. (2003) find the opposite, so that the net SMB change contributes negatively to sea level in the 21st century. Wild et al. (2003) attribute this

Table 10.6. *Comparison of ice sheet (grounded ice area) SMB changes calculated from high-resolution climate models. $\Delta P/\Delta T$ is the change in accumulation divided by change in temperature over the ice sheet, expressed as sea level equivalent (positive for falling sea level), and $\Delta R/\Delta T$ the corresponding quantity for ablation (positive for rising sea level). Note that ablation increases more rapidly than linearly with ΔT (van de Wal et al., 2001; Gregory and Huybrechts, 2006). To convert from mm yr^{-1} °C^{-1} to kg yr^{-1} °C^{-1}, multiply by 3.6×10^{14} m^2. To convert mm yr^{-1} °C^{-1} of sea level equivalent to mm yr^{-1} °C^{-1} averaged over the ice sheet, multiply by –206 for Greenland and –26 for Antarctica. $\Delta P/(P\Delta T)$ is the fractional change in accumulation divided by the change in temperature.*

Study	Climate model[a]	Model resolution and SMB source[b]	Greenland			Antarctica	
			$\Delta P/\Delta T$ (mm yr^{-1} °C^{-1})	$\Delta P/(P\Delta T)$ (% °C^{-1})	$\Delta R/\Delta T$ (mm yr^{-1} °C^{-1})	$\Delta P/\Delta T$ (mm yr^{-1} °C^{-1})	$\Delta P/(P\Delta T)$ (% °C^{-1})
Van de Wal et al. (2001)	ECHAM4	20 km EB	0.14	8.5	0.16	n.a.	n.a.
Wild and Ohmura (2000)	ECHAM4	T106 ≈ 1.1° EB	0.13	8.2	0.22	0.47	7.4
Wild et al. (2003)	ECHAM4	2 km TI	0.13	8.2	0.04	0.47	7.4
Bugnion and Stone (2002)	ECHAM4	20 km EB	0.10	6.4	0.13	n.a.	n.a.
Huybrechts et al. (2004)	ECHAM4	20 km TI	0.13[c]	7.6[c]	0.14	0.49[c]	7.3[c]
Huybrechts et al. (2004)	HadAM3H	20 km TI	0.09[c]	4.7[c]	0.23	0.37[c]	5.5[c]
Van Lipzig et al. (2002)	RACMO	55 km EB	n.a.	n.a.	n.a.	0.53	9.0
Krinner et al. (2007)	LMDZ4	60 km EB	n.a.	n.a.	n.a.	0.49	8.4

Notes:

[a] ECHAM4: Max Planck Institute for Meteorology AGCM; HadAM3H: high-resolution Met Office Hadley Centre AGCM; RACMO: Regional Atmospheric Climate Model (for Antarctica); LMDZ4: Laboratoire de Météorologie Dynamique AGCM (with high resolution over Antarctica).

[b] EB: SMB calculated from energy balance; TI: SMB calculated from temperature index.

[c] In these cases *P* is precipitation rather than accumulation.

difference to the reduced ablation area in their higher-resolution grid. A positive SMB change is not consistent with analyses of recent changes in Greenland SMB (see Section 4.6.3.1).

For an average temperature change of 3°C over each ice sheet, a combination of four high-resolution AGCM simulations and 18 AR4 AOGCMs (Huybrechts et al., 2004; Gregory and Huybrechts, 2006) gives SMB changes of 0.3 ± 0.3 mm yr^{-1} for Greenland and –0.9 ± 0.5 mm yr^{-1} for Antarctica (sea level equivalent), that is, sensitivities of 0.11 ± 0.09 mm yr^{-1} °C^{-1} for Greenland and –0.29 ± 0.18 mm yr^{-1} °C^{-1} for Antarctica. These results generally cover the range shown in Table 10.6, but tend to give more positive (Greenland) or less negative (Antarctica) sea level rise because of the smaller precipitation increases projected by the AOGCMs than by the high-resolution AGCMs. The uncertainties are from the spatial and seasonal patterns of precipitation and temperature change over the ice sheets, and from the ablation calculation. Projections under SRES scenarios for the 21st century are shown in Table 10.7.

10.6.4.2 Dynamics

Ice sheet flow reacts to changes in topography produced by SMB change. Projections for the 21st century are given in Section 10.6.5 and Table 10.7, based on the discussion in this section. In Antarctica, topographic change tends to increase ice flow and discharge. In Greenland, lowering of the surface tends to increase the ablation, while a steepening slope in the ablation zone opposes the lowering, and thinning of outlet glaciers reduces discharge. Topographic and dynamic changes simulated by ice flow models (Huybrechts and De Wolde, 1999; van de Wal et al., 2001; Huybrechts et al., 2002, 2004; Gregory and Huybrechts, 2006) can be roughly represented as modifying the sea level changes due to SMB change with fixed topography by –5% ± 5% from Antarctica, and 0% ±10% from Greenland (± one standard deviation) during the 21st century.

The TAR concluded that accelerated sea level rise caused by rapid dynamic response of the ice sheets to climate change is very unlikely during the 21st century (Church et al., 2001). However, new evidence of recent rapid changes in the Antarctic Peninsula, West Antarctica and Greenland (see Section 4.6.3.3) has again raised the possibility of larger dynamical changes in the future than are projected by state-of-the-art continental models, such as cited above, because these models do not incorporate all the processes responsible for the rapid marginal thinning currently taking place (Box 4.1; Alley et al., 2005a; Vaughan, 2007).

The main uncertainty is the degree to which the presence of ice shelves affects the flow of inland ice across the grounding

Frequently Asked Question 10.2

How Likely are Major or Abrupt Climate Changes, such as Loss of Ice Sheets or Changes in Global Ocean Circulation?

Abrupt climate changes, such as the collapse of the West Antarctic Ice Sheet, the rapid loss of the Greenland Ice Sheet or large-scale changes of ocean circulation systems, are not considered likely to occur in the 21st century, based on currently available model results. However, the occurrence of such changes becomes increasingly more likely as the perturbation of the climate system progresses.

Physical, chemical and biological analyses from Greenland ice cores, marine sediments from the North Atlantic and elsewhere and many other archives of past climate have demonstrated that local temperatures, wind regimes and water cycles can change rapidly within just a few years. The comparison of results from records in different locations of the world shows that in the past major changes of hemispheric to global extent occurred. This has led to the notion of an unstable past climate that underwent phases of abrupt change. Therefore, an important concern is that the continued growth of greenhouse gas concentrations in the atmosphere may constitute a perturbation sufficiently strong to trigger abrupt changes in the climate system. Such interference with the climate system could be considered dangerous, because it would have major global consequences.

Before discussing a few examples of such changes, it is useful to define the terms 'abrupt' and 'major'. 'Abrupt' conveys the meaning that the changes occur much faster than the perturbation inducing the change; in other words, the response is nonlinear. A 'major' climate change is one that involves changes that exceed the range of current natural variability and have a spatial extent ranging from several thousand kilometres to global. At local to regional scales, abrupt changes are a common characteristic of natural climate variability. Here, isolated, short-lived events that are more appropriately referred to as 'extreme events' are not considered, but rather large-scale changes that evolve rapidly and persist for several years to decades. For instance, the mid-1970s shift in sea surface temperatures in the Eastern Pacific, or the salinity reduction in the upper 1,000 m of the Labrador Sea since the mid-1980s, are examples of abrupt events with local to regional consequences, as opposed to the larger-scale, longer-term events that are the focus here.

One example is the potential collapse, or shut-down of the Gulf Stream, which has received broad public attention. The Gulf Stream is a primarily horizontal current in the north-western Atlantic Ocean driven by winds. Although a stable feature of the general circulation of the ocean, its northern extension, which feeds deep-water formation in the Greenland-Norwegian-Iceland Seas and thereby delivers substantial amounts of heat to these seas and nearby land areas, is influenced strongly by changes in the density of the surface waters in these areas. This current constitutes the northern end of a basin-scale meridional overturning circulation (MOC) that is established along the western boundary of the Atlantic basin. A consistent result from climate model simulations is that if the density of the surface waters in the North Atlantic decreases due to warming or a reduction in salinity, the strength of the MOC is decreased, and with it, the delivery of heat into these areas. Strong sustained reductions in salinity could induce even more substantial reduction, or complete shut-down of the MOC in all climate model projections. Such changes have indeed happened in the distant past.

The issue now is whether the increasing human influence on the atmosphere constitutes a strong enough perturbation to the MOC that such a change might be induced. The increase in greenhouse gases in the atmosphere leads to warming and an intensification of the hydrological cycle, with the latter making the surface waters in the North Atlantic less salty as increased rain leads to more freshwater runoff to the ocean from the region's rivers. Warming also causes land ice to melt, adding more freshwater and further reducing the salinity of ocean surface waters. Both effects would reduce the density of the surface waters (which must be dense and heavy enough to sink in order to drive the MOC), leading to a reduction in the MOC in the 21st century. This reduction is predicted to proceed in lockstep with the warming: none of the current models simulates an abrupt (nonlinear) reduction or a complete shut-down in this century. There is still a large spread among the models' simulated reduction in the MOC, ranging from virtually no response to a reduction of over 50% by the end of the 21st century. This cross-model variation is due to differences in the strengths of atmosphere and ocean feedbacks simulated in these models.

Uncertainty also exists about the long-term fate of the MOC. Many models show a recovery of the MOC once climate is stabilised. But some models have thresholds for the MOC, and they are passed when the forcing is strong enough and lasts long enough. Such simulations then show a gradual reduction of the MOC that continues even after climate is stabilised. A quantification of the likelihood of this occurring is not possible at this stage. Nevertheless, even if this were to occur, Europe would still experience warming, since the radiative forcing caused by increasing greenhouse gases would overwhelm the cooling associated with the MOC reduction. Catastrophic scenarios suggesting the beginning of an ice age triggered by a shutdown of the MOC are thus mere speculations, and no climate model has produced such an outcome. In fact, the processes leading to an ice age are sufficiently well understood and so completely different from those discussed here, that we can confidently exclude this scenario.

(continued)

Irrespective of the long-term evolution of the MOC, model simulations agree that the warming and resulting decline in salinity will significantly reduce deep and intermediate water formation in the Labrador Sea during the next few decades. This will alter the characteristics of the intermediate water masses in the North Atlantic and eventually affect the deep ocean. The long-term effects of such a change are unknown.

Other widely discussed examples of abrupt climate changes are the rapid disintegration of the Greenland Ice Sheet, or the sudden collapse of the West Antarctic Ice Sheet. Model simulations and observations indicate that warming in the high latitudes of the Northern Hemisphere is accelerating the melting of the Greenland Ice Sheet, and that increased snowfall due to the intensified hydrological cycle is unable to compensate for this melting. As a consequence, the Greenland Ice Sheet may shrink substantially in the coming centuries. Moreover, results suggest that there is a critical temperature threshold beyond which the Greenland Ice Sheet would be committed to disappearing completely, and that threshold could be crossed in this century. However, the total melting of the Greenland Ice Sheet, which would raise global sea level by about seven metres, is a slow process that would take many hundreds of years to complete.

Recent satellite and *in situ* observations of ice streams behind disintegrating ice shelves highlight some rapid reactions of ice sheet systems. This raises new concern about the overall stability of the West Antarctic Ice Sheet, the collapse of which would trigger another five to six metres of sea level rise. While these streams appear buttressed by the shelves in front of them, it is currently unknown whether a reduction or failure of this buttressing of relatively limited areas of the ice sheet could actually trigger a widespread discharge of many ice streams and hence a destabilisation of the entire West Antarctic Ice Sheet. Ice sheet models are only beginning to capture such small-scale dynamical processes that involve complicated interactions with the glacier bed and the ocean at the perimeter of the ice sheet. Therefore, no quantitative information is available from the current generation of ice sheet models as to the likelihood or timing of such an event.

line. A strong argument for enhanced flow when the ice shelf is removed is yielded by the acceleration of Jakobshavn Glacier (Greenland) following the loss of its floating tongue, and of the glaciers supplying the Larsen B Ice Shelf (Antarctic Peninsula) after it collapsed (see Section 4.6.3.3). The onset of disintegration of the Larsen B Ice Shelf has been attributed to enhanced fracturing by crevasses promoted by surface melt water (Scambos et al., 2000). Large portions of the Ross and Filchner-Ronne Ice Shelves (West Antarctica) currently have mean summer surface temperatures of around –5°C (Comiso, 2000, updated). Four high-resolution GCMs (Gregory and Huybrechts, 2006) project summer surface warming in these major ice shelf regions of between 0.2 and 1.3 times the antarctic annual average warming, which in turn will be a factor 1.1 ± 0.3 greater than global average warming according to AOGCM simulations using SRES scenarios. These figures indicate that a local mean summer warming of 5°C is unlikely for a global warming of less than 5°C (see Appendix 10.A). This suggests that ice shelf collapse due to surface melting is unlikely under most SRES scenarios during the 21st century, but we have low confidence in the inference because there is evidently large systematic uncertainty in the regional climate projections, and it is not known whether episodic surface melting might initiate disintegration in a warmer climate while mean summer temperatures remain below freezing.

In the Amundsen Sea sector of West Antarctica, ice shelves are not so extensive and the cause of ice shelf thinning is not surface melting, but bottom melting at the grounding line (Rignot and Jacobs, 2002). Shepherd et al. (2004) find an average ice-shelf thinning rate of 1.5 ± 0.5 m yr^{-1}. At the same time as the basal melting, accelerated inland flow has been observed for Pine Island, Thwaites and other glaciers in the sector (Rignot, 1998, 2001; Thomas et al., 2004). The synchronicity of these changes strongly implies that their cause lies in oceanographic change in the Amundsen Sea, but this has not been attributed to anthropogenic climate change and could be connected with variability in the SAM.

Because the acceleration took place in only a few years (Rignot et al., 2002; Joughin et al., 2003) but appears up to about 150 km inland, it implies that the dynamical response to changes in the ice shelf can propagate rapidly up the ice stream. This conclusion is supported by modelling studies of Pine Island Glacier by Payne et al. (2004) and Dupont and Alley (2005), in which a single and instantaneous reduction of the basal or lateral drag at the ice front is imposed in idealised ways, such as a step retreat of the grounding line. The simulated acceleration and inland thinning are rapid but transient; the rate of contribution to sea level declines as a new steady state is reached over a few decades. In the study of Payne et al. (2004) the imposed perturbations were designed to resemble loss of drag in the 'ice plain', a partially grounded region near the ice front, and produced a velocity increase of about 1 km yr^{-1} there. Thomas et al. (2005) suggest the ice plain will become ungrounded during the next decade and obtain a similar velocity increase using a simplified approach.

Most of inland ice of West Antarctica is grounded below sea level and so it could float if it thinned sufficiently; discharge therefore promotes inland retreat of the grounding line, which represents a positive feedback by further reducing basal traction. Unlike the one-time change in the idealised studies, this would represent a sustained dynamical forcing that would prolong the contribution to sea level rise. Grounding line retreat of the ice streams has been observed recently at rates of up to about 1 km yr^{-1} (Rignot, 1998, 2001; Shepherd et al., 2002), but a numerical model formulation is difficult to construct (Vieli and Payne, 2005).

The majority of West Antarctic ice discharge is through the ice streams that feed the Ross and Ronne-Filchner ice shelves, but in these regions no accelerated flow causing thinning is currently observed; on the contrary, they are thickening or near balance (Zwally et al., 2005). Excluding these regions, and likewise those parts of the East Antarctic Ice Sheet that drain into the large Amery ice shelf, the total area of ice streams (areas flowing faster than 100 m yr^{-1}) discharging directly into the sea or via a small ice shelf is 270,000 km^2. If all these areas thinned at 2 m yr^{-1}, the order of magnitude of the larger rates observed in fast-flowing areas of the Amundsen Sea sector (Shepherd et al., 2001, 2002), the contribution to sea level rise would be about 1.5 mm yr^{-1}. This would require sustained retreat simultaneously on many fronts, and should be taken as an indicative upper limit for the 21st century (see also Section 10.6.5).

The observation in west-central Greenland of seasonal variation in ice flow rate and of a correlation with summer temperature variation (Zwally et al., 2002) suggest that surface melt water may join a sub-glacially routed drainage system lubricating the ice flow (although this implies that it penetrates more than 1,200 m of subfreezing ice). By this mechanism, increased surface melting during the 21st century could cause acceleration of ice flow and discharge; a sensitivity study (Parizek and Alley, 2004) indicated that this might increase the sea level contribution from the Greenland Ice Sheet during the 21st century by up to 0.2 m, depending on the warming and other assumptions. However, other studies (Echelmeyer and Harrison, 1990; Joughin et al., 2004) found no evidence of seasonal fluctuations in the flow rate of nearby Jakobshavn Glacier despite a substantial supply of surface melt water.

10.6.5 Projections of Global Average Sea Level Change for the 21st Century

Table 10.7 and Figure 10.33 show projected changes in global average sea level under the SRES marker scenarios for the 21st century due to thermal expansion and land ice changes based on AR4 AOGCM results (see Sections 10.6.1, 10.6.3 and 10.6.4 for discussion). The ranges given are 5 to 95% intervals characterising the spread of model results, but we are not able to assess their likelihood in the way we have done for temperature change (Section 10.5.4.6), for two main reasons. First, the observational constraint on sea level rise projections is weaker, because records are shorter and subject to more uncertainty. Second, current scientific understanding leaves poorly known uncertainties in the methods used to make projections for land ice (Sections 10.6.3 and 10.6.4). Since the AOGCMs are integrated with scenarios of CO_2 concentration, uncertainties in carbon cycle feedbacks are not included in the results. The carbon cycle uncertainty in projections of temperature change cannot be translated into sea level rise because thermal expansion is a major contributor and its relation to temperature change is uncertain (Section 10.6.1).

Table 10.7. *Projected global average sea level rise during the 21st century and its components under SRES marker scenarios. The upper row in each pair gives the 5 to 95% range (m) of the rise in sea level between 1980 to 1999 and 2090 to 2099. The lower row in each pair gives the range of the rate of sea level rise (mm yr^{-1}) during 2090 to 2099. The land ice sum comprises G&IC and ice sheets, including dynamics, but excludes the scaled-up ice sheet discharge (see text). The sea level rise comprises thermal expansion and the land ice sum. Note that for each scenario the lower/upper bound for sea level rise is larger/smaller than the total of the lower/upper bounds of the contributions, since the uncertainties of the contributions are largely independent. See Appendix 10.A for methods.*

		B1		B2		A1B		A1T		A2		A1FI	
Thermal expansion	m	0.10	0.24	0.12	0.28	0.13	0.32	0.12	0.30	0.14	0.35	0.17	0.41
	mm yr^{-1}	1.1	2.6	1.6	4.0	1.7	4.2	1.3	3.2	2.6	6.3	2.8	6.8
G&IC	m	0.07	0.14	0.07	0.15	0.08	0.15	0.08	0.15	0.08	0.16	0.08	0.17
	mm yr^{-1}	0.5	1.3	0.5	1.5	0.6	1.6	0.5	1.4	0.6	1.9	0.7	2.0
Greenland Ice Sheet SMB	m	0.01	0.05	0.01	0.06	0.01	0.08	0.01	0.07	0.01	0.08	0.02	0.12
	mm yr^{-1}	0.2	1.0	0.2	1.5	0.3	1.9	0.2	1.5	0.3	2.8	0.4	3.9
Antarctic Ice Sheet SMB	m	-0.10	-0.02	-0.11	-0.02	-0.12	-0.02	-0.12	-0.02	-0.12	-0.03	-0.14	-0.03
	mm yr^{-1}	-1.4	-0.3	-1.7	-0.3	-1.9	-0.4	-1.7	-0.3	-2.3	-0.4	-2.7	-0.5
Land ice sum	m	0.04	0.18	0.04	0.19	0.04	0.20	0.04	0.20	0.04	0.20	0.04	0.23
	mm yr^{-1}	0.0	1.8	-0.1	2.2	-0.2	2.5	-0.1	2.1	-0.4	3.2	-0.8	4.0
Sea level rise	m	0.18	0.38	0.20	0.43	0.21	0.48	0.20	0.45	0.23	0.51	0.26	0.59
	mm yr^{-1}	1.5	3.9	2.1	5.6	2.1	6.0	1.7	4.7	3.0	8.5	3.0	9.7
Scaled-up ice sheet discharge	m	0.00	0.09	0.00	0.11	-0.01	0.13	-0.01	0.13	-0.01	0.13	-0.01	0.17
	mm yr^{-1}	0.0	1.7	0.0	2.3	0.0	2.6	0.0	2.3	-0.1	3.2	-0.1	3.9

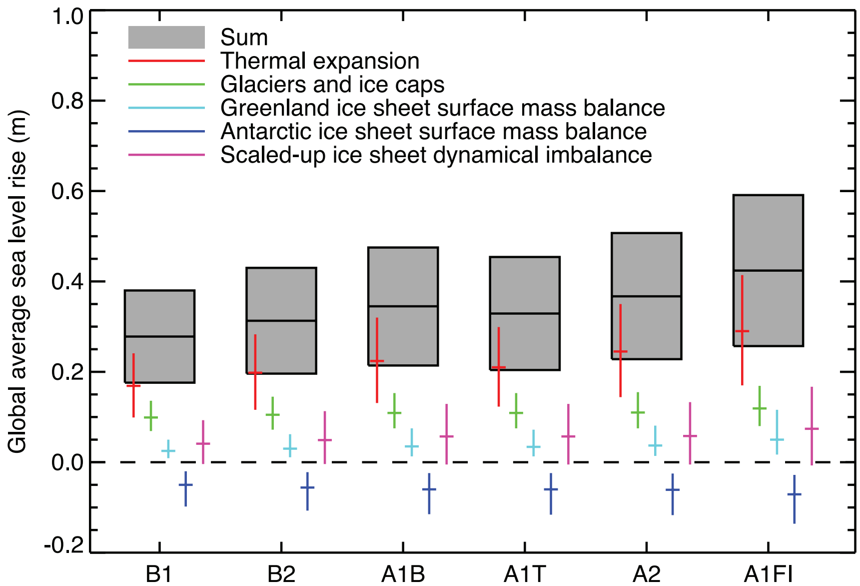


Figure 10.33. *Projections and uncertainties (5 to 95% ranges) of global average sea level rise and its components in 2090 to 2099 (relative to 1980 to 1999) for the six SRES marker scenarios. The projected sea level rise assumes that the part of the present-day ice sheet mass imbalance that is due to recent ice flow acceleration will persist unchanged. It does not include the contribution shown from scaled-up ice sheet discharge, which is an alternative possibility. It is also possible that the present imbalance might be transient, in which case the projected sea level rise is reduced by 0.02 m. It must be emphasized that we cannot assess the likelihood of any of these three alternatives, which are presented as illustrative. The state of understanding prevents a best estimate from being made.*

In all scenarios, the average rate of rise during the 21st century is very likely to exceed the 1961 to 2003 average rate of 1.8 ± 0.5 mm yr^{-1} (see Section 5.5.2.1). The central estimate of the rate of sea level rise during 2090 to 2099 is 3.8 mm yr^{-1} under A1B, which exceeds the central estimate of 3.1 mm yr^{-1} for 1993 to 2003 (see Section 5.5.2.2). The 1993 to 2003 rate may have a contribution of about 1 mm yr^{-1} from internally generated or naturally forced decadal variability (see Sections 5.5.2.4 and 9.5.2). These sources of variability are not predictable and not included in the projections; the actual rate during any future decade might therefore be more or less than the projected rate by a similar amount. Although simulated and observed sea level rise agree reasonably well for 1993 to 2003, the observed rise for 1961 to 2003 is not satisfactorily explained (Section 9.5.2), as the sum of observationally estimated components is 0.7 ± 0.7 mm yr^{-1} less than the observed rate of rise (Section 5.5.6). This indicates a deficiency in current scientific understanding of sea level change and may imply an underestimate in projections.

For an average model (the central estimate for each scenario), the scenario spread (from B1 to A1FI) in sea level rise is only 0.02 m by the middle of the century. This is small because of the time-integrating effect of sea level rise, on which the divergence among the scenarios has had little effect by then. By 2090 to 2099 it is 0.15 m.

In all scenarios, the central estimate for thermal expansion by the end of the century is 70 to 75% of the central estimate for the sea level rise. In all scenarios, the average rate of expansion during the 21st century is larger than central estimate of 1.6 mm yr^{-1} for 1993 to 2003 (Section 5.5.3). Likewise, in all scenarios the average rate of mass loss by G&IC during the 21st century is greater than the central estimate of 0.77 mm yr^{-1} for 1993 to 2003 (Section 4.5.2). By the end of the century, a large fraction of the present global G&IC mass is projected to have been lost (see, e.g., Table 4.3). The G&IC projections are rather insensitive to the scenario because the main uncertainties come from the G&IC model.

Further accelerations in ice flow of the kind recently observed in some Greenland outlet glaciers and West Antarctic ice streams could increase the ice sheet contributions substantially, but quantitative projections cannot be made with confidence (see Section 10.6.4.2). The land ice sum in Table 10.7 includes the effect of dynamical changes in the ice sheets that can be simulated with a continental ice sheet model (Section 10.6.4.2). It also includes a scenario-independent term of 0.32 ± 0.35 mm yr^{-1} (0.035 ± 0.039 m in 110 years). This is the central estimate for 1993 to 2003 of the sea level contribution from the Antarctic Ice Sheet, plus half of that from Greenland (Sections 4.6.2.2 and 5.5.5.2). We take this as an estimate of the part of the present ice sheet mass imbalance that is due to recent ice flow acceleration (Section 4.6.3.2), and assume that this contribution will persist unchanged.

We also evaluate the contribution of rapid dynamical changes under two alternative assumptions (see, e.g., Alley et al., 2005b). First, the present imbalance might be a rapid short-term adjustment, which will diminish during coming decades. We take an e-folding time of 100 years, on the basis of an idealised model study (Payne et al., 2004). This assumption reduces the sea level rise in Table 10.7 by 0.02 m. Second, the present imbalance might be a response to recent climate change, perhaps through oceanic or surface warming (Section 10.6.4.2). No models are available for such a link, so we assume that the imbalance might scale up with global average surface temperature change, which we take as a measure of the magnitude of climate change (see Appendix 10.A). This assumption adds 0.1 to 0.2 m to the estimated upper bound for sea level rise depending on the scenario (Table 10.7). During 2090 to 2099, the rate of scaled-up antarctic discharge roughly balances the increased rate of antarctic accumulation (SMB). The central estimate for the increased antarctic discharge under the SRES scenario A1FI is about 1.3 mm yr^{-1}, a factor of 5 to 10 greater than in recent years, and similar to the order-of-magnitude upper limit of Section 10.6.4.2. It must be emphasized that we cannot assess the likelihood of any of these three alternatives, which are presented as illustrative. The state of understanding prevents a best estimate from being made.

The central estimates for sea level rise in Table 10.7 are smaller than the TAR model means (Church et al., 2001) by 0.03 to 0.07 m, depending on scenario, for two reasons. First, these projections are for 2090-2099, whereas the TAR projections were for 2100. Second, the TAR included some small constant additional contributions to sea level rise which are omitted here (see below regarding permafrost). If the TAR model means are adjusted for this, they are within 10% of the central estimates from Table 10.7. (See Appendix 10.A for further information.) For each scenario, the upper bound of sea level rise in Table 10.7 is smaller than in the TAR, and the lower bound is larger than in the TAR. This is because the uncertainty on the sea level projection has been reduced, for a combination of reasons (see Appendix 10.A for details). The TAR would have had similar ranges to those shown here if it had treated the uncertainties in the same way.

Thawing of permafrost is projected to contribute about 5 mm during the 21st century under the SRES scenario A2 (calculated from Lawrence and Slater, 2005). The mass of the ocean will also be changed by climatically driven alteration in other water storage, in the forms of atmospheric water vapour, seasonal snow cover, soil moisture, groundwater, lakes and rivers. All of these are expected to be relatively small terms, but there may be substantial contributions from anthropogenic change in terrestrial water storage, through extraction from aquifers and impounding in reservoirs (see Sections 5.5.5.3 and 5.5.5.4).

10.7 Long Term Climate Change and Commitment

10.7.1 Climate Change Commitment to Year 2300 Based on AOGCMs

Building on Wigley (2005), we use three specific definitions of climate change commitment: (i) the 'constant composition commitment', which denotes the further change of temperature ('constant composition temperature commitment' or 'committed warming'), sea level ('constant composition sea level commitment') or any other quantity in the climate system, since the time the composition of the atmosphere, and hence the radiative forcing, has been held at a constant value; (ii) the 'constant emission commitment', which denotes the further change of, for example, temperature ('constant emission temperature commitment') since the time the greenhouse gas emissions have been held at a constant value; and (iii) the 'zero emission commitment', which denotes the further change of, for example, temperature ('zero emission temperature commitment') since the time the greenhouse gas emissions have been set to zero.

The concept that the climate system exhibits commitment when radiative forcing has changed is mainly due to the thermal inertia of the oceans, and was discussed independently by Wigley (1984), Hansen et al. (1984) and Siegenthaler and Oeschger (1984). The term 'commitment' in this regard was introduced by Ramanathan (1988). In the TAR, this was illustrated in idealised scenarios of doubling and quadrupling atmospheric CO_2, and stabilisation at 2050 and 2100 after an IS92a forcing scenario. Various temperature commitment values were reported (about 0.3°C per century with much model dependency), and EMIC simulations were used to illustrate the long-term influence of the ocean owing to long mixing times and the MOC. Subsequent studies have confirmed this behaviour of the climate system and ascribed it to the inherent property of the climate system that the thermal inertia of the ocean introduces a lag to the warming of the climate system after concentrations of greenhouse gases are stabilised (Mitchell et al., 2000; Wetherald et al., 2001; Wigley and Raper, 2003; Hansen et al., 2005b; Meehl et al., 2005c; Wigley, 2005). Climate change commitment as discussed here should not be confused with 'unavoidable climate change' over the next half century, which would surely be greater because forcing cannot be instantly stabilised. Furthermore, in the very long term it is plausible that climate change could be less than in a commitment run since forcing could plausibly be reduced below current levels as illustrated in the overshoot simulations and zero emission commitment simulations discussed below.

Three constant composition commitment experiments have recently been performed by the global coupled climate modelling community: (1) stabilising concentrations of greenhouse gases at year 2000 values after a 20th-century climate simulation, and running the model for an additional 100 years; (2) stabilising concentrations of greenhouse gases at year 2100 values after a 21st-century B1 experiment (e.g., CO_2 near 550 ppm) and running the model for an additional 100 years (with some models run to 200 years); and (3) stabilising concentrations of greenhouse gases at year 2100 values after a 21st-century A1B experiment (e.g., CO_2 near 700 ppm), and running the model for an additional 100 years (and some models to 200 years). Multi-model mean warming in these experiments is depicted in Figure 10.4. Time series of the globally averaged surface temperature and percent precipitation change after stabilisation are shown for all the models in the Supplementary Material, Figure S10.3.

The multi-model average warming for all radiative forcing agents held constant at year 2000 (reported earlier for several of the models by Meehl et al., 2005c), is about 0.6°C for the period 2090 to 2099 relative to the 1980 to 1999 reference period. This is roughly the magnitude of warming simulated in the 20th century. Applying the same uncertainty assessment as for the SRES scenarios in Fig. 10.29 (–40 to +60%), the likely uncertainty range is 0.3°C to 0.9°C. Hansen et al. (2005a) calculate the current energy imbalance of the Earth to be 0.85 W m^{-2}, implying that the unrealised global warming is about 0.6°C without any further increase in radiative forcing. The committed warming trend values show a rate of warming averaged over the first two decades of the 21st century of about 0.1°C per decade, due mainly to the slow response of the oceans. About twice as much warming (0.2°C per decade) would be expected if emissions are within the range of the SRES scenarios.

For the B1 constant composition commitment run, the additional warming after 100 years is also about 0.5°C, and roughly the same for the A1B constant composition commitment (Supplementary Material, Figure S10.3). These new results quantify what was postulated in the TAR in that the warming commitment after stabilising concentrations is about 0.5°C for the first century, and considerably smaller after that, with most of the warming commitment occurring in the first several decades of the 22nd century.

Constant composition precipitation commitment for the multi-model ensemble average is about 1.1% by 2100 for the 20th-century constant composition commitment experiment, and for the B1 constant composition commitment experiment it is 0.8% by 2200 and 1.5% by 2300, while for the A1B constant composition commitment experiment it is 1.5% by 2200 and 2% by 2300.

The patterns of change in temperature in the B1 and A1B experiments, relative to the pre-industrial period, do not change greatly after stabilisation (Table 10.5). Even the 20th-century stabilisation case warms with some similarity to the A1B pattern (Table 10.5). However, there is some contrast in the land and ocean warming rates, as seen from Figure 10.6. Mid- and low-latitude land warms at rates closer to the global mean of that of A1B, while high-latitude ocean warming is larger.

10.7.2 Climate Change Commitment to Year 3000 and Beyond to Equilibrium

Earth System Models of Intermediate Complexity are used to extend the projections for a scenario that follows A1B to 2100 and then keeps atmospheric composition, and hence radiative forcing, constant to the year 3000 (see Figure 10.34). By 2100, the projected warming is between 1.2°C and 4.1°C, similar to the range projected by AOGCMs. A large constant composition temperature and sea level commitment is evident in the simulations and is slowly realised over coming centuries. By the year 3000, the warming range is 1.9°C to 5.6°C. While surface temperatures approach equilibrium relatively quickly, sea level continues to rise for many centuries.

Five of these EMICs include interactive representations of the marine and terrestrial carbon cycle and, therefore, can be used to assess carbon cycle-climate feedbacks and effects of

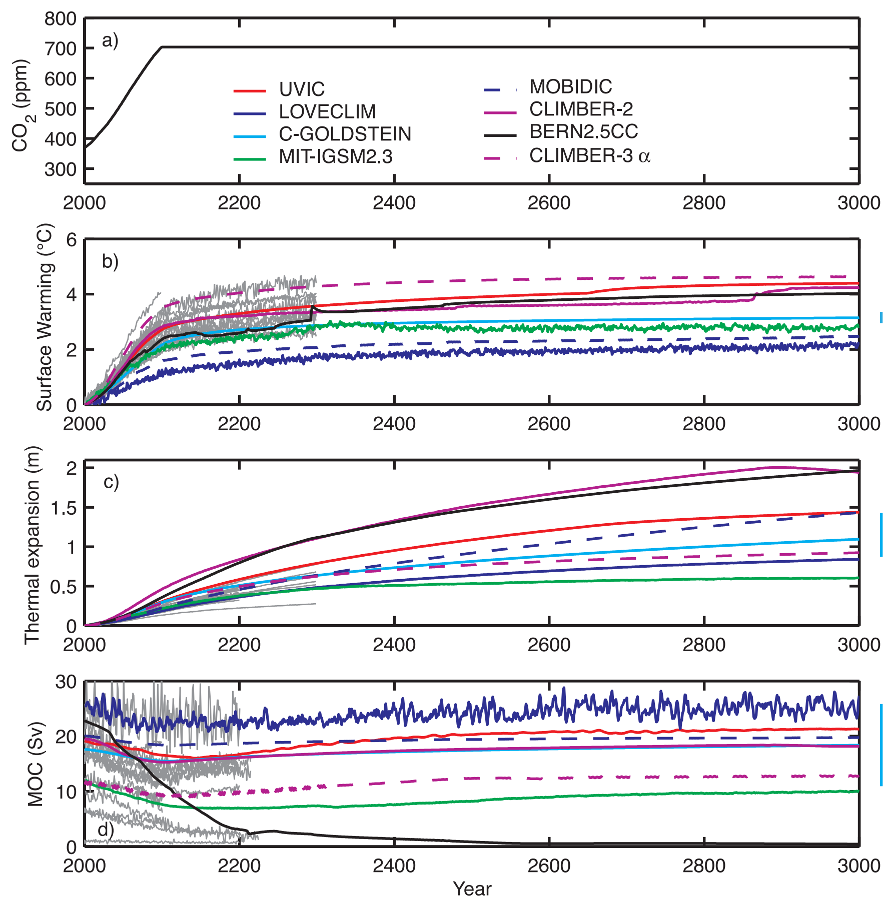


Figure 10.34. *(a) Atmospheric CO_2, (b) global mean surface warming, (c) sea level rise from thermal expansion and (d) Atlantic meridional overturning circulation (MOC) calculated by eight EMICs for the SRES A1B scenario and stable radiative forcing after 2100, showing long-term commitment after stabilisation. Coloured lines are results from EMICs, grey lines indicate AOGCM results where available for comparison. Anomalies in (b) and (c) are given relative to the year 2000. Vertical bars indicate ±2 standard deviation uncertainties due to ocean parameter perturbations in the C-GOLDSTEIN model. The MOC shuts down in the BERN2.5CC model, leading to an additional contribution to sea level rise. Individual EMICs (see Table 8.3 for model details) treat the effect from non-CO_2 greenhouse gases and the direct and indirect aerosol effects on radiative forcing differently. Despite similar atmospheric CO_2 concentrations, radiative forcing among EMICs can thus differ within the uncertainty ranges currently available for present-day radiative forcing (see Chapter 2).*

Frequently Asked Question 10.3

If Emissions of Greenhouse Gases are Reduced, How Quickly do Their Concentrations in the Atmosphere Decrease?

The adjustment of greenhouse gas concentrations in the atmosphere to reductions in emissions depends on the chemical and physical processes that remove each gas from the atmosphere. Concentrations of some greenhouse gases decrease almost immediately in response to emission reduction, while others can actually continue to increase for centuries even with reduced emissions.

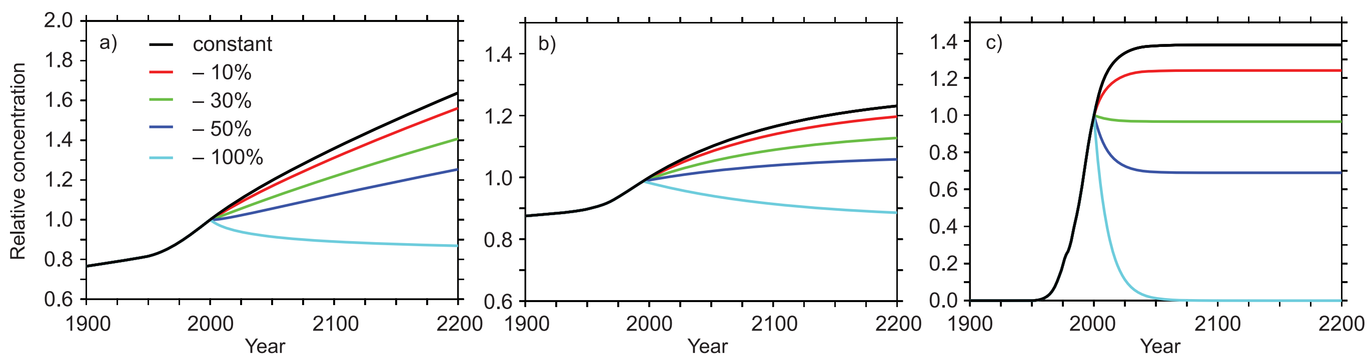
The concentration of a greenhouse gas in the atmosphere depends on the competition between the rates of emission of the gas into the atmosphere and the rates of processes that remove it from the atmosphere. For example, carbon dioxide (CO_2) is exchanged between the atmosphere, the ocean and the land through processes such as atmosphere-ocean gas transfer and chemical (e.g., weathering) and biological (e.g., photosynthesis) processes. While more than half of the CO_2 emitted is currently removed from the atmosphere within a century, some fraction (about 20%) of emitted CO_2 remains in the atmosphere for many millennia. Because of slow removal processes, atmospheric CO_2 will continue to increase in the long term even if its emission is substantially reduced from present levels. Methane (CH_4) is removed by chemical processes in the atmosphere, while nitrous oxide (N_2O) and some halocarbons are destroyed in the upper atmosphere by solar radiation. These processes each operate at different time scales ranging from years to millennia. A measure for this is the lifetime of a gas in the atmosphere, defined as the time it takes for a perturbation to be reduced to 37% of its initial amount. While for CH_4, N_2O, and other trace gases such as hydrochlorofluorocarbon-22 (HCFC-22), a refrigerant fluid, such lifetimes can be reasonably determined (for CH_4 it is about 12 yr, for N_2O about 110 yr and for HCFC-22 about 12 yr), a lifetime for CO_2 cannot be defined.

The change in concentration of any trace gas depends in part on how its emissions evolve over time. If emissions increase with time, the atmospheric concentration will also increase with time, regardless of the atmospheric lifetime of the gas. However, if actions are taken to reduce the emissions, the fate of the trace gas concentration will depend on the relative changes not only of emissions but also of its removal processes. Here we show how the lifetimes and removal processes of different gases dictate the evolution of concentrations when emissions are reduced.

As examples, FAQ 10.3, Figure 1 shows test cases illustrating how the future concentration of three trace gases would respond to illustrative changes in emissions (represented here as a response to an imposed pulse change in emission). We consider CO_2, which has no specific lifetime, as well as a trace gas with a well-defined long lifetime on the order of a century (e.g., N_2O), and a trace gas with a well-defined short lifetime on the order of decade (such as CH_4, HCFC-22 or other halocarbons). For each gas, five illustrative cases of future emissions are presented: stabilisation of emissions at present-day levels, and immediate emission reduction by 10%, 30%, 50% and 100%.

The behaviour of CO_2 (Figure 1a) is completely different from the trace gases with well-defined lifetimes. Stabilisation of CO_2 emissions at current levels would result in a continuous increase of atmospheric CO_2 over the 21st century and beyond, whereas for a gas with a lifetime on the order of a century (Figure 1b) or a decade (Figure 1c), stabilisation of emissions at current levels would lead to a stabilisation of its concentration at a level higher than today within a couple of centuries, or decades, respectively. In fact, only in the case of essentially complete elimination of

(continued)



FAQ 10.3, Figure 1. *(a) Simulated changes in atmospheric CO_2 concentration relative to the present-day for emissions stabilised at the current level (black), or at 10% (red), 30% (green), 50% (dark blue) and 100% (light blue) lower than the current level; (b) as in (a) for a trace gas with a lifetime of 120 years, driven by natural and anthropogenic fluxes; and (c) as in (a) for a trace gas with a lifetime of 12 years, driven by only anthropogenic fluxes.*

emissions can the atmospheric concentration of CO_2 ultimately be stabilised at a constant level. All other cases of moderate CO_2 emission reductions show increasing concentrations because of the characteristic exchange processes associated with the cycling of carbon in the climate system.

More specifically, the rate of emission of CO_2 currently greatly exceeds its rate of removal, and the slow and incomplete removal implies that small to moderate reductions in its emissions would not result in stabilisation of CO_2 concentrations, but rather would only reduce the rate of its growth in coming decades. A 10% reduction in CO_2 emissions would be expected to reduce the growth rate by 10%, while a 30% reduction in emissions would similarly reduce the growth rate of atmospheric CO_2 concentrations by 30%. A 50% reduction would stabilise atmospheric CO_2, but only for less than a decade. After that, atmospheric CO_2 would be expected to rise again as the land and ocean sinks decline owing to well-known chemical and biological adjustments. Complete elimination of CO_2 emissions is estimated to lead to a slow decrease in atmospheric CO_2 of about 40 ppm over the 21st century.

The situation is completely different for the trace gases with a well-defined lifetime. For the illustrative trace gas with a lifetime of the order of a century (e.g., N_2O), emission reduction of more than 50% is required to stabilise the concentrations close to present-day values (Figure 1b). Constant emission leads to a stabilisation of the concentration within a few centuries.

In the case of the illustrative gas with the short lifetime, the present-day loss is around 70% of the emissions. A reduction in emissions of less than 30% would still produce a short-term increase in concentration in this case, but, in contrast to CO_2, would lead to stabilisation of its concentration within a couple of decades (Figure 1c). The decrease in the level at which the concentration of such a gas would stabilise is directly proportional to the emission reduction. Thus, in this illustrative example, a reduction in emissions of this trace gas larger than 30% would be required to stabilise concentrations at levels significantly below those at present. A complete cut-off of the emissions would lead to a return to pre-industrial concentrations within less than a century for a trace gas with a lifetime of the order of a decade.

carbon emission reductions on atmospheric CO_2 and climate. Although carbon cycle processes in these models are simplified, global-scale quantities are in good agreement with more complex models (Doney et al., 2004).

Results for one carbon emission scenario are shown in Figure 10.35, where anthropogenic emissions follow a path towards stabilisation of atmospheric CO_2 at 750 ppm but at year 2100 are reduced to zero. This permits the determination of the zero emission climate change commitment. The prescribed emissions were calculated from the SP750 profile (Knutti et al., 2005) using the BERN-CC model (Joos et al., 2001). Although unrealistic, such a scenario permits the calculation of zero emission commitment, i.e., climate change due to 21st-century emissions. Even though emissions are instantly reduced to zero at year 2100, it takes about 100 to 400 years in the different models for the atmospheric CO_2 concentration to drop from the maximum (ranges between 650 to 700 ppm) to below the level of doubled pre-industrial CO_2 (~560 ppm) owing to a continuous transfer of carbon from the atmosphere into the terrestrial and oceanic reservoirs. Emissions during the 21st century continue to have an impact even at year 3000 when both surface temperature and sea level rise due to thermal expansion are still substantially higher than pre-industrial. Also shown are atmospheric CO_2 concentrations and ocean/terrestrial carbon inventories at year 3000 versus total emitted carbon for similar emission pathways targeting (but not actually reaching) 450, 550, 750 and 1,000 ppm atmospheric CO_2 and with carbon emissions reduced to zero at year 2100. Atmospheric CO_2 at year 3000 is approximately linearly related to the total amount of carbon emitted in each model, but with a substantial spread among the models in both slope and absolute values, because the redistribution of carbon between the different reservoirs is model dependent. In summary, the model results show that 21st-century emissions represent a minimum commitment of climate change for several centuries, irrespective of later emissions. A reduction of this 'minimum' commitment is possible only if, in addition to avoiding CO_2 emissions after 2100, CO_2 were actively removed from the atmosphere.

Using a similar approach, Friedlingstein and Solomon (2005) show that even if emissions were immediately cut to zero, the system would continue to warm for several more decades before starting to cool. It is important also to note that ocean heat content and changes in the cryosphere evolve on time scales extending over centuries.

On very long time scales (order several thousand years as estimated by AOGCM experiments, Bi et al., 2001; Stouffer, 2004), equilibrium climate sensitivity is a useful concept to characterise the ultimate response of climate models to different future levels of greenhouse gas radiative forcing. This concept can be applied to climate models irrespective of their complexity. Based on a global energy balance argument, equilibrium climate sensitivity S and global mean surface temperature increase ΔT at equilibrium relative to pre-industrial for an equivalent stable CO_2 concentration are linearly related according to $\Delta T = S \times \log(CO_2 / 280 \text{ ppm}) / \log(2)$, which follows from the definition of climate sensitivity and simplified expressions for the radiative forcing of CO_2 (Section 6.3.5 of the TAR). Because the combination of various lines of modelling results and expert judgement yields a quantified range of climate sensitivity S (see Box 10.2), this can be carried over to equilibrium temperature increase. Most likely values, and the likely range, as well as a very likely lower bound for the warming, all consistent with the quantified range of S, are given in Table 10.8.

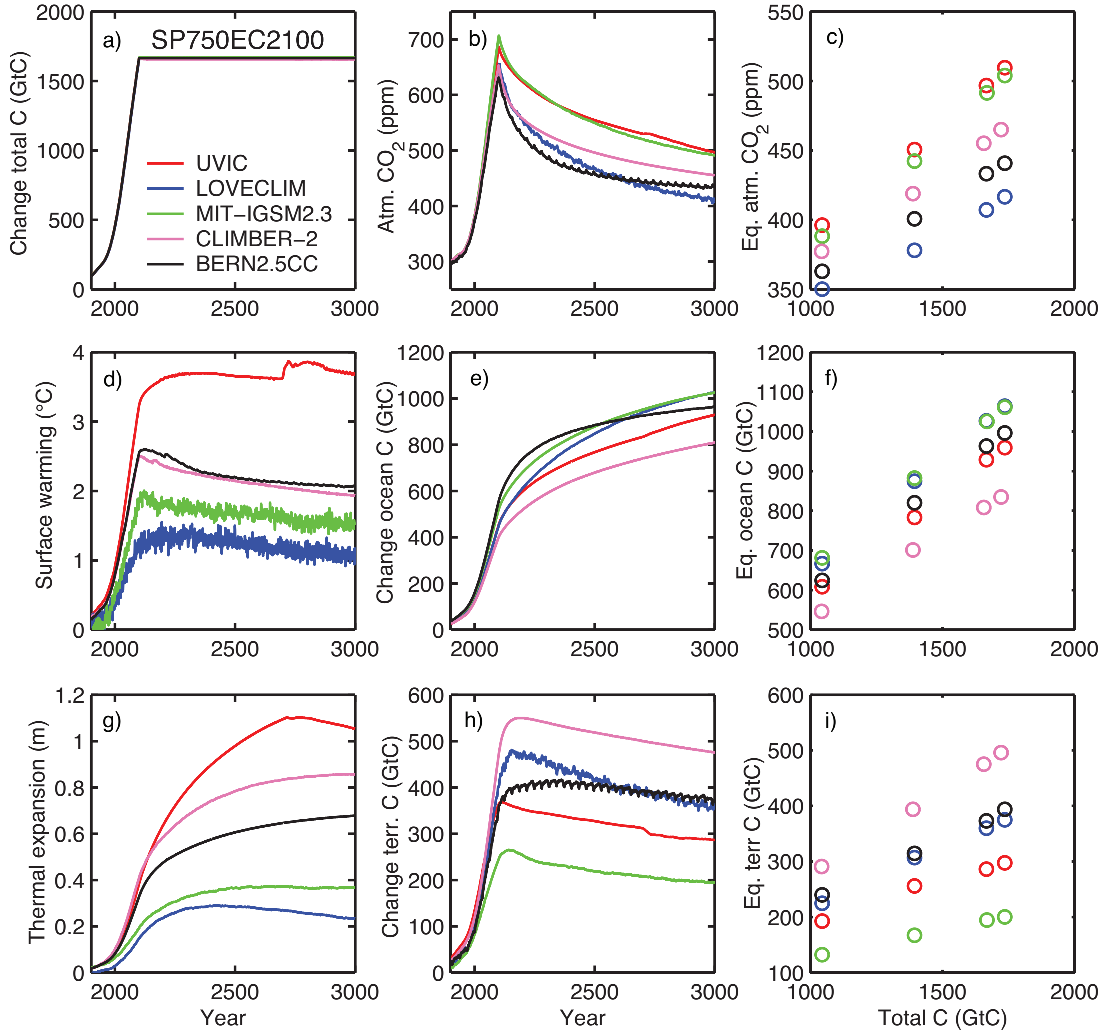


Figure 10.35. *Changes in carbon inventories and climate response relative to the pre-industrial period simulated by five different intermediate complexity models (see Table 8.3 for model descriptions) for a scenario where emissions follow a pathway leading to stabilisation of atmospheric CO_2 at 750 ppm, but before reaching this target, emissions are reduced to zero instantly at year 2100. (a) Change in total carbon, (b) atmospheric CO_2, (d) change in surface temperature, (e) change in ocean carbon, (g) sea level rise from thermal expansion and (h) change in terrestrial carbon. Right column: (c) atmospheric CO_2 and the change in (f) oceanic and (i) terrestrial carbon inventories at year 3000 relative to the pre-industrial period for several emission scenarios of similar shape but with different total carbon emissions.*

Table 10.8. *Best guess (i.e. most likely), likely and very likely bounds/ranges of global mean equilibrium surface temperature increase ΔT(°C) above pre-industrial temperatures for different levels of CO_2 equivalent concentrations (ppm), based on the assessment of climate sensitivity given in Box 10.2.*

Equivalent CO_2	Best Guess	Very Likely Above	Likely in the Range
350	1.0	0.5	0.6–1.4
450	2.1	1.0	1.4–3.1
550	2.9	1.5	1.9–4.4
650	3.6	1.8	2.4–5.5
750	4.3	2.1	2.8–6.4
1,000	5.5	2.8	3.7–8.3
1,200	6.3	3.1	4.2–9.4

It is emphasized that this table does not contain more information than the best knowledge of *S* and that the numbers are not the result of any climate model simulation. Rather it is assumed that the above relationship between temperature increase and CO_2 holds true for the entire range of equivalent CO_2 concentrations. There are limitations to the concept of radiative forcing and climate sensitivity (Senior and Mitchell, 2000; Joshi et al., 2003; Shine et al., 2003; Hansen et al., 2005b). Only a few AOGCMs have been run to equilibrium under elevated CO_2 concentrations, and some results show that nonlinearities in the feedbacks (e.g., clouds, sea ice and snow cover) may cause a time dependence of the effective climate sensitivity and substantial deviations from the linear relation assumed above (Manabe and Stouffer, 1994; Senior and Mitchell, 2000; Voss and Mikolajewicz, 2001; Gregory et al., 2004b), with effective climate sensitivity tending to grow with time in some of the AR4 AOGCMs. Some studies suggest that climate sensitivities larger than the likely estimate given below (which would suggest greater warming) cannot be ruled out (see Box 10.2 on climate sensitivity).

Another way to address eventual equilibrium temperature for different CO_2 concentrations is to use the projections from the AOGCMs in Figure 10.4, and an idealised 1% yr^{-1} CO_2 increase to 4 × CO_2. The equivalent CO_2 concentrations in the AOGCMs can be estimated from the forcings given in Table 6.14 in the TAR. The actual CO_2 concentrations for A1B and B1 are roughly 715 ppm and 550 ppm (depending on which model is used to convert emissions to concentrations), and equivalent CO_2 concentrations are estimated to be about 835 ppm and 590 ppm, respectively. Using the equation above for an equilibrium climate sensitivity of 3.0°C, eventual equilibrium warming in these experiments would be 4.8°C and 3.3°C, respectively. The multi-model average warming in the AOGCMs at the end of the 21st century (relative to pre-industrial temperature) is 3.1°C and 2.3°C, or about 65 to 70% of the eventual estimated equilibrium warming. Given rates of CO_2 increase of between 0.5 and 1.0% yr^{-1} in these two scenarios, this can be compared to the calculated fraction of eventual warming of around 50% in AOGCM experiments with those CO_2 increase rates (Stouffer and Manabe, 1999). The Stouffer and Manabe (1999) model has somewhat higher equilibrium climate sensitivity, and was actually run to equilibrium in a 4-kyr integration to enable comparison of transient and equilibrium warming. Therefore, the AOGCM results combined with the estimated equilibrium warming seem roughly consistent with earlier AOGCM experiments of transient warming rates. Additionally, similar numbers for the 4 × CO_2 stabilisation experiments performed with the AOGCMs can be computed. In that case, the actual and equivalent CO_2 concentrations are the same, since there are no other radiatively active species changing in the models, and the multi-model CO_2 concentration at quadrupling would produce an eventual equilibrium warming of 6°C, where the multi-model average warming at the time of quadrupling is about 4.0°C or 66% of eventual equilibrium. This is consistent with the numbers for the A1B and B1 scenario integrations with the AOGCMs.

It can be estimated how much closer to equilibrium the climate system is 100 years after stabilisation in these AOGCM experiments. After 100 years of stabilised concentrations, the warming relative to pre-industrial temperature is 3.8°C in A1B and 2.6°C in B1, or about 80% of the estimated equilibrium warming. For the stabilised 4 × CO_2 experiment, after 100 years of stabilised CO_2 concentrations the warming is 4.7°C, or 78% of the estimated equilibrium warming. Therefore, about an additional 10 to 15% of the eventual equilibrium warming is achieved after 100 years of stabilised concentrations (Stouffer, 2004). This emphasizes that the approach to equilibrium takes a long time, and even after 100 years of stabilised atmospheric concentrations, only about 80% of the eventual equilibrium warming is realised.

10.7.3 Long-Term Integrations: Idealised Overshoot Experiments

The concept of mitigation related to overshoot scenarios has implications for IPCC Working Groups II and III and was addressed in the Second Assessment Report. A new suite of mitigation scenarios is currently being assessed for the AR4. Working Group I does not have the expertise to assess such scenarios, so this section assesses the processes and response of the physical climate system in a very idealised overshoot experiment. Plausible new mitigation and overshoot scenarios will be run subsequently by modelling groups and assessed in the next IPCC report.

An idealised overshoot scenario has been run in an AOGCM where the CO_2 concentration decreases from the A1B stabilised level to the B1 stabilised level between 2150 and 2250, followed by 200 years of integration with that constant B1 level (Figure 10.36a). This reduction in CO_2 concentration would require large reductions in emissions, but such an idealised experiment illustrates the processes involved in how the climate system would respond to such a large change in emissions and concentrations. Yoshida et al. (2005) and Tsutsui et al. (2007) show that there is a relatively fast response in the surface and upper ocean, which start to recover to temperatures at the B1 level after several decades, but a much more sluggish response with more commitment in the deep ocean. As shown in Figure 10.36b and c, the overshoot scenario temperatures only slowly decrease to approach the lower temperatures of the B1 experiment, and continue a slow convergence that has still not cooled to the B1 level at the year 2350, or 100 years after the CO_2 concentration in the overshoot experiment was reduced to equal the concentration in the B1 experiment. However, Dai et al. (2001a) show that reducing emissions to achieve a stabilised CO_2 concentration in the 21st century reduces warming moderately (less than 0.5°C) by the end of the 21st century in comparison to a business-as-usual scenario, but the warming reduction is about 1.5°C by the end of the 22nd century in that experiment. Other climate system responses include the North Atlantic MOC and sea ice volume that almost recover to the B1 level in the overshoot scenario experiment, except for a significant hysteresis effect that is shown in the sea level change due to thermal expansion (Yoshida et al., 2005; Nakashiki et al., 2006).

Such stabilisation and overshoot scenarios have implications for risk assessment as suggested by Yoshida et al. (2005) and others. For example, in a probabilistic study using an SCM and multi-gas scenarios, Meinshausen (2006) estimated that the probability of exceeding a 2°C warming is between 68 and 99% for a stabilisation of equivalent CO_2 at 550 ppm. They also considered scenarios with peaking CO_2 and subsequent stabilisation at lower levels as an alternative pathway and found that if the risk of exceeding a warming of 2°C is not to be greater than 30%, it is necessary to peak equivalent CO_2 concentrations around 475 ppm before returning to lower concentrations of about 400 ppm. These overshoot and targeted climate change estimations take into account the climate change commitment

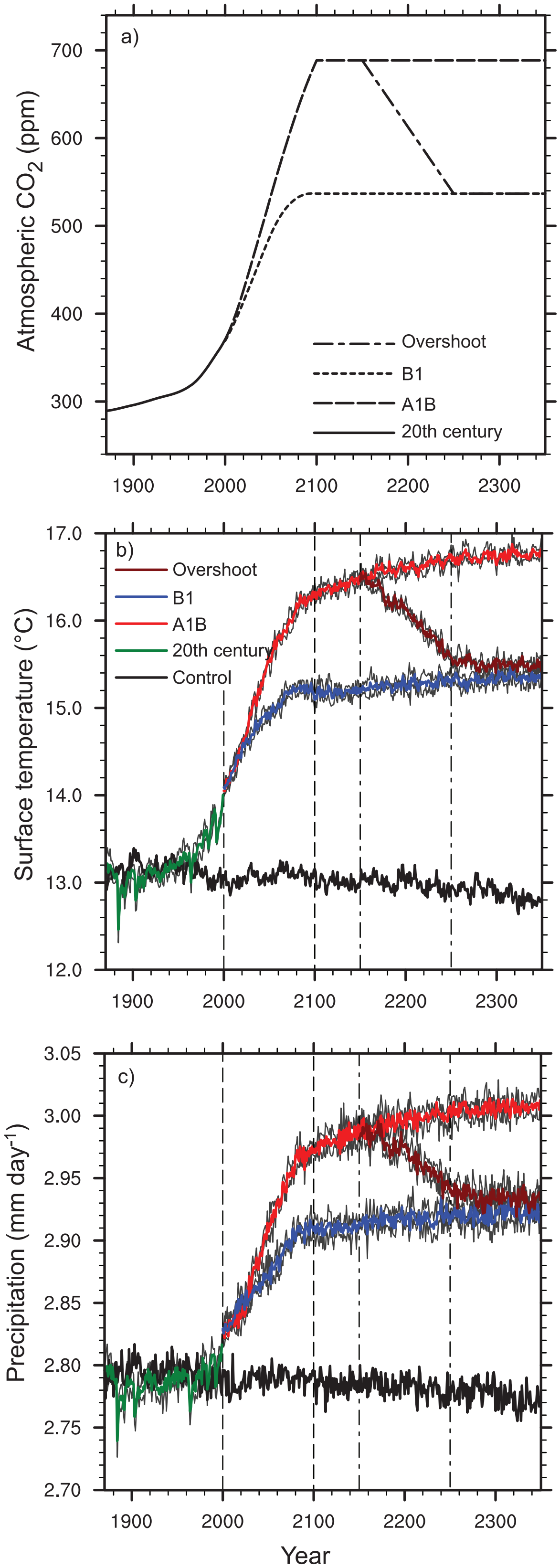


Figure 10.36. *(a) Atmospheric CO_2 concentrations for several experiments simulated with an AOGCM; (b) globally averaged surface air temperatures for the overshoot scenario and the A1B and B1 experiments; (c) same as in (b) but for globally averaged precipitation rate. Modified from Yoshida et al. (2005).*

in the system that must be overcome on the time scale of any overshoot or emissions target calculation. The probabilistic studies also show that when certain thresholds of climate change are to be avoided, emission pathways depend on the certainty requested of not exceeding the threshold.

Earth System Models of Intermediate Complexity have been used to calculate the long-term climate response to stabilisation of atmospheric CO_2, although EMICs have not been adjusted to take into account the full range of AOGCM sensitivities. The newly developed stabilisation profiles were constructed following Enting et al. (1994) and Wigley et al. (1996) using the most recent atmospheric CO_2 observations, CO_2 projections with the BERN-CC model (Joos et al., 2001) for the A1T scenario over the next few decades, and a ratio of two polynomials (Enting et al., 1994) leading to stabilisation at levels of 450, 550, 650, 750 and 1,000 ppm atmospheric CO_2 equivalent. Other forcings are not considered. Supplementary Material, Figure S10.4a shows the equilibrium surface warming for seven different EMICs and six stabilisation levels. Model differences arise mainly from the models having different climate sensitivities.

Knutti et al. (2005) explore this further with an EMIC using several published PDFs of climate sensitivity and different ocean heat uptake parametrizations and calculate probabilities of not overshooting a certain temperature threshold given an equivalent CO_2 stabilisation level (Supplementary Material, Figure S10.4b). This plot illustrates, for example, that for low values of stabilised CO_2, the range of response of possible warming is smaller than for high values of stabilised CO_2. This is because with greater CO_2 forcing, there is a greater spread of outcomes as illustrated in Figure 10.26. Figure S10.4b also shows that for any given temperature threshold, the smaller the desired probability of exceeding the target is, the lower the stabilisation level that must be chosen. Stabilisation of atmospheric greenhouse gases below about 400 ppm CO_2 equivalent is required to keep the global temperature increase likely less than 2°C above pre-industrial temperature (Knutti et al., 2005).

10.7.4 Commitment to Sea Level Rise

10.7.4.1 Thermal Expansion

The sea level rise commitment due to thermal expansion has much longer time scales than the surface warming commitment, owing to the slow processes that mix heat into the deep ocean (Church et al., 2001). If atmospheric composition were stabilised at A1B levels in 2100, thermal expansion in the 22nd century would be similar to in the 21st (see, e.g., Section 10.6.1; Meehl et al., 2005c), reaching 0.3 to 0.8 m by 2300 (Figure 10.37). The ranges of thermal expansion overlap substantially for stabilisation at different levels, since model uncertainty is dominant; A1B is given here because results are available from more models for this scenario than for other scenarios. Thermal expansion would continue over many centuries at a gradually decreasing rate (Figure 10.34). There is a wide spread among

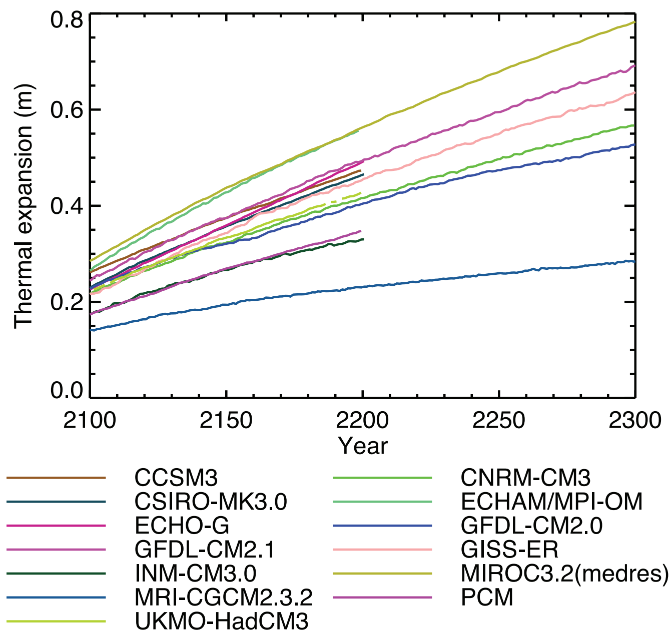


Figure 10.37. *Globally averaged sea level rise from thermal expansion relative to the period 1980 to 1999 for the A1B commitment experiment calculated from AOGCMs. See Table 8.1 for model details.*

the models for the thermal expansion commitment at constant composition due partly to climate sensitivity, and partly to differences in the parametrization of vertical mixing affecting ocean heat uptake (e.g., Weaver and Wiebe, 1999). If there is deep-water formation in the final steady state as in the present day, the ocean will eventually warm up fairly uniformly by the amount of the global average surface temperature change (Stouffer and Manabe, 2003), which would result in about 0.5 m of thermal expansion per degree celsius of warming, calculated from observed climatology; the EMICs in Figure 10.34 indicate 0.2 to 0.6 m °C^{-1} for their final steady state (year 3000) relative to 2000. If deep-water formation is weakened or suppressed, the deep ocean will warm up more (Knutti and Stocker, 2000). For instance, in the 3 × CO_2 experiment of Bi et al. (2001) with the CSIRO AOGCM, both North Atlantic Deep Water and Antarctic Bottom Water formation cease, and the steady-state thermal expansion is 4.5 m. Although these commitments to sea level rise are large compared with 21st-century changes, the eventual contributions from the ice sheets could be larger still.

10.7.4.2 Glaciers and Ice Caps

Steady-state projections for G&IC require a model that evolves their area-altitude distribution (see, e.g., Section 10.6.3.3). Little information is available on this. A comparative study including seven GCM simulations at 2 × CO_2 conditions inferred that many glaciers may disappear completely due to an increase of the equilibrium line altitude (Bradley et al., 2004), but even in a warmer climate, some glacier volume may persist at high altitude. With a geographically uniform warming relative to 1900 of 4°C maintained after 2100, about 60% of G&IC volume would vanish by 2200 and practically all by 3000 (Raper and Braithwaite, 2006). Nonetheless, this commitment to sea level rise is relatively small (<1 m; Table 4.4) compared with those from thermal expansion and ice sheets.

10.7.4.3 Greenland Ice Sheet

The present SMB of Greenland is a net accumulation estimated as 0.6 mm yr^{-1} of sea level equivalent from a compilation of studies (Church et al., 2001) and 0.47 mm yr^{-1} for 1988 to 2004 (Box et al., 2006). In a steady state, the net accumulation would be balanced by calving of icebergs. General Circulation Models suggest that ablation increases more rapidly than accumulation with temperature (van de Wal et al., 2001; Gregory and Huybrechts, 2006), so warming will tend to reduce the SMB, as has been observed in recent years (see Section 4.6.3), and is projected for the 21st century (Section 10.6.4.1). Sufficient warming will reduce the SMB to zero. This gives a threshold for the long-term viability of the ice sheet because negative SMB means that the ice sheet must contract even if ice discharge has ceased owing to retreat from the coast. If a warmer climate is maintained, the ice sheet will eventually be eliminated, except perhaps for remnant glaciers in the mountains, raising sea level by about 7 m (see Table 4.1). Huybrechts et al. (1991) evaluated the threshold as 2.7°C of seasonally and geographically uniform warming over Greenland relative to a steady state (i.e. pre-industrial temperature). Gregory et al. (2004a) examine the probability of this threshold being reached under various CO_2 stabilisation scenarios for 450 to 1000 ppm using TAR projections, and find that it was exceeded in 34 out of 35 combinations of AOGCM and CO_2 concentration considering seasonally uniform warming, and 24 out of 35 considering summer warming and using an upper bound on the threshold.

Assuming the warming to be uniform underestimates the threshold, because warming is projected by GCMs to be weaker in the ablation area and in summer, when ablation occurs. Using geographical and seasonal patterns of simulated temperature change derived from a combination of four high-resolution AGCM simulations and 18 AR4 AOGCMs raises the threshold to 3.2°C to 6.2°C in annual- and area-average warming in Greenland, and 1.9°C to 4.6°C in the global average (Gregory and Huybrechts, 2006), relative to pre-industrial temperatures. This is likely to be reached by 2100 under the SRES A1B scenario, for instance (Figure 10.29). These results are supported by evidence from the last interglacial, when the temperature in Greenland was 3°C to 5°C warmer than today and the ice sheet survived, but may have been smaller by 2 to 4 m in sea level equivalent (including contributions from arctic ice caps, see Section 6.4.3). However, a lower threshold of 1°C (Hansen, 2005) in global warming above present-day temperatures has also been suggested, on the basis that global mean (rather than Greenland) temperatures during previous interglacials exceeded today's temperatures by no more than that.

For stabilisation in 2100 with SRES A1B atmospheric composition, Greenland would initially contribute 0.3 to

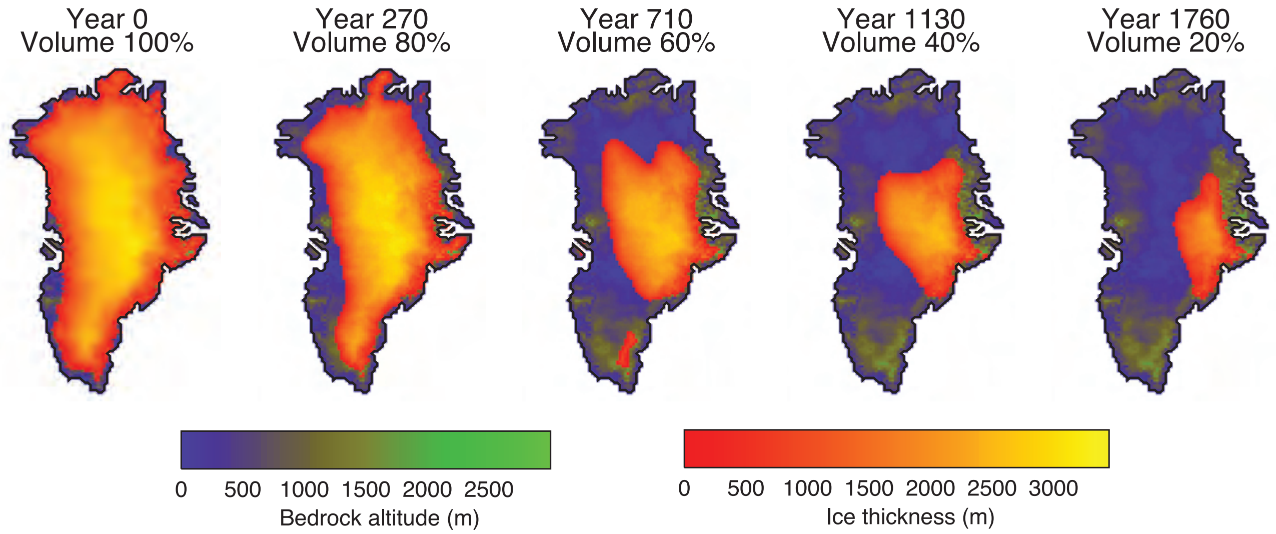


Figure 10.38. *Evolution of Greenland surface elevation and ice sheet volume versus time in the experiment of Ridley et al. (2005) with the UKMO-HadCM3 AOGCM coupled to the Greenland Ice Sheet model of Huybrechts and De Wolde (1999) under a climate of constant quadrupled pre-industrial atmospheric CO_2.*

2.1 mm yr^{-1} to sea level (Table 10.7). The greater the warming, the faster the loss of mass. Ablation would be further enhanced by the lowering of the surface, which is not included in the calculations in Table 10.7. To include this and other climate feedbacks in calculating long-term rates of sea level rise requires coupling an ice sheet model to a climate model. Ridley et al. (2005) couple the Greenland Ice Sheet model of Huybrechts and De Wolde (1999) to the UKMO-HadCM3 AOGCM. Under constant 4 × CO_2, the sea level contribution is 5.5 mm yr^{-1} over the first 300 years and declines as the ice sheet contracts; after 1 kyr only about 40% of the original volume remains and after 3 kyr only 4% (Figure 10.38). The rate of deglaciation would increase if ice flow accelerated, as in recent years (Section 4.6.3.3). Basal lubrication due to surface melt water might cause such an effect (see Section 10.6.4.2). The best estimate of Parizek and Alley (2004) is that this could add an extra 0.15 to 0.40 m to sea level by 2500, compared with 0.4 to 3.2 m calculated by Huybrechts and De Wolde (1999) without this effect. The processes whereby melt water might penetrate through subfreezing ice to the bed are unclear and only conceptual models exist at present (Alley et al., 2005b).

Under pre-industrial or present-day atmospheric CO_2 concentrations, the climate of Greenland would be much warmer without the ice sheet, because of lower surface altitude and albedo, so it is possible that Greenland deglaciation and the resulting sea level rise would be irreversible. Toniazzo et al. (2004) find that snow does not accumulate anywhere on an ice-free Greenland with pre-industrial atmospheric CO_2, whereas Lunt et al. (2004) obtain a substantial regenerated ice sheet in east and central Greenland using a higher-resolution model.

10.7.4.4 Antarctic Ice Sheet

With rising global temperature, GCMs indicate increasingly positive SMB for the Antarctic Ice Sheet as a whole because of greater accumulation (Section 10.6.4.1). For stabilisation in 2100 with SRES A1B atmospheric composition, antarctic SMB would contribute 0.4 to 2.0 mm yr^{-1} of sea level fall (Table 10.7). Continental ice sheet models indicate that this would be offset by tens of percent by increased ice discharge (Section 10.6.4.2), but still give a negative contribution to sea level, of –0.8 m by 3000 in one simulation with antarctic warming of about 4.5°C (Huybrechts and De Wolde, 1999).

However, discharge could increase substantially if buttressing due to the major West Antarctic ice shelves were reduced (see Sections 4.6.3.3 and 10.6.4.2), and could outweigh the accumulation increase, leading to a net positive antarctic sea level contribution in the long term. If the Amundsen Sea sector were eventually deglaciated, it would add about 1.5 m to sea level, while the entire West Antarctic Ice Sheet (WAIS) would account for about 5 m (Vaughan, 2007). Contributions could also come in this manner from the limited marine-based portions of East Antarctica that discharge into large ice shelves.

Weakening or collapse of the ice shelves could be caused either by surface melting or by thinning due to basal melting. In equilibrium experiments with mixed-layer ocean models, the ratio of antarctic to global annual warming is 1.4 ± 0.3. Following reasoning in Section 10.6.4.2 and Appendix 10.A, it appears that mean summer temperatures over the major West Antarctic ice shelves are about as likely as not to pass the melting point if global warming exceeds 5°C, and disintegration might be initiated earlier by surface melting. Observational and modelling studies indicate that basal melt rates depend on water temperature near to the base, with a constant of proportionality of about 10 m yr^{-1} °C^{-1} indicated for the Amundsen Sea ice shelves (Rignot and Jacobs, 2002; Shepherd et al., 2004) and 0.5 to 10 m yr^{-1} °C^{-1} for the Amery ice shelf (Williams et al., 2002). If this order of magnitude applies to future changes, a warming of about 1°C under the major ice shelves would eliminate them within centuries. We are not able to relate this quantitatively to global warming with any confidence, because the issue has so far received little attention, and current models may be inadequate to treat it because of limited resolution and poorly understood processes. Nonetheless, it is reasonable to suppose that sustained global warming would eventually lead to warming in the seawater circulating beneath the ice shelves.

Because the available models do not include all relevant processes, there is much uncertainty and no consensus about what dynamical changes could occur in the Antarctic Ice Sheet (see, e.g., Vaughan and Spouge, 2002; Alley et al., 2005a). One line of argument is to consider an analogy with palaeoclimate (see Box 4.1). Palaeoclimatic evidence that sea level was 4 to 6 m above present during the last interglacial may not all be explained by reduction in the Greenland Ice Sheet, implying a contribution from the Antarctic Ice Sheet (see Section 6.4.3). On this basis, using the limited available evidence, sustained global warming of 2°C (Oppenheimer and Alley, 2005) above present-day temperatures has been suggested as a threshold beyond which there will be a commitment to a large sea level contribution from the WAIS. The maximum rates of sea level rise during previous glacial terminations were of the order of 10 mm yr^{-1} (Church et al., 2001). We can be confident that future accelerated discharge from WAIS will not exceed this size, which is roughly an order of magnitude increase in present-day WAIS discharge, since no observed recent acceleration has exceeded a factor of ten.

Another line of argument is that there is insufficient evidence that rates of dynamical discharge of this magnitude could be sustained over long periods. The WAIS is 20 times smaller than the LGM NH ice sheets that contributed most of the melt water during the last deglaciation at rates that can be explained by surface melting alone (Zweck and Huybrechts, 2005). In the study of Huybrechts and De Wolde (1999), the largest simulated rate of sea level rise from the Antarctic Ice Sheet over the next 1 kyr is 2.5 mm yr^{-1}. This is dominated by dynamical discharge associated with grounding line retreat. The model did not simulate ice streams, for which widespread acceleration would give larger rates. However, the maximum loss of ice possible from rapid discharge of existing ice streams is the volume in excess of flotation in the regions occupied by these ice streams (defined as regions of flow exceeding 100 m yr^{-1}; see Section 10.6.4.2). This volume (in both West and East Antarctica) is 230,000 km^3, equivalent to about 0.6 m of sea level, or about 1% of the mass of the Antarctic Ice Sheet, most of which does not flow in ice streams. Loss of ice affecting larger portions of the ice sheet could be sustained at rapid rates only if new ice streams developed in currently slow-moving ice. The possible extent and rate of such changes cannot presently be estimated, since there is only very limited understanding of controls on the development and variability of ice streams. In this argument, rapid discharge may be transient and the long-term sign of the antarctic contribution to sea level depends on whether increased accumulation is more important than large-scale retreat of the grounding line.

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Appendix 10.A: Methods for Sea Level Projections for the 21st Century

10.A.1 Scaling MAGICC Results

The MAGICC SCM was tuned to emulate global average surface air temperature change and radiative flux at the top of the atmosphere (assumed equal to ocean heat uptake on decadal time scales; Section 5.2.2.3 and Figure 5.4) simulated by each of 19 AOGCMs in scenarios with CO_2 increasing at 1% yr^{-1} (Section 10.5.3). Under SRES scenarios for which AOGCMs have been run (B1, A1B and A2), the ensemble average of the tuned versions of MAGICC gives about 10% greater temperature rise and 25% more thermal expansion over the 21st century (2090 to 2099 minus 1980 to 1999) than the average of the corresponding AOGCMs. The MAGICC radiative forcing is close to that of the AOGCMs (as estimated for A1B by Forster and Taylor, 2006), so the mismatch suggests there may be structural limitations on the accurate emulation of AOGCMs by the SCM. We therefore do not use the tuned SCM results directly to make projections, unlike in the TAR. The TAR model means for thermal expansion were 0.06–0.10 m larger than the central estimates in Table 10.7, probably because the simple climate model used in the TAR overestimated the TAR AOGCM results.

The SCM may nonetheless be used to estimate results for scenarios that have not been run in AOGCMs, by calculating time-dependent ratios between pairs of scenarios (Section 10.5.4.6). This procedure is supported by the close match between the ratios derived from the AOGCM and MAGICC ensemble averages under the scenarios for which AOGCMs are available. Applying the MAGICC ratios to the A1B AOGCM results yields estimates of temperature rise and thermal expansion for B1 and A2 differing by less than 5% from the AOGCM ensemble averages. We have high confidence that the procedure will yield similarly accurate estimates for the results that the AOGCMs would give under scenarios B2, A1T and A1FI.

The spread of MAGICC models is much narrower than the AOGCM ensemble because the AOGCMs have internally generated climate variability and a wider range of forcings. We assume inter-model standard deviations of 20% of the model average for temperature rise and 25% for thermal expansion, since these proportions are found to be fairly time and scenario independent in the AOGCM ensemble.

10.A.2 Mass Balance Sensitivity of Glaciers and Ice Caps

A linear relationship $r_g = b_g \times (T - T_0)$ is found for the period 1961 to 2003 between the observational time series of the contribution r_g to the rate of sea level rise from the world's glaciers and ice caps (G&IC, excluding those on Antarctica and Greenland; Section 4.5.2, Figure 4.14) and global average surface air temperature T (Hadley Centre/Climatic Research Unit gridded surface temperature dataset HadCRUT3; Section 3.2.2.4, Figure 3.6), where b_g is the global total G&IC mass balance sensitivity and T_0 is the global average temperature of the climate in which G&IC are in a steady state, T and T_0 being expressed relative to the average of 1865 to 1894. The correlation coefficient is 0.88. Weighted least-squares regression gives a slope b_g = 0.84 ± 0.15 (one standard deviation) mm yr^{-1} °C^{-1}, with $T_0 = -0.13$°C. Surface mass balance models driven with climate change scenarios from AOGCMs (Section 10.6.3.1) also indicate such a linear relationship, but the model results give a somewhat lower b_g of around 0.5 to 0.6 mm yr^{-1} °C^{-1} (Section 10.6.3.1). To cover both observations and models, we adopt a value of b_g = 0.8 ± 0.2 (one standard deviation) mm yr^{-1} °C^{-1}. This uncertainty of ±25% is smaller than that of ±40% used in the TAR because of the improved observational constraint now available. To make projections, we choose a set of values of b_g randomly from a normal distribution. We use $T_0 = T - r_g/b_g$, where T = 0.40 °C and r_g = 0.45 mm yr^{-1}, are the averages over the period 1961 to 2003. This choice of T_0 minimises the root mean square difference of the predicted r_g from the observed, and gives T_0 in the range −0.5°C to 0.0°C (5 to 95%). Note that a constant b_g is not expected to be a good approximation if glacier area changes substantially (see Section 10.A.3).

10.A.3 Area Scaling of Glaciers and Ice Caps

Model results using area-volume scaling of G&IC (Section 10.6.3.2) are approximately described by the relations $b_g / b_1 = (A_g / A_1)^{1.96}$ and $A_g / A_1 = (V_g / V_1)^{0.84}$, where A_g and V_g are the global G&IC area and volume (excluding those on Greenland and Antarctica) and variable X_1 is the initial value of X_g. The first relation describes how total SMB sensitivity declines as the most sensitive areas are ablated most rapidly. The second relation follows Wigley and Raper (2005) in its form, and describes how area declines as volume is lost, with $dV_g / dt = -r_g$ (expressing V as sea level equivalent, i.e., the liquid-water-equivalent volume of ice divided by the surface area of the world ocean). Projections are made starting from 1990 using T from Section 10.A.1 with initial values of the present-day b_g from Section 10.A.2 and the three recent estimates V_g = 0.15, 0.24 and 0.37 m from Table 4.4, which are assumed equally likely. We use T = 0.48°C at 1990 relative to 1865 to 1894, and choose T_0 as in Section 10.A.2. An uncertainty of 10% (one standard deviation) is assumed because of the scaling relations. The results are multiplied by 1.2 (Section 10.6.3.3) to include contributions from G&IC on Greenland and Antarctica (apart from the ice sheets). These scaling relations are expected to give a decreasingly adequate approximation as greater area and volume is lost, because they do not model hypsometry explicitly; they predict that V will tend eventually to zero in any steady-state warmer climate, for instance, although this is not necessarily the case. A similar scaling procedure was used in the TAR. Current estimates of present-day G&IC mass are smaller than those used in the TAR, leading to more rapid wastage of area. Hence, the central estimates for the G&IC contribution to sea level rise in Table 10.7 are similar to those in the TAR, despite our use of a larger mass balance sensitivity (Section 10.A.2).

10.A.4 Changes in Ice Sheet Surface Mass Balance

Quadratic fits are made to the results of Gregory and Huybrechts (2006) (Section 10.6.4.1) for the SMB change of each ice sheet as a function of global average temperature change relative to a steady state, which is taken to be the late 19th century (1865–1894). The spread of results for the various models used by Gregory and Huybrechts represents uncertainty in the patterns of temperature and precipitation change. The Greenland contribution has a further uncertainty of 20% (one standard deviation) from the ablation calculation. The Antarctic SMB projections are similar to those of the TAR, while the Greenland SMB projections are larger by 0.01–0.04 m because of the use of a quadratic fit to temperature change rather than the constant sensitivity of the TAR, which gave an underestimate for larger warming.

10.A.5 Changes in Ice Sheet Dynamics

Topographic and dynamic changes that can be simulated by currently available ice flow models are roughly represented as modifying the sea level changes due to SMB change by –5% ± 5% from Antarctica, and 0% ± 10% from Greenland (± one standard deviation) (Section 10.6.4.2).

The contribution from scaled-up ice sheet discharge, given as an illustration of the effect of accelerated ice flow (Section 10.6.5), is calculated as $r_1 \times T / T_1$, with T and T_1 expressed relative to the 1865 to 1894 average, where $r_1 = 0.32$ mm yr^{-1} is an estimate of the contribution during 1993 to 2003 due to recent acceleration and $T_1 = 0.63$°C is the global average temperature during that period.

10.A.6 Combination of Uncertainties

For each scenario, time series of temperature rise and the consequent land ice contributions to sea level are generated using a Monte Carlo simulation (van der Veen, 2002). Temperature rise and thermal expansion have some correlation for a given scenario in AOGCM results (Section 10.6.1). In the Monte Carlo simulation, we assume them to be perfectly correlated; by correlating the uncertainties in the thermal expansion and land ice contributions, this increases the resulting uncertainty in the sea level rise projections. However, the uncertainty in the projections of the land ice contributions is dominated by the various uncertainties in the land ice models themselves (Sections 10.A.2–4) rather than in the temperature projections. We assume the uncertainties in land ice models and temperature projections to be uncorrelated. The procedure used in the TAR, however, effectively assumed the land ice model uncertainty to be correlated with the temperature and expansion projection uncertainty. This is the main reason why the TAR ranges for sea level rise under each of the scenarios are wider than those of Table 10.7. Also, the TAR gave uncertainty ranges of ±2 standard deviations, whereas the present report gives ±1.65 standard deviations (5 to 95%).

10.A.7 Change in Surface Air Temperature Over the Major West Antarctic Ice Shelves

The mean surface air temperature change over the area of the Ross and Filchner-Ronne ice shelves in December and January, divided by the mean annual antarctic surface air temperature change, is $F_1 = 0.62 \pm 0.48$ (one standard deviation) on the basis of the climate change simulations from the four high-resolution GCMs used by Gregory and Huybrechts (2006). From AR4 AOGCMs, the ratio of mean annual antarctic temperature change to global mean temperature change is $F_2 = 1.1 \pm 0.2$ (one standard deviation) under SRES scenarios with stabilisation beyond 2100 (Gregory and Huybrechts, 2006), while from AR4 AGCMs coupled to mixed-layer ocean models it is $F_2 = 1.4 \pm 0.2$ (one standard deviation) at equilibrium under doubled CO_2. To evaluate the probability of ice shelf mean summer temperature increase exceeding a particular value, given the global temperature rise, a Monte Carlo distribution of $F_1 \times F_2$ is used, generated by assuming the two factors to be normal and independent random variables. Since this procedure is based on a small number of models, and given other caveats noted in Sections 10.6.4.2 and 10.7.4.4, we have low confidence in these probabilities.

evaluated from radiative fluxes at the top of the atmosphere calculated with or without the presence of clouds that are output by the GCMs. In the multi-model mean (not shown) values vary in sign over the globe. The global and annual mean averaged over the models, for 1980 to 1999, is –22.3 W m^{-2}. The change in mean cloud radiative forcing has been shown to have different signs in a limited number of previous modelling studies (Meehl et al., 2004b; Tsushima et al., 2006). Figure 10.11a shows globally averaged cloud radiative forcing changes for 2080 to 2099 under the A1B scenario for individual models of the data set, which have a variety of different magnitudes and even signs. The ensemble mean change is –0.6 W m^{-2}. This range indicates that cloud feedback is still an uncertain feature of the global coupled models (see Section 8.6.3.2.2).

The DTR has been shown to be decreasing in several land areas of the globe in 20th-century observations (see Section 3.2.2.7), together with increasing cloud cover (see also Section 9.4.2.3). In the multi-model mean of present climate, DTR over land is indeed closely spatially anti-correlated with the total cloud cover field. This is true also of the 21st-century changes in the fields under the A1B scenario, as can be seen by comparing the change in DTR shown in Figure 10.11b with the cloud area fraction shown in Figure 10.10b. Changes in DTR reach a magnitude of 0.5°C in some regions, with some consistency among the models. Smaller widespread decreases are likely due to the radiative effect of the enhanced greenhouse gases including water vapour (see also Stone and Weaver, 2002). Further discussion of DTR is provided in Section 10.3.6.2.

In addition to the DTR, Kitoh and Arakawa (2005) document changes in the regional patterns of diurnal precipitation over the Indonesian region, and show that over ocean, nighttime precipitation decreases and daytime precipitation increases, while over land the opposite is the case, thus producing a decrease in the diurnal precipitation amplitude over land and ocean. They attribute these changes to a larger nighttime temperature increase over land due to increased greenhouse gases.

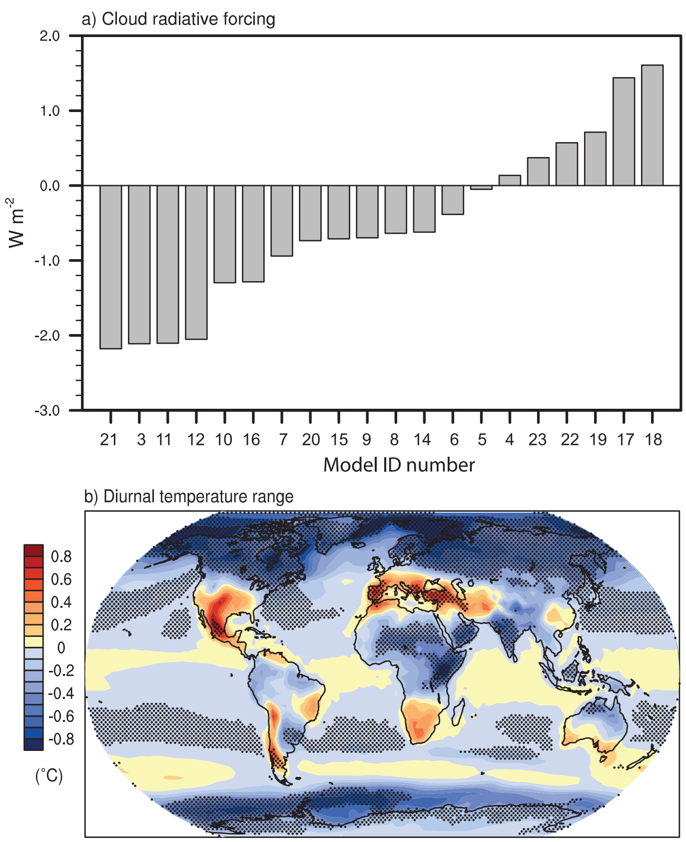


Figure 10.11. *Changes in (a) global mean cloud radiative forcing (W m^{-2}) from individual models (see Table 10.4 for the list of models) and (b) multi-model mean diurnal temperature range (°C). Changes are annual means for the SRES A1B scenario for the period 2080 to 2099 relative to 1980 to 1999. Stippling denotes areas where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation. Results for individual models can be seen in the Supplementary Material for this chapter.*

10.3.2.3 Precipitation and Surface Water

Models simulate that global mean precipitation increases with global warming. However, there are substantial spatial and seasonal variations in this field even in the multi-model means depicted in Figure 10.9. There are fewer areas stippled for precipitation than for the warming, indicating more variation in the magnitude of change among the ensemble of models. Increases in precipitation at high latitudes in both seasons are very consistent across models. The increases in precipitation over the tropical oceans and in some of the monsoon regimes (e.g., South Asian monsoon in JJA, Australian monsoon in DJF) are notable, and while not as consistent locally, considerable agreement is found at the broader scale in the tropics (Neelin et al., 2006). There are widespread decreases in mid-latitude summer precipitation, except for increases in eastern Asia. Decreases in precipitation over many subtropical areas are evident in the multi-model ensemble mean, and consistency in the sign of change among the models is often high (Wang, 2005), particularly in some regions like the tropical Central American-Caribbean (Neelin et al., 2006). Further discussion of regional changes is presented in Chapter 11.

The global map of the A1B 2080 to 2099 change in annual mean precipitation is shown in Figure 10.12, along with other hydrological quantities from the multi-model ensemble. Emori and Brown (2005) show percentage changes of annual precipitation from the ensemble. Increases of over 20% occur at most high latitudes, as well as in eastern Africa, central Asia and the equatorial Pacific Ocean. The change over the ocean between 10°S and 10°N accounts for about half the increase in the global mean (Figure 10.5). Substantial decreases, reaching 20%, occur in the Mediterranean region (Rowell and Jones, 2006), the Caribbean region (Neelin et al., 2006) and the subtropical western coasts of each continent. Overall, precipitation over land increases by about 5%, while precipitation over ocean increases 4%, but with regional changes of both signs. The net change over land accounts for 24% of the global mean increase in precipitation, a little less than the areal proportion of land (29%). In Figure 10.12, stippling indicates that the sign of the

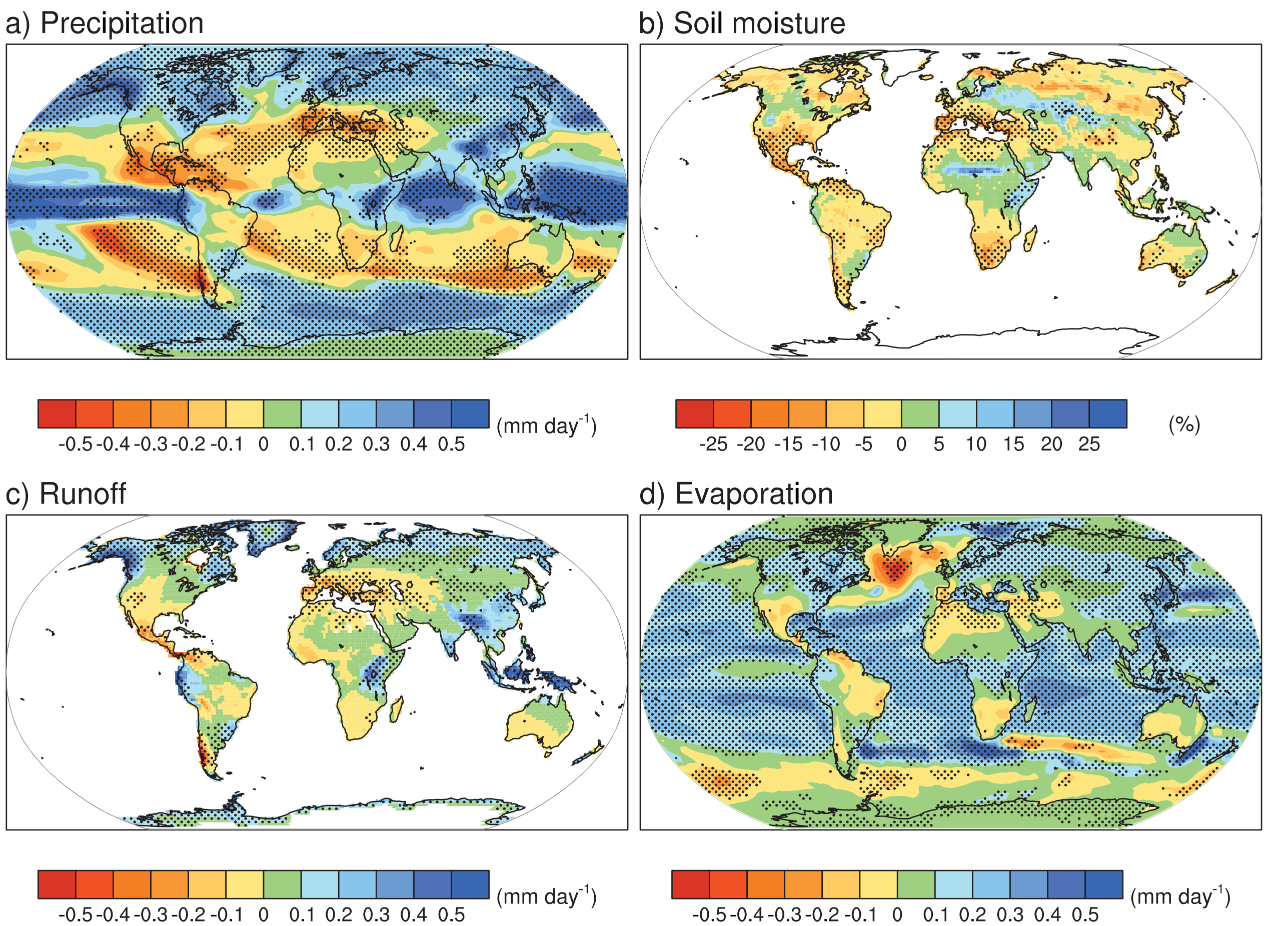


Figure 10.12. *Multi-model mean changes in (a) precipitation (mm day^{-1}), (b) soil moisture content (%), (c) runoff (mm day^{-1}) and (d) evaporation (mm day^{-1}). To indicate consistency in the sign of change, regions are stippled where at least 80% of models agree on the sign of the mean change. Changes are annual means for the SRES A1B scenario for the period 2080 to 2099 relative to 1980 to 1999. Soil moisture and runoff changes are shown at land points with valid data from at least 10 models. Details of the method and results for individual models can be found in the Supplementary Material for this chapter.*

local change is common to at least 80% of the models (with the alternative test shown in the Supplementary Material). This simpler test for consistency is of particular interest for quantities where the magnitudes for the base climate vary across models.

These patterns of change occur in the other scenarios, although with agreement (by the metric M) a little lower than for the warming. The predominance of increases near the equator and at high latitudes, for both land and ocean, is clear from the zonal mean changes of precipitation included in Figure 10.6. The results for change scaled by global mean warming are rather similar across the four scenarios, an exception being a relatively large increase over the equatorial ocean for the commitment case. As with surface temperature, the A1B and B1 scaled values are always close to the A2 results. The zonal means of the percentage change map (shown in Figure 10.6) feature substantial decreases in the subtropics and lower mid-latitudes of both hemispheres in the A2 case, even if increases occur over some regions.

Wetherald and Manabe (2002) provide a good description of the mechanism of hydrological change simulated by GCMs. In GCMs, the global mean evaporation changes closely balance the precipitation change, but not locally because of changes in the atmospheric transport of water vapour. Annual average evaporation (Figure 10.12) increases over much of the ocean, with spatial variations tending to relate to those in the surface warming (Figure 10.8). As found by Kutzbach et al. (2005) and Bosilovich et al. (2005), atmospheric moisture convergence increases over the equatorial oceans and over high latitudes. Over land, rainfall changes tend to be balanced by both evaporation and runoff. Runoff (Figure 10.12) is notably reduced in southern Europe and increased in Southeast Asia and at high latitudes, where there is consistency among models in the sign of change (although less consistency in the magnitude of change). The larger changes reach 20% or more of the simulated 1980 to 1999 values, which range from 1 to 5 mm day^{-1} in wetter regions to below 0.2 mm day^{-1} in deserts. Runoff from the melting of ice sheets (Section 10.3.3) is not included here. Nohara et al. (2006) and Milly et al. (2005) assess the impacts of these changes in terms of river flow, and find that discharges from high-latitude rivers increase, while those from major rivers in the Middle East, Europe and Central America tend to decrease.

Models simulate the moisture in the upper few metres of the land surface in varying ways, and evaluation of the soil moisture content is still difficult (See Section 8.2.3.2; Wang, 2005; Gao and Dirmeyer, 2006 for multi-model analyses). The average of the total soil moisture content quantity submitted to the data set is presented here to indicate typical trends. In the annual mean (Figure 10.12), decreases are common in the subtropics and the Mediterranean region. There are increases in east Africa, central Asia, and some other regions with increased precipitation. Decreases also occur at high latitudes, where snow cover diminishes (Section 10.3.3). While the magnitudes of change are quite uncertain, there is good consistency in the signs of change in many of these regions. Similar patterns of change occur in seasonal results (Wang, 2005). Regional hydrological changes are considered in Chapter 11 and in the IPCC Working Group II report.

10.3.2.4 Sea Level Pressure and Atmospheric Circulation

As a basic component of the mean atmospheric circulations and weather patterns, projections of the mean sea level pressure for the medium scenario A1B are considered. Seasonal mean changes for DJF and JJA are shown in Figure 10.9 (matching results in Wang and Swail, 2006b). Sea level pressure differences show decreases at high latitudes in both seasons in both hemispheres. The compensating increases are predominantly over the mid-latitude and subtropical ocean regions, extending across South America, Australia and southern Asia in JJA, and the Mediterranean in DJF. Many of these increases are consistent across the models. This pattern of change, discussed further in Section 10.3.5.3, has been linked to an expansion of the Hadley Circulation and a poleward shift of the mid-latitude storm tracks (Yin, 2005). This helps explain, in part, the increases in precipitation at high latitudes and decreases in the subtropics and parts of the mid-latitudes. Further analysis of the regional details of these changes is given in Chapter 11. The pattern of pressure change implies increased westerly flows across the western parts of the continents. These contribute to increases in mean precipitation (Figure 10.9) and increased precipitation intensity (Meehl et al., 2005a).

10.3.3 Changes in Ocean/Ice and High-Latitude Climate

10.3.3.1 Changes in Sea Ice Cover

Models of the 21st century project that future warming is amplified at high latitudes resulting from positive feedbacks involving snow and sea ice, and other processes (Section 8.6.3.3). The warming is particularly large in autumn and early winter (Manabe and Stouffer, 1980; Holland and Bitz, 2003) when sea ice is thinnest and the snow depth is insufficient to blur the relationship between surface air temperature and sea ice thickness (Maykut and Untersteiner, 1971). As shown by Zhang and Walsh (2006), the coupled models show a range of responses in NH sea ice areal extent ranging from very little change to a strong and accelerating reduction over the 21st century (Figure 10.13a,b).

An important characteristic of the projected change is for summer ice area to decline far more rapidly than winter ice area (Gordon and O'Farrell, 1997), and hence sea ice rapidly approaches a seasonal ice cover in both hemispheres (Figures 10.13b and 10.14). Seasonal ice cover is, however, rather robust and persists to some extent throughout the 21st century in most (if not all) models. Bitz and Roe (2004) note that future projections show that arctic sea ice thins fastest where it is initially thickest, a characteristic that future climate projections share with sea ice thinning observed in the late 20th century (Rothrock et al., 1999). Consistent with these results, a projection by Gregory et al. (2002b) shows that arctic sea ice volume decreases more quickly than sea ice area (because trends in winter ice area are low) in the 21st century.

In 20th- and 21st-century simulations, antarctic sea ice cover is projected to decrease more slowly than in the Arctic (Figures 10.13c,d and 10.14), particularly in the vicinity of the Ross Sea where most models predict a local minimum in surface warming. This is commensurate with the region with the greatest reduction in ocean heat loss, which results from reduced vertical mixing in the ocean (Gregory, 2000). The ocean stores much of its increased heat below 1 km depth in the Southern Ocean. In contrast, horizontal heat transport poleward of about 60°N increases in many models (Holland and Bitz, 2003), but much of this heat remains in the upper 1 km of the northern subpolar seas and Arctic Ocean (Gregory, 2000; Bitz et al., 2006). Bitz et al. (2006) argue that these differences in the depth where heat is accumulating in the high-latitude oceans have consequences for the relative rates of sea ice decay in the Arctic and Antarctic.

While most climate models share these common characteristics (peak surface warming in autumn and early winter, sea ice rapidly becomes seasonal, arctic ice decays faster than antarctic ice, and northward ocean heat transport increases into the northern high latitudes), models have poor agreement on the amount of thinning of sea ice (Flato and Participating CMIP Modeling Groups, 2004; Arzel et al., 2006) and the overall climate change in the polar regions (IPCC, 2001; Holland and Bitz, 2003). Flato (2004) shows that the basic state of the sea ice and the reduction in thickness and/or extent have little to do with sea ice model physics among CMIP2 models. Holland and Bitz (2003) and Arzel et al. (2006) find serious biases in the basic state of simulated sea ice thickness and extent. Further, Rind et al. (1995), Holland and Bitz (2003) and Flato (2004) show that the basic state of the sea ice thickness and extent have a significant influence on the projected change in sea ice thickness in the Arctic and extent in the Antarctic.

10.3.3.2 Changes in Snow Cover and Frozen Ground

Snow cover is an integrated response to both temperature and precipitation and exhibits strong negative correlation with air temperature in most areas with a seasonal snow cover (see Section 8.6.3.3 for an evaluation of model-simulated

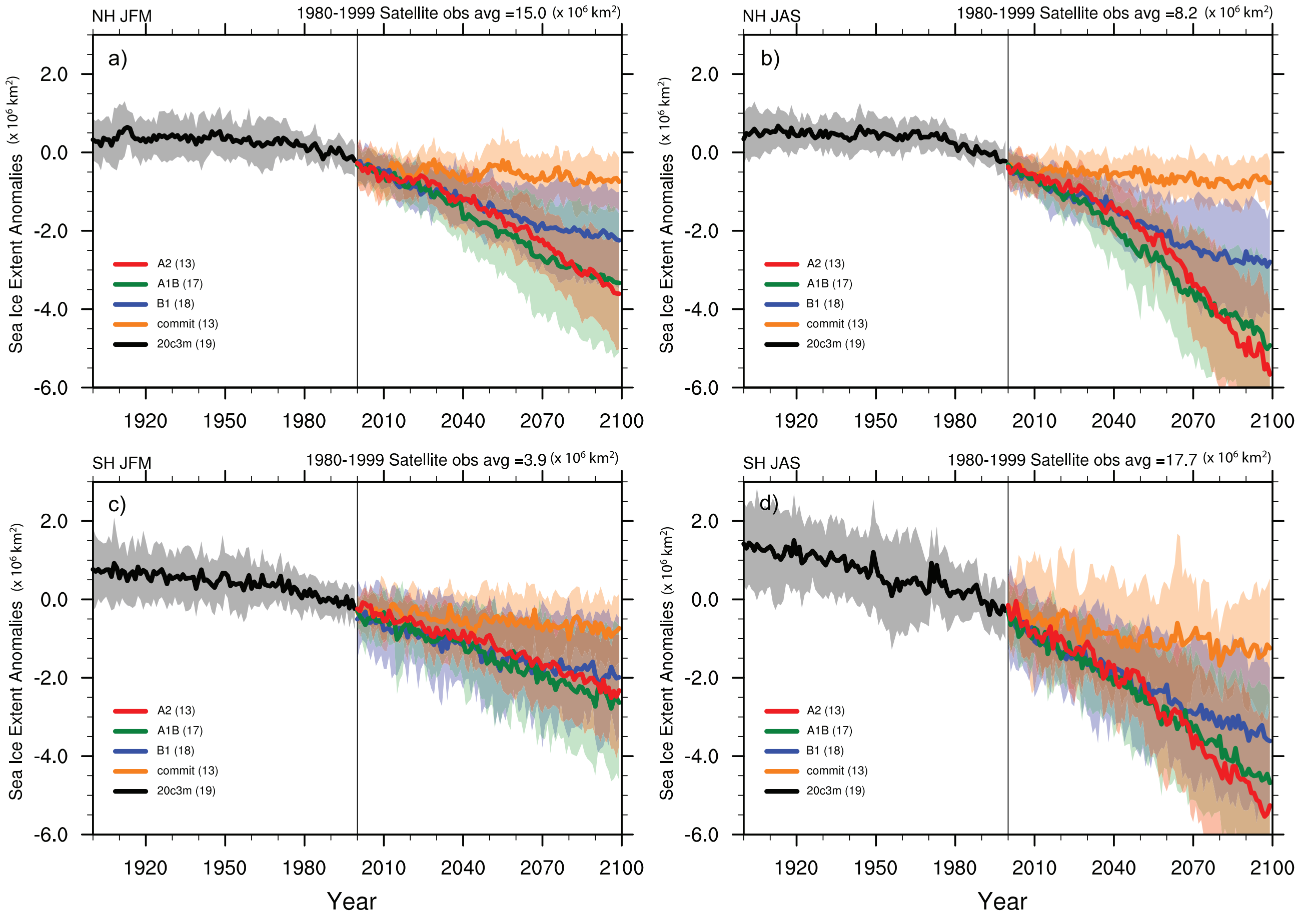


Figure 10.13. *Multi-model simulated anomalies in sea ice extent for the 20th century (20c3m) and 21st century using the SRES A2, A1B and B1 as well as the commitment scenario for (a) Northern Hemisphere January to March (JFM), (b) Northern Hemisphere July to September (JAS). Panels (c) and (d) are as for (a) and (b) but for the Southern Hemisphere. The solid lines show the multi-model mean, shaded areas denote ±1 standard deviation. Sea ice extent is defined as the total area where sea ice concentration exceeds 15%. Anomalies are relative to the period 1980 to 2000. The number of models is given in the legend and is different for each scenario.*

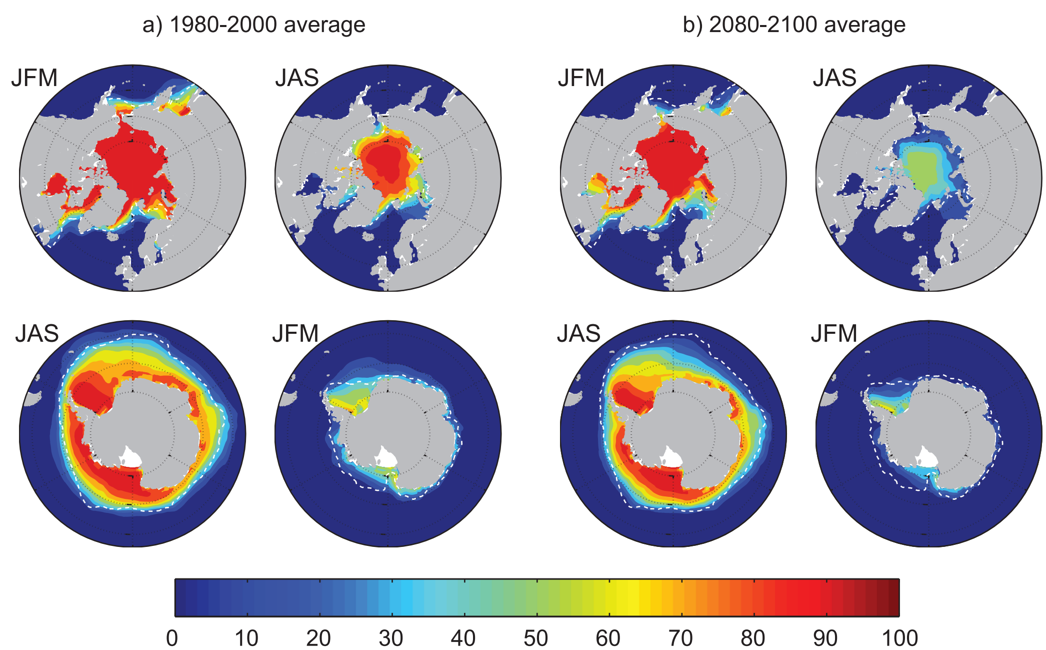


Figure 10.14. *Multi-model mean sea ice concentration (%) for January to March (JFM) and June to September (JAS), in the Arctic (top) and Antarctic (bottom) for the periods (a) 1980 to 2000 and b) 2080 to 2100 for the SRES A1B scenario. The dashed white line indicates the present-day 15% average sea ice concentration limit. Modified from Flato et al. (2004).*

present-day snow cover). Because of this temperature association, the simulations project widespread reductions in snow cover over the 21st century (Supplementary Material, Figure S10.1). For the Arctic Climate Impact Assessment (ACIA) model mean, at the end of the 21st century the projected reduction in the annual mean NH snow cover is 13% under the B2 scenario (ACIA, 2004). The individual model projections range from reductions of 9 to 17%. The actual reductions are greatest in spring and late autumn/early winter, indicating a shortened snow cover season (ACIA, 2004). The beginning of the snow accumulation season (the end of the snowmelt season) is projected to be later (earlier), and the fractional snow coverage is projected to decrease during the snow season (Hosaka et al., 2005).

Warming at high northern latitudes in climate model simulations is also associated with large increases in simulated thaw depth over much of the permafrost regions (Lawrence and Slater, 2005; Yamaguchi et al., 2005; Kitabata et al., 2006). Yamaguchi et al. (2005) show that initially soil moisture increases during the summer. In the late 21st century when the thaw depth has increased substantially, a reduction in summer soil moisture eventually occurs (Kitabata et al., 2006). Stendel and Christensen (2002) show poleward movement of permafrost extent, and a 30 to 40% increase in active layer thickness for most of the permafrost area in the NH, with the largest relative increases concentrated in the northernmost locations.

Regionally, the changes are a response to both increased temperature and increased precipitation (changes in circulation patterns) and are complicated by the competing effects of warming and increased snowfall in those regions that remain below freezing (see Section 4.2 for a further discussion of processes that affect snow cover). In general, snow amount and snow coverage decreases in the NH (Supplementary Material, Figure S10.1). However, in a few regions (e.g., Siberia), snow amount is projected to increase. This is attributed to the increase in precipitation (snowfall) from autumn to winter (Meleshko et al., 2004; Hosaka et al., 2005).

10.3.3.3 Changes in Greenland Ice Sheet Mass Balance

As noted in Section 10.6, modelling studies (e.g., Hanna et al., 2002; Kiilsholm et al., 2003; Wild et al., 2003) as well as satellite observations, airborne altimeter surveys and other studies (Abdalati et al., 2001; Thomas et al., 2001; Krabill et al., 2004; Johannessen et al., 2005; Zwally et al., 2005; Rignot and Kanagaratnam, 2006) suggest a slight inland thickening and strong marginal thinning resulting in an overall negative Greenland Ice Sheet mass balance which has accelerated recently (see Section 4.6.2.2.). A consistent feature of all climate models is that projected 21st-century warming is amplified in northern latitudes. This suggests continued melting of the Greenland Ice Sheet, since increased summer melting dominates over increased winter precipitation in model projections of future climate. Ridley et al. (2005) coupled UKMO-HadCM3 to an ice sheet model to explore the melting of the Greenland Ice Sheet under elevated (four times pre-industrial) levels of atmospheric CO_2 (see Section 10.7.4.3, Figure 10.38). While the entire Greenland Ice Sheet eventually completely ablated (after 3 kyr), the peak rate of melting was 0.06 Sv (1 Sv = 10^6 m^3 s^{-1}) corresponding to about 5.5 mm yr^{-1} global sea level rise (see Sections 10.3.4 and 10.6.6). Toniazzo et al. (2004) further show that in UKMO-HadCM3, the complete melting of the Greenland Ice sheet is an irreversible process even if pre-industrial levels of atmospheric CO_2 are re-established after it melts.

10.3.4 Changes in the Atlantic Meridional Overturning Circulation

A feature common to all climate model projections is the increase in high-latitude temperature as well as an increase in high-latitude precipitation. This was reported in the TAR and is confirmed by the projections using the latest versions of comprehensive climate models (see Section 10.3.2). Both of these effects tend to make the high-latitude surface waters less dense and hence increase their stability, thereby inhibiting convective processes. As more coupled models have become available since the TAR, the evolution of the Atlantic Meridional Overturning Circulation (MOC) can be more thoroughly assessed. Figure 10.15 shows simulations from 19 coupled models integrated from 1850 to 2100 under SRES A1B atmospheric CO_2 and aerosol scenarios up to year 2100, and constant concentrations thereafter (see Figure 10.5). All of the models, except CGCM3.1, INM-CM3.0 and MRI-CGCM2.3.2, were run without flux adjustments (see Table 8.1). The MOC is influenced by the density structure of the Atlantic Ocean, small-scale mixing and the surface momentum and buoyancy fluxes. Some models simulate a MOC strength that is inconsistent with the range of present-day estimates (Smethie and Fine, 2001; Ganachaud, 2003; Lumpkin and Speer, 2003; Talley, 2003). The MOC for these models is shown for completeness but is not used in assessing potential future changes in the MOC in response to various emissions scenarios.

Fewer studies have focused on projected changes in the Southern Ocean resulting from future climate warming. A common feature of coupled model simulations is the projected poleward shift and strengthening of the SH westerlies (Yin, 2005; Fyfe and Saenko, 2006). This in turn leads to a strengthening, poleward shift and narrowing of the Antarctic Circumpolar Current. Fyfe and Saenko (2006) further note that the enhanced equatorward surface Ekman transport, associated with the intensified westerlies, is balanced by an enhanced deep geostrophic poleward return flow below 2,000 m.

Generally, the simulated late-20th century Atlantic MOC shows a spread ranging from a weak MOC of about 12 Sv to over 20 Sv (Figure 10.15; Schmittner et al., 2005). When forced with the SRES A1B scenario, the models show a reduction in the MOC of up to 50% or more, but in one model, the changes are not distinguishable from the simulated natural variability. The reduction in the MOC proceeds on the time scale of the simulated warming because it is a direct response to the increase in buoyancy at the ocean surface. A positive North Atlantic Oscillation (NAO) trend might delay this response by a few decades but not prevent it (Delworth and Dixon, 2000). Such

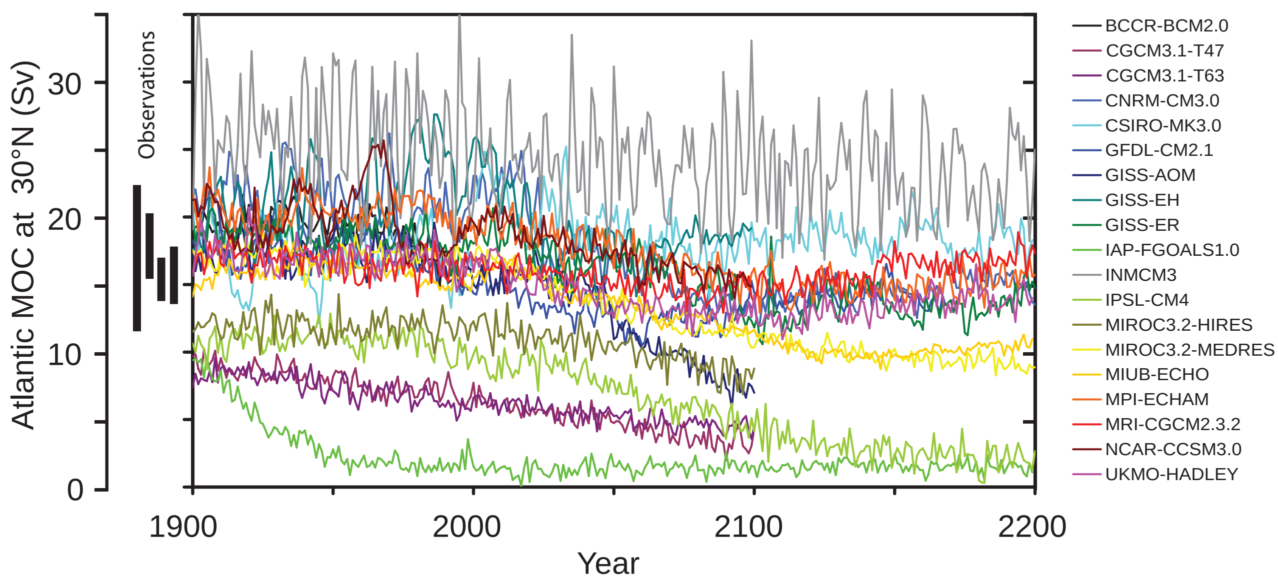


Figure 10.15. *Evolution of the Atlantic meridional overturning circulation (MOC) at 30°N in simulations with the suite of comprehensive coupled climate models (see Table 8.1 for model details) from 1850 to 2100 using 20th Century Climate in Coupled Models (20C3M) simulations for 1850 to 1999 and the SRES A1B emissions scenario for 1999 to 2100. Some of the models continue the integration to year 2200 with the forcing held constant at the values of year 2100. Observationally based estimates of late-20th century MOC are shown as vertical bars on the left. Three simulations show a steady or rapid slow down of the MOC that is unrelated to the forcing; a few others have late-20th century simulated values that are inconsistent with observational estimates. Of the model simulations consistent with the late-20th century observational estimates, no simulation shows an increase in the MOC during the 21st century; reductions range from indistinguishable within the simulated natural variability to over 50% relative to the 1960 to 1990 mean; and none of the models projects an abrupt transition to an off state of the MOC. Adapted from Schmittner et al. (2005) with additions.*

a weakening of the MOC in future climate causes reduced sea surface temperature (SST) and salinity in the region of the Gulf Stream and North Atlantic Current (Dai et al., 2005). This can produce a decrease in northward heat transport south of 60°N, but increased northward heat transport north of 60°N (A. Hu et al., 2004). No model shows an increase in the MOC in response to the increase in greenhouse gases, and no model simulates an abrupt shut-down of the MOC within the 21st century. One study suggests that inherent low-frequency variability in the Atlantic region, the Atlantic Multidecadal Oscillation, may produce a natural weakening of the MOC over the next few decades that could further accentuate the decrease due to anthropogenic climate change (Knight et al., 2005; see Section 8.4.6).

In some of the older models (e.g., Dixon et al., 1999), increased high-latitude precipitation dominates over increased high-latitude warming in causing the weakening, while in others (e.g., Mikolajewicz and Voss, 2000), the opposite is found. In a recent model intercomparison, Gregory et al. (2005) find that for all 11 models analysed, the MOC reduction is caused more by changes in surface heat flux than changes in surface freshwater flux. In addition, simulations using models of varying complexity (Stocker et al., 1992b; Saenko et al., 2003; Weaver et al., 2003) show that freshening or warming in the Southern Ocean acts to increase or stabilise the Atlantic MOC. This is likely a consequence of the complex coupling of Southern Ocean processes with North Atlantic Deep Water production.

A few simulations using coupled models are available that permit the assessment of the long-term stability of the MOC (Stouffer and Manabe, 1999; Voss and Mikolajewicz, 2001; Stouffer and Manabe, 2003; Wood et al., 2003; Yoshida et al., 2005; Bryan et al., 2006). Most of these simulations assume an idealised increase in atmospheric CO_2 by 1% yr^{-1} to various levels ranging from two to four times pre-industrial levels. One study also considers slower increases (Stouffer and Manabe, 1999), or a reduction in CO_2 (Stouffer and Manabe, 2003). The more recent models are not flux adjusted and have higher resolution (about 1.0°) (Yoshida et al., 2005; Bryan et al., 2006). A common feature of all simulations is a reduction in the MOC in response to the warming and a stabilisation or recovery of the MOC when the concentration is kept constant after achieving a level of two to four times the pre-industrial atmospheric CO_2 concentration. None of these models shows a shutdown of the MOC that continues after the forcing is kept constant. But such a long-term shutdown cannot be excluded if the amount of warming and its rate exceed certain thresholds as shown using an EMIC (Stocker and Schmittner, 1997). Complete shut-downs, although not permanent, were also simulated by a flux-adjusted coupled model (Manabe and Stouffer, 1994; Stouffer and Manabe, 2003; see also Chan and Motoi, 2005). In none of these AOGCM simulations were the thresholds, as determined by the EMIC, passed (Stocker and Schmittner, 1997). As such, the long-term stability of the MOC found in the present AOGCM simulations is consistent with the results from the simpler models.

The reduction in MOC strength associated with increasing greenhouse gases represents a negative feedback for the warming in and around the North Atlantic. That is, through reducing the transport of heat from low to high latitudes, SSTs are cooler than they would otherwise be if the MOC was unchanged. As such, warming is reduced over and downstream of the North Atlantic. It is important to note that in models where the MOC weakens, warming still occurs downstream over Europe due to the overall dominant role of the radiative forcing associated with increasing greenhouse gases (Gregory et al., 2005). Many future projections show that once the radiative forcing is held fixed, re-establishment of the MOC occurs to a state similar to that of the present day. The partial or complete re-establishment of the MOC is slow and causes additional warming in and around the North Atlantic. While the oceanic meridional heat flux at low latitudes is reduced upon a slowdown of the MOC, many simulations show increasing meridional heat flux into the Arctic which contributes to accelerated warming and sea ice melting there. This is due to both the advection of warmer water and an intensification of the influx of North Atlantic water into the Arctic (A. Hu et al., 2004).

Climate models that simulated a complete shutdown of the MOC in response to sustained warming were flux-adjusted coupled GCMs or EMICs. A robust result from such simulations is that the shutdown of the MOC takes several centuries after the forcing is kept fixed (e.g., at 4 × atmospheric CO_2 concentration). Besides the forcing amplitude and rate (Stocker and Schmittner, 1997), the amount of mixing in the ocean also appears to determine the stability of the MOC: increased vertical and horizontal mixing tends to stabilise the MOC and to eliminate the possibility of a second equilibrium state (Manabe and Stouffer, 1999; Knutti and Stocker, 2000; Longworth et al., 2005). Random internal variability or noise, often not present in simpler models, may also be important in determining the effective MOC stability (Knutti and Stocker, 2002; Monahan, 2002).

The MOC is not necessarily a comprehensive indicator of ocean circulation changes in response to global warming. In a transient 2 × atmospheric CO_2 experiment using a coupled AOGCM, the MOC changes were small, but convection in the Labrador Sea stopped due to warmer and hence less dense waters that inflow from the Greenland-Iceland-Norwegian Sea (GIN Sea) (Wood et al., 1999; Stouffer et al., 2006a). Similar results were found by A. Hu et al. (2004), who also report an increase in convection in the GIN Sea due to the influx of more saline waters from the North Atlantic. Various simulations using coupled models of different complexity find significant reductions in convection in the GIN Sea in response to warming (Schaeffer et al., 2004; Bryan et al., 2006). Presumably, a delicate balance exists in the GIN Sea between the circum-arctic river runoff, sea ice production and advection of saline waters from the North Atlantic, and on a longer time scale, the inflow of freshwater through Bering Strait. The projected increases in circum-arctic river runoff (Wu et al., 2005) may enhance the tendency towards a reduction in GIN Sea convection (Stocker and Raible, 2005; Wu et al., 2005). Cessation of convection in the Labrador Sea in the next few decades is also simulated in a high-resolution model of the Atlantic Ocean driven by surface fluxes from two AOGCMs (Schweckendiek and Willebrand, 2005). The large-scale responses of the high-resolution ocean model (e.g., MOC, Labrador Seas) agree with those from the AOGCMs. The grid resolution of the ocean components in the coupled AOGCMs has significantly increased since the TAR, and some consistent patterns of changes in convection and water mass properties in the Atlantic Ocean emerge in response to the warming, but models still show a variety of responses in the details.

The best estimate of sea level from 1993 to 2003 (see Section 5.5.5.2) associated with the slight net negative mass balance from Greenland is 0.1 to 0.3 mm yr^{-1} over the total ocean surface. This converts to only about 0.002 to 0.003 Sv of freshwater forcing. Such an amount, even when added directly and exclusively to the North Atlantic, has been suggested to be too small to affect the North Atlantic MOC (see Weaver and Hillaire-Marcel, 2004a). While one model exhibits a MOC weakening in the later part of the 21st century due to Greenland Ice Sheet melting (Fichefet et al., 2003), this same model had a very large downward drift of its overturning in the control climate, making it difficult to actually attribute the model MOC changes to the ice sheet melting. As noted in Section 10.3.3.3, Ridley et al. (2005) find the peak rate of Greenland Ice Sheet melting is about 0.1 Sv when they instantaneously elevate greenhouse gas levels in UKMO-HadCM3. They further note that this has little effect on the North Atlantic meridional overturning, although 0.1 Sv is sufficiently large to cause more dramatic transient changes in the strength of the MOC in other models (Stouffer et al., 2006b).

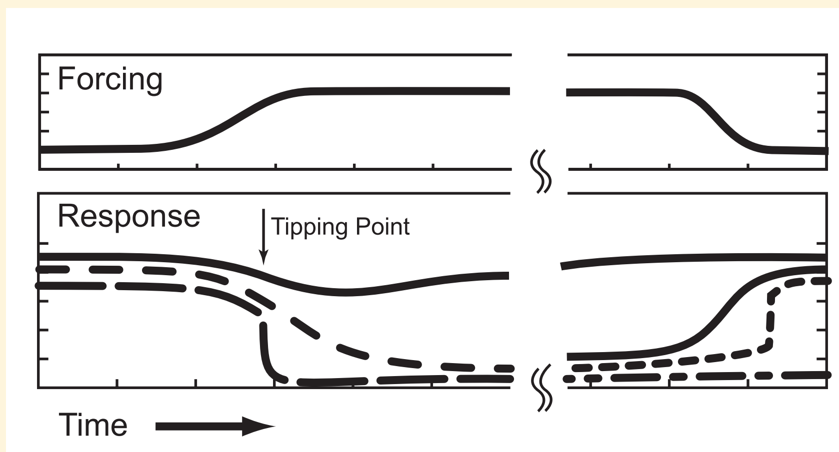
Taken together, it is very likely that the MOC, based on currently available simulations, will decrease, perhaps associated with a significant reduction in Labrador Sea Water formation, but very unlikely that the MOC will undergo an abrupt transition during the course of the 21st century. At this stage, it is too early to assess the likelihood of an abrupt change of the MOC beyond the end of the 21st century, but the possibility cannot be excluded (see Box 10.1). The few available simulations with models of different complexity instead suggest a centennial slowdown. Recovery of the MOC is simulated in some models if the radiative forcing is stabilised but would take several centuries; in other models, the reduction persists.

Box 10.1: Future Abrupt Climate Change, 'Climate Surprises', and Irreversible Changes

Theory, models and palaeoclimatic reconstructions (see Chapter 6) have established the fact that changes in the climate system can be abrupt and widespread. A working definition of 'abrupt climate change' is given in Alley et al. (2002): 'Technically, an abrupt climate change occurs when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause'. More generally, a gradual change in some determining quantity of the climate system (e.g., radiation balance, land surface properties, sea ice, etc.) can cause a variety of structurally different responses (Box 10.1, Figure 1). The response of a purely linear system scales with the forcing, and at stabilisation of the forcing, a new equilibrium is achieved which is structurally similar, but not necessarily close to the original state. However, if the system contains more than one equilibrium state, transitions to structurally different states are possible. Upon the crossing of a tipping point (bifurcation point), the evolution of the system is no longer controlled by the time scale of the forcing, but rather determined by its internal dynamics, which can either be much faster than the forcing, or significantly slower. Only the former case would be termed 'abrupt climate change', but the latter case is of equal importance. For the long-term evolution of a climate variable one must distinguish between reversible and irreversible changes. The notion of 'climate surprises' usually refers to abrupt transitions and temporary or permanent transitions to a different state in parts of the climate system such as, for example, the 8.2 kyr event (see Section 6.5.2.1).

Atlantic Meridional Overturning Circulation and other ocean circulation changes:

The best-documented type of abrupt climate change in the palaeoclimatic archives is that associated with changes in the ocean circulation (Stocker, 2000). Since the TAR, many new results from climate models of different complexity have provided a more detailed view on the anticipated changes in the Atlantic MOC in response to global warming. Most models agree that the MOC weakens over the next 100 years and that this reduction ranges from indistinguishable from natural variability to over 50% by 2100 (Figure 10.15). None of the AOGCM simulations shows an abrupt change when forced with the SRES emissions scenarios until 2100, but some long-term model simulations suggest that a complete cessation can result for large forcings (Stouffer and Manabe, 2003). Models of intermediate complexity indicate that thresholds in the MOC may be present but that they depend on the amount and rate of warming for a given model (Stocker and Schmittner, 1997). The few long-term simulations from AOGCMs indicate that even complete shutdowns of the MOC may be reversible (Stouffer and Manabe, 2003; Yoshida et al., 2005; Stouffer et al., 2006b). However, until millennial simulations with AOGCMs are available, the important question of potential irreversibility of an MOC shutdown remains unanswered. Both simplified models and AOGCMs agree, however, that a potentially complete shut-down of the MOC, induced by global warming, would take many decades to more than a century. There is no direct model evidence that the MOC could collapse within a few decades in response to global warming. However, a few studies do show the potential for rapid changes in the MOC (Manabe and Stouffer, 1999), and the processes concerned are poorly understood (see Section 8.7). This is not inconsistent with the palaeoclimate records. The cooling events during the last ice ages registered in the Greenland ice cores developed over a couple of centuries to millennia. In contrast, there were also a number of very rapid warmings, the so-called Dansgaard-Oeschger events (NorthGRIP Members, 2004), or rapid cooling (LeGrande et al., 2006), which evolved over decades or less, most probably associated with rapid latitudinal shifts in ocean convection sites and changes in strength of the MOC (see Section 6.3.2).



Box 10.1, Figure 1. *Schematic illustration of various responses of a climate variable to forcing. The forcing (top panels) reaches a new stable level (left part of figure), and later approaches the original level on very long time scales (right part of the figure). The response of the climate variable (bottom panels) can be smooth (solid line) or cross a tipping point inducing a transition to a structurally different state (dashed lines). That transition can be rapid (abrupt change, long-dashed), or gradual (short-dashed), but is usually dictated by the internal dynamics of the climate system rather than the forcing. The long-term behaviour (right part) also exhibits different possibilities. Changes can be irreversible (dash-dotted) with the system settling at a different stable state, or reversible (solid, dotted) when the forcing is set back to its original value. In the latter case, the transition again can be gradual or abrupt. An example for illustration, but not the only one, is the response of the Atlantic meridional overturning circulation to a gradual change in radiative forcing.*

(continued)

Recent simulations with models with ocean components that resolve topography in sufficient detail obtain a consistent pattern of a strong to complete reduction of convection in the Labrador Sea (Wood et al., 1999; Schweckendiek and Willebrand, 2005). Such changes in the convection, with implications for the atmospheric circulation, can develop within a few years (Schaeffer et al., 2002). The long-term and regional-to-hemispheric scale effects of such changes in water mass properties have not yet been investigated.

With a reduction in the MOC, the meridional heat flux also decreases in the subtropical and mid-latitudes with large-scale effects on the atmospheric circulation. In consequence, the warming of the North Atlantic surface proceeds more slowly. Even for strong reductions in MOC towards the end of the 21st century, no cooling is observed in the regions around the North Atlantic because it is overcompensated by the radiative forcing that caused the ocean response in the first place.

At high latitudes, an increase in the oceanic meridional heat flux is simulated by these models. This increase is due to both an increase in the overturning circulation in the Arctic and the advection of warmer waters from lower latitudes and thus contributes significantly to continuing sea ice reduction in the Atlantic sector of the Arctic (A. Hu et al., 2004). Few simulations have also addressed the changes in overturning in the South Atlantic and Southern Ocean. In addition to water mass modifications, this also has an effect on the transport by the Antarctic Circumpolar Current, but results are not yet conclusive.

Current understanding of the processes responsible for the initiation of an ice age indicate that a reduction or collapse of the MOC in response to global warming could not start an ice age (Berger and Loutre, 2002; Crucifix and Loutre, 2002; Yoshimori et al., 2002; Weaver and Hillaire-Marcel, 2004b).

Arctic sea ice:

Arctic sea ice is responding sensitively to global warming. While changes in winter sea ice cover are moderate, late summer sea ice is projected to disappear almost completely towards the end of the 21st century. A number of positive feedbacks in the climate system accelerate the melt back of sea ice. The ice-albedo feedback allows open water to receive more heat from the Sun during summer, and the increase in ocean heat transport to the Arctic through the advection of warmer waters and stronger circulation further reduces ice cover. Minimum arctic sea ice cover is observed in September. Model simulations indicate that the September sea ice cover decreases substantially in response to global warming, generally evolving on the time scale of the warming. With sustained warming, the late summer disappearance of a major fraction of arctic sea ice is permanent.

Glaciers and ice caps:

Glaciers and ice caps are sensitive to changes in temperature and precipitation. Observations point to a reduction in volume over the last 20 years (see Section 4.5.2), with a rate during 1993 to 2003 corresponding to 0.77 ± 0.22 mm yr^{-1} sea level equivalent, with a larger mean central estimate than that for 1961 to 1998 (corresponding to 0.50 ± 0.18 mm yr^{-1} sea level equivalent). Rapid changes are therefore already underway and enhanced by positive feedbacks associated with the surface energy balance of shrinking glaciers and newly exposed land surface in periglacial areas. Acceleration of glacier loss over the next few decades is likely (see Section 10.6.3). Based on simulations of 11 glaciers in various regions, a volume loss of 60% of these glaciers is projected by the year 2050 (Schneeberger et al., 2003). Glaciated areas in the Americas are also affected. A comparative study including seven GCM simulations at 2 × atmospheric CO_2 conditions inferred that many glaciers may disappear completely due to an increase in the equilibrium line altitude (Bradley et al., 2004). The disappearance of these ice bodies is much faster than a potential re-glaciation several centuries hence, and may in some areas be irreversible.

Greenland and West Antarctic Ice Sheets:

Satellite and *in situ* measurement networks have demonstrated increasing melting and accelerated ice flow around the periphery of the Greenland Ice Sheet (GIS) over the past 25 years (see Section 4.6.2). The few simulations of long-term ice sheet simulations suggest that the GIS will significantly decrease in volume and area over the coming centuries if a warmer climate is maintained (Gregory et al., 2004a; Huybrechts et al., 2004; Ridley et al., 2005). A threshold of annual mean warming of 1.9°C to 4.6°C in Greenland has been estimated for elimination of the GIS (Gregory and Huybrechts, 2006; see section 10.7.3.3), a process which would take many centuries to complete. Even if temperatures were to decrease later, the reduction of the GIS to a much smaller extent might be irreversible, because the climate of an ice-free Greenland could be too warm for accumulation; however, this result is model dependent (see Section 10.7.3.3). The positive feedbacks involved here are that once the ice sheet gets thinner, temperatures in the accumulation region are higher, increasing the melting and causing more precipitation to fall as rain rather than snow; that the lower albedo of the exposed ice-free land causes a local climatic warming; and that surface melt water might accelerate ice flow (see Section 10.6.4.2).

A collapse of the West Antarctic Ice Sheet (WAIS) has been discussed as a potential response to global warming for many years (Bindschadler, 1998; Oppenheimer, 1998; Vaughan, 2007). A complete collapse would cause a global sea level rise of about 5 m. The observed acceleration of ice streams in the Amundsen Sea sector of the WAIS, the rapidity of propagation of this signal upstream and the acceleration of glaciers that fed the Larsen B Ice Shelf after its collapse have renewed these concerns (see Section 10.6.4.2).

(continued)

It is possible that the presence of ice shelves tends to stabilise the ice sheet, at least regionally. Therefore, a weakening or collapse of ice shelves, caused by melting on the surface or by melting at the bottom by a warmer ocean, might contribute to a potential destabilisation of the WAIS, which could proceed through the positive feedback of grounding-line retreat. Present understanding is insufficient for prediction of the possible speed or extent of such a collapse (see Box 4.1 and Section 10.7.3.4).

Vegetation cover:

Irreversible and relatively rapid changes in vegetation cover and composition have occurred frequently in the past. The most prominent example is the desertification of the Sahara region about 4 to 6 ka (Claussen et al., 1999). The reason for this behaviour is believed to lie in the limits of plant communities with respect to temperature and precipitation. Once critical levels are crossed, certain species can no longer compete within their ecosystem. Areas close to vegetation boundaries will experience particularly large and rapid changes due to the slow migration of these boundaries induced by global warming. A climate model simulation into the future shows that drying and warming in South America leads to a continuous reduction in the forest of Amazonia (Cox et al., 2000, 2004). While evolving continuously over the 21st century, such a change and ultimate disappearance could be irreversible, although this result could be model dependent since an analysis of 11 AOGCMs shows a wide range of future possible rainfall changes over the Amazon (Li et al., 2006).

One of the possible 'climate surprises' concerns the role of the soil in the global carbon cycle. As the concentration of CO_2 is increasing, the soil is acting, in the global mean, as a carbon sink by assimilating carbon due to accelerated growth of the terrestrial biosphere (see also Section 7.3.3.1.1). However, by about 2050, a model simulation suggests that the soil changes to a source of carbon by releasing previously accumulated carbon due to increased respiration (Cox et al., 2000) induced by increasing temperature and precipitation. This represents a positive feedback to the increase in atmospheric CO_2. While different models agree regarding the sign of the feedback, large uncertainties exist regarding the strength (Cox et al., 2000; Dufresne et al., 2002; Friedlingstein et al., 2006). However, the respiration increase is caused by a warmer and wetter climate. The switch from moderate sink to strong source of atmospheric carbon is rather rapid and occurs within two decades (Cox et al., 2004), but the timing of the onset is uncertain (Huntingford et al., 2004). A model intercomparison reveals that once set in motion, the increase in respiration continues even after the CO_2 levels are held constant (Cramer et al., 2001). Although considerable uncertainties still exist, it is clear that feedback mechanisms between the terrestrial biosphere and the physical climate system exist which can qualitatively and quantitatively alter the response to an increase in radiative forcing.

Atmospheric and ocean-atmosphere regimes:

Changes in weather patterns and regimes can be abrupt processes that might occur spontaneously due to dynamical interactions in the atmosphere-ice-ocean system, or manifest as the crossing of a threshold in the system due to slow external forcing. Such shifts have been reported in SST in the tropical Pacific, leading to a more positive ENSO phase (Trenberth, 1990), in the stratospheric polar vortex (Christiansen, 2003), in a shut-down of deep convection in the Greenland Sea (Bönisch et al., 1997; Ronski and Budeus, 2005) and in an abrupt freshening of the Labrador Sea (Dickson et al., 2002). In the latter, the freshening evolved throughout the entire depth but the shift in salinity was particularly rapid: the 34.87 psu isohaline plunged from seasonally surface to 1,600 metres within 2 years with no return since 1973.

In a long, unforced model simulation, a period of a few decades with anomalously cold temperatures (up to 10 standard deviations below average) in the region south of Greenland was found (Hall and Stouffer, 2001). It was caused by persistent winds that changed the stratification of the ocean and inhibited convection, thereby reducing heat transfer from the ocean to the atmosphere. Similar results were found in a different model in which the major convection site in the North Atlantic spontaneously switched to a more southerly location for several decades to centuries (Goosse et al., 2002). Other simulations show that the slowly increasing radiative forcing is able to cause transitions in the convective activity in the Greenland-Iceland-Norwegian Sea that have an influence on the atmospheric circulation over Greenland and Western Europe (Schaeffer et al., 2002). The changes unfold within a few years and indicate that the system has crossed a threshold.

A multi-model analysis of regimes of polar variability (NAO, Arctic and Antarctic Oscillations) reveals that the simulated trends in the 21st century influence the Arctic and Antarctic Oscillations and point towards more zonal circulation (Rauthe et al., 2004). Temperature changes associated with changes in atmospheric circulation regimes such as the NAO can exceed in certain regions (e.g., Northern Europe) the long-term global warming that causes such inter-decadal regime shifts (Dorn et al., 2003).

10.3.5 Changes in Properties of Modes of Variability

10.3.5.1 Interannual Variability in Surface Air Temperature and Precipitation

Future changes in anthropogenic forcing will result not only in changes in the mean climate state but also in the variability of climate. Addressing the interannual variability in monthly mean surface air temperature and precipitation of 19 AOGCMs in CMIP2, Räisänen (2002) finds a decrease in temperature variability during the cold season in the extratropical NH and a slight increase in temperature variability in low latitudes and in warm season northern mid-latitudes. The former is likely due to the decrease of sea ice and snow with increasing temperature. The summer decrease in soil moisture over the mid-latitude land surfaces contributes to the latter. Räisänen (2002) also finds an increase in monthly mean precipitation variability in most areas, both in absolute value (standard deviation) and in relative value (coefficient of variation). However, the significance level of these variability changes is markedly lower than that for time mean climate change. Similar results were obtained from 18 AOGCM simulations under the SRES A2 scenario (Giorgi and Bi, 2005).

10.3.5.2 Monsoons

In the tropics, an increase in precipitation is projected by the end of the 21st century in the Asian monsoon and the southern part of the West African monsoon with some decreases in the Sahel in northern summer (Cook and Vizy, 2006), as well as increases in the Australian monsoon in southern summer in a warmer climate (Figure 10.9). The monsoonal precipitation in Mexico and Central America is projected to decrease in association with increasing precipitation over the eastern equatorial Pacific that affects Walker Circulation and local Hadley Circulation changes (Figure 10.9). A more detailed assessment of regional monsoon changes is provided in Chapter 11.

As a projected global warming will be more rapid over land than over the oceans, the continental-scale land-sea thermal contrast will become larger in summer and smaller in winter. Based on this, a simple idea is that the summer monsoon will be stronger and the winter monsoon will be weaker in the future than the present. However, model results are not as straightforward as this simple consideration. Tanaka et al. (2005) define the intensities of Hadley, Walker and monsoon circulations using the velocity potential fields at 200 hPa. Using 15 AOGCMs, they show a weakening of these tropical circulations by 9%, 8% and 14%, respectively, by the late 21st century compared to the late 20th century. Using eight AOGCMs, Ueda et al. (2006) demonstrate that pronounced warming over the tropics results in a weakening of the Asian summer monsoon circulations in relation to a reduction in the meridional thermal gradients between the Asian continent and adjacent oceans.

Despite weakening of the dynamical monsoon circulation, atmospheric moisture buildup due to increased greenhouse gases and consequent temperature increase results in a larger moisture flux and more precipitation for the Indian monsoon (Douville et al., 2000; IPCC, 2001; Ashrit et al., 2003; Meehl and Arblaster, 2003; May, 2004; Ashrit et al., 2005). For the South Asian summer monsoon, models suggest a northward shift of lower-tropospheric monsoon wind systems with a weakening of the westerly flow over the northern Indian Ocean (Ashrit et al., 2003, 2005). Over Africa in northern summer, multi-model analysis projects an increase in rainfall in East and Central Africa, a decrease in the Sahel, and increases along the Gulf of Guinea coast (Figure 10.9). However, some individual models project an increase of rainfall in more extensive areas of West Africa related to a projected northward movement of the Sahara and the Sahel (Liu et al., 2002; Haarsma et al., 2005). Whether the Sahel will be more or less wet in the future is thus uncertain, although a multi-model assessment of the West African monsoon indicates that the Sahel could become marginally more dry (Cook and Vizy, 2006). This inconsistency of the rainfall projections may be related to AOGCM biases, or an unclear relationship between Gulf of Guinea and Indian Ocean warming, land use change and the West African monsoon. Nonlinear feedbacks that may exist within the West African climate system should also be considered (Jenkins et al., 2005).

Most model results project increased interannual variability in season-averaged Asian monsoon precipitation associated with an increase in its long-term mean value (e.g., Hu et al., 2000b; Räisänen, 2002; Meehl and Arblaster, 2003). Hu et al. (2000a) relate this to increased variability in the tropical Pacific SST (El Niño variability) in their model. Meehl and Arblaster (2003) relate the increased monsoon precipitation variability to increased variability in evaporation and precipitation in the Pacific due to increased SSTs. Thus, the South Asian monsoon variability is affected through the Walker Circulation such that the role of the Pacific Ocean dominates and that of the Indian Ocean is secondary.

Atmospheric aerosol loading affects regional climate and its future changes (see Chapter 7). If the direct effect of the aerosol increase is considered, surface temperatures will not get as warm because the aerosols reflect solar radiation. For this reason, land-sea temperature contrast becomes smaller than in the case without the direct aerosol effect, and the summer monsoon becomes weaker. Model simulations of the Asian monsoon project that the sulphate aerosols' direct effect reduces the magnitude of precipitation change compared with the case of only greenhouse gas increases (Emori et al., 1999; Roeckner et al., 1999; Lal and Singh, 2001). However, the relative cooling effect of sulphate aerosols is dominated by the effects of increasing greenhouse gases by the end of the 21st century in the SRES marker scenarios (Figure 10.26), leading to the increased monsoon precipitation at the end of the 21st century in these scenarios (see Section 10.3.2.3). Furthermore, it is suggested that aerosols with high absorptivity such as black carbon absorb solar radiation in the lower atmosphere, cool the surface, stabilise the atmosphere and reduce precipitation (Ramanathan et al., 2001). The solar radiation reaching the surface decreases as much as 50% locally, which could reduce the surface warming by greenhouse gases (Ramanathan et al., 2005). These atmospheric brown clouds could cause precipitation to increase over the Indian Ocean in winter and decrease in the surrounding Indonesia region and the western Pacific Ocean (Chung et al., 2002), and could reduce the summer monsoon precipitation in South and East Asia (Menon et al., 2002; Ramanathan et al., 2005). However, the total influence on monsoon precipitation of temporally varying direct and indirect effects of various aerosol species is still not resolved and the subject of active research.

10.3.5.3 Mean Tropical Pacific Climate Change

This subsection assesses changes in mean tropical Pacific climate. Enhanced greenhouse gas concentrations result in a general increase in SST, which will not be spatially uniform in association with a general reduction in tropical circulations in a warmer climate (see Section 10.3.5.2). Figures 10.8 and 10.9 indicate that SST increases more over the eastern tropical Pacific than over the western tropical Pacific, together with a decrease in the sea level pressure (SLP) gradient along the equator and an eastward shift of the tropical Pacific rainfall distribution. These background tropical Pacific changes can be called an El Niño-like mean state change (upon which individual El Niño-Southern Oscillation (ENSO) events occur). Although individual models show a large scatter of 'ENSO-ness' (Collins and The CMIP Modelling Groups, 2005; Yamaguchi and Noda, 2006), an ENSO-like global warming pattern with positive polarity (i.e., El Niño-like mean state change) is simulated based on the spatial anomaly patterns of SST, SLP and precipitation (Figure 10.16; Yamaguchi and Noda, 2006). The El Niño-like change may be attributable to the general reduction in tropical circulations resulting from the increased dry static stability in the tropics in a warmer climate (Knutson and Manabe, 1995; Sugi et al., 2002; Figure 10.7). An eastward displacement of precipitation in the tropical Pacific accompanies an intensified and south-westward displaced subtropical anticyclone in the western Pacific, which can be effective in transporting moisture from the low latitudes to the Meiyu/Baiu region, thus generating more precipitation in the East Asian summer monsoon (Kitoh and Uchiyama, 2006).

In summary, the multi-model mean projects a weak shift towards conditions which may be described as 'El Niño-like', with SSTs in the central and eastern equatorial Pacific warming more than those in the west, and with an eastward shift in mean precipitation, associated with weaker tropical circulations.

10.3.5.4 El Niño

This subsection addresses the projected change in the amplitude, frequency and spatial pattern of El Niño. Guilyardi (2006) assessed mean state, coupling strength and modes (SST mode resulting from local SST-wind interaction or thermocline mode resulting from remote wind-thermocline feedbacks), using the pre-industrial control and stabilised 2 × and 4 × atmospheric

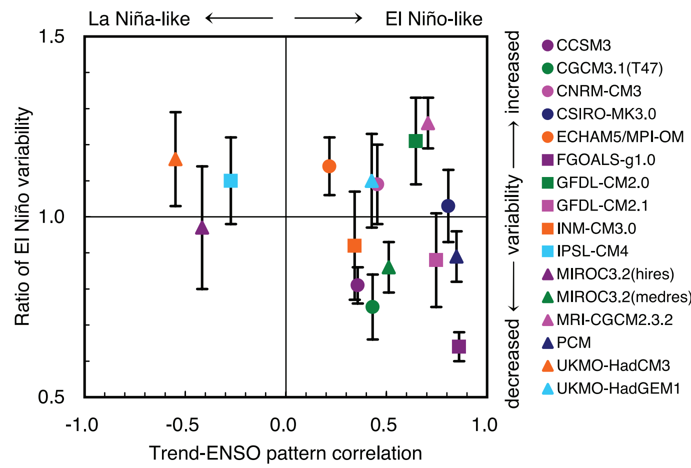


Figure 10.16. *Base state change in average tropical Pacific SSTs and change in El Niño variability simulated by AOGCMs (see Table 8.1 for model details). The base state change (horizontal axis) is denoted by the spatial anomaly pattern correlation coefficient between the linear trend of SST in the 1% yr^{-1} CO_2 increase climate change experiment and the first Empirical Orthogonal Function (EOF) of SST in the control experiment over the area 10°S to 10°N, 120°E to 80°W (reproduced from Yamaguchi and Noda, 2006). Positive correlation values indicate that the mean climate change has an El Niño-like pattern, and negative values are La Niña-like. The change in El Niño variability (vertical axis) is denoted by the ratio of the standard deviation of the first EOF of sea level pressure (SLP) between the current climate and the last 50 years of the SRES A2 experiments (2051–2100), except for FGOALS-g1.0 and MIROC3.2(hires), for which the SRES A1B was used, and UKMO-HadGEM1 for which the 1% yr^{-1} CO_2 increase climate change experiment was used, in the region 30°S to 30°N, 30°E to 60°W with a five-month running mean (reproduced from van Oldenborgh et al., 2005). Error bars indicate the 95% confidence interval. Note that tropical Pacific base state climate changes with either El Niño-like or La Niña-like patterns are not permanent El Niño or La Niña events, and all still have ENSO inter-annual variability superimposed on that new average climate state in a future warmer climate.*

CO_2 simulations in a multi-model ensemble. The models that exhibit the largest El Niño amplitude change in scenario experiments are those that shift towards a thermocline mode. The observed 1976 climate shift in the tropical Pacific actually involved such a mode shift (Fedorov and Philander, 2001). The mean state change, through change in the sensitivity of SST variability to surface wind stress, plays a key role in determining the ENSO variance characteristics (Z. Hu et al., 2004; Zelle et al., 2005). For example, a more stable ENSO system is less sensitive to changes in the background state than one that is closer to instability (Zelle et al., 2005). Thus, GCMs with an improper simulation of present-day climate mean state and air-sea coupling strength are not suitable for ENSO amplitude projections. Van Oldenborgh et al. (2005) calculate the change in ENSO variability by the ratio of the standard deviation of the first Empirical Orthogonal Function (EOF) of SLP between the current climate and in the future (Figure 10.16), which shows that changes in ENSO interannual variability differ from model to model. They categorised 19 models based on their skill in the present-day ENSO simulations. Using the most realistic 6 out of 19 models, they find no statistically significant changes in the amplitude of ENSO variability in the future. Large uncertainty in the skewness of the variability limits the assessment of the future relative strength of El Niño and La Niña events.

Merryfield (2006) also analysed a multi-model ensemble and finds a wide range of behaviour for future El Niño amplitude, ranging from little change to larger El Niño events to smaller El Niño events, although several models that simulated some observed aspects of present-day El Niño events showed future increases in El Niño amplitude. However, significant multi-decadal fluctuations in El Niño amplitude in observations and in long coupled model control runs add another complicating factor to attempting to discern whether any future changes in El Niño amplitude are due to external forcing or are simply a manifestation of internal multi-decadal variability (Meehl et al., 2006a). Even with the larger warming scenario under 4 × atmospheric CO_2 climate, Yeh and Kirtman (2005) find that despite the large changes in the tropical Pacific mean state, the changes in ENSO amplitude are highly model dependent. Therefore, there are no clear indications at this time regarding future changes in El Niño amplitude in a warmer climate. However, as first noted in the TAR, ENSO teleconnections over North America appear to weaken due at least in part to the mean change of base state mid-latitude atmospheric circulation (Meehl et al., 2006a).

In summary, all models show continued ENSO interannual variability in the future no matter what the change in average background conditions, but changes in ENSO interannual variability differ from model to model. Based on various assessments of the current multi-model archive, in which present-day El Niño events are now much better simulated than in the TAR, there is no consistent indication at this time of discernible future changes in ENSO amplitude or frequency.

10.3.5.5 ENSO-Monsoon Relationship

The El Niño-Southern Oscillation affects interannual variability throughout the tropics through changes in the Walker Circulation. Analysis of observational data finds a significant correlation between ENSO and tropical circulation and precipitation such that there is a tendency for less Indian summer monsoon rainfall in El Niño years and above normal rainfall in La Niña years. Recent analyses have revealed that the correlation between ENSO and the Indian summer monsoon has decreased recently, and many hypotheses have been put forward (see Chapter 3). With respect to global warming, one hypothesis is that the Walker Circulation (accompanying ENSO) shifted south-eastward, reducing downward motion in the Indian monsoon region, which originally suppressed precipitation in that region at the time of El Niño, but now produces normal precipitation as a result (Krishna Kumar et al., 1999). Another explanation is that as the ground temperature of the Eurasian continent has risen in the winter-spring season, the temperature difference between the continent and the ocean has increased, thereby causing more precipitation, and the Indian monsoon is normal in spite of the occurrence of El Niño (Ashrit et al., 2001).

An earlier version of an AOGCM developed at the Max Planck Institute (MPI) (Ashrit et al., 2001) and the Action de Recherche Petite Echelle Grande Echelle/Océan Parallélisé (ARPEGE/OPA) model (Ashrit et al., 2003) simulated no global-warming related change in the ENSO-monsoon relationship, although a decadal-scale fluctuation is seen, suggesting that a weakening of the relationship might be part of the natural variability. However, Ashrit et al. (2001) show that while the impact of La Niña does not change, the influence of El Niño on the monsoon becomes small, suggesting the possibility of asymmetric behaviour of the changes in the ENSO-monsoon relationship. On the other hand, the MRI-CGCM2 (see Table 8.1 for model details) indicates a weakening of the correlation into the 21st century, particularly after 2050 (Ashrit et al., 2005). The MRI-CGCM2 model results support the above hypothesis that the Walker Circulation shifts eastward and no longer influences India at the time of El Niño in a warmer climate. Camberlin et al. (2004) and van Oldenborgh and Burgers (2005) find decadal fluctuations in the effect of ENSO on regional precipitation. In most cases, these fluctuations may reflect natural variability in the ENSO teleconnection, and long-term correlation trends may be comparatively weaker.

The Tropospheric Biennial Oscillation (TBO) has been suggested as a fundamental set of coupled interactions in the Indo-Pacific region that encompasses ENSO and the Asian-Australian monsoon, and the TBO has been shown to be simulated by current AOGCMs (see Chapter 8). Nanjundiah et al. (2005) analyse a multi-model data set to show that, for models that successfully simulate the TBO for present-day climate, the TBO becomes more prominent in a future warmer climate due to changes in the base state climate, although, as with ENSO, there is considerable inherent decadal variability in the relative dominance of TBO and ENSO.

In summary, the ENSO-monsoon relationship can vary due to natural variability. Model projections suggest that a future weakening of the ENSO-monsoon relationship could occur in a future warmer climate.

10.3.5.6 Annular Modes and Mid-Latitude Circulation Changes

Many simulations project some decrease in the arctic surface pressure in the 21st century, as seen in the multi-model average (see Figure 10.9). This contributes to an increase in indices of the Northern Annular Mode (NAM) or the Arctic Oscillation (AO), as well as the NAO, which is closely related to the NAM in the Atlantic sector (see Chapter 8). In the recent multi-model analyses, more than half of the models exhibit a positive trend in the NAM (Rauthe et al., 2004; Miller et al., 2006) and/or NAO (Osborn, 2004; Kuzmina et al., 2005). Although the magnitude of the trends shows a large variation among different models, Miller et al. (2006) find that none of the 14 models exhibits a trend towards a lower NAM index and higher arctic SLP. In another multi-model analysis, Stephenson et al. (2006) show that of the 15 models able to simulate the NAO pressure dipole, 13 predict a positive increase in the NAO index with increasing CO_2 concentrations, although the magnitude of the response is generally small and model dependent. However, the multi-model average from the larger number (21) of models shown in

Figure 10.9 indicates that it is likely that the NAM index would not notably decrease in a future warmer climate. The average of IPCC-AR4 simulations from 13 models suggests the increase of the NAM index becomes statistically significant early in the 21st century (Figure 10.17a, Miller et al., 2006).

The spatial patterns of the simulated SLP trends vary among different models, in spite of close correlations of the models' leading patterns of interannual (or internal) variability with the observations (Osborn, 2004; Miller et al., 2006). However, at the hemispheric scale of SLP change, the reduction in the Arctic is seen in the multi-model mean (Figure 10.9), although the change is smaller than the inter-model standard deviation. Besides the decrease in the arctic region, increases over the North Pacific and the Mediterranean Sea exceed the inter-model standard deviation; the latter suggests an association with a north-eastward shift of the NAO's centre of action (Hu and Wu, 2004). The diversity of the patterns seems to reflect different responses in the Aleutian Low (Rauthe et al., 2004) in the North Pacific. Yamaguchi and Noda (2006) discuss the modelled response of ENSO versus AO, and find that many models project a positive AO-like change. In the North Pacific at high latitudes, however, the SLP anomalies are incompatible between the El Niño-like change and the positive AO-like change, because models that project an El Niño-like change over the Pacific simulate a non-AO-like pattern in the polar region. As a result, the present models cannot fully determine the relative importance of the mechanisms inducing the positive AO-like change and those inducing the ENSO-like change, leading to scatter in global warming patterns at regional scales over the North Pacific. Rauthe et al. (2004) suggest that the effects of sulphate aerosols contribute to a deepening of the Aleutian Low resulting in a slower or smaller increase in the AO index.

Analyses of results from various models indicate that the NAM can respond to increasing greenhouse gas concentrations through tropospheric processes (Fyfe et al., 1999; Gillett et al., 2003; Miller et al., 2006). Greenhouse gases can also drive a positive NAM trend through changes in the stratospheric circulation, similar to the mechanism by which volcanic aerosols in the stratosphere force positive annular changes (Shindell et al., 2001). Models with their upper boundaries extending farther into the stratosphere exhibit, on average, a relatively larger increase in the NAM index and respond consistently to the observed volcanic forcing (Figure 10.17a, Miller et al., 2006), implying the importance of the connection between the troposphere and the stratosphere.

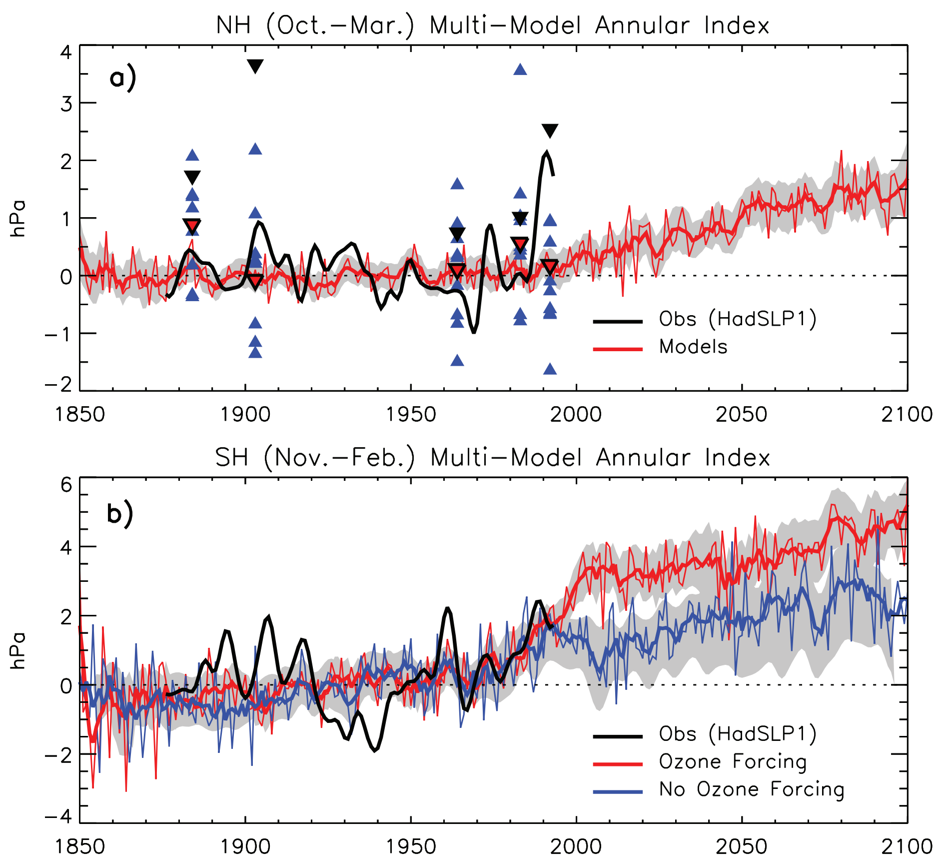


Figure 10.17. *(a) Multi-model mean of the regression of the leading EOF of ensemble mean Northern Hemisphere sea level pressure (NH SLP, thin red line). The time series of regression coefficients has zero mean between year 1900 and 1970. The thick red line is a 10-year low-pass filtered version of the mean. The grey shading represents the inter-model spread at the 95% confidence level and is filtered. A filtered version of the observed SLP from the Hadley Centre (HadSLP1) is shown in black. The regression coefficient for the winter following a major tropical eruption is marked by red, blue and black triangles for the multi-model mean, the individual model mean and observations, respectively. (b) As in (a) for Southern Hemisphere SLP for models with (red) and without (blue) ozone forcing. Adapted from Miller et al. (2006).*

A plausible explanation for the cause of the upward NAM trend simulated by the models is an intensification of the polar vortex resulting from both tropospheric warming and stratospheric cooling mainly due to the increase in greenhouse gases (Shindell et al., 2001; Sigmond et al., 2004; Rind et al., 2005a). The response may not be linear with the magnitude of radiative forcing (Gillett et al., 2002) since the polar vortex response is attributable to an equatorward refraction of planetary waves (Eichelberger and Holton, 2002) rather than radiative forcing itself. Since the long-term variation in the NAO is closely related to SST variations (Rodwell et al., 1999), it is considered essential that the projection of the changes in the tropical SST (Hoerling et al., 2004; Hurrell et al., 2004) and/or meridional gradient of the SST change (Rind et al., 2005b) is reliable.

The future trend in the Southern Annular Mode (SAM) or the Antarctic Oscillation (AAO) has been projected in a number of model simulations (Gillett and Thompson, 2003; Shindell and Schmidt, 2004; Arblaster and Meehl, 2006; Miller et al., 2006). According to the latest multi-model analysis (Miller et al., 2006), most models indicate a positive trend in the SAM index, and a declining trend in the antarctic SLP (as seen in Figure 10.9), with a higher likelihood than for the future NAM trend. On average, a larger positive trend is projected during the late 20th century by models that include stratospheric ozone changes than those that do not (Figure 10.17b), although during the 21st century, when ozone changes are smaller, the SAM trends of models with and without ozone are similar. The cause of the positive SAM trend in the second half of the 20th century is mainly attributed to stratospheric ozone depletion, evidenced by the fact that the signal is largest in the lower stratosphere in austral spring through summer (Thompson and Solomon, 2002; Arblaster and Meehl, 2006). However, increases in greenhouse gases are also important factors (Shindell and Schmidt, 2004; Arblaster and Meehl, 2006) for the year-round positive SAM trend induced by meridional temperature gradient changes (Brandefelt and Källén, 2004). During the 21st century, although the ozone amount is expected to stabilise or recover, the polar vortex intensification is likely to continue due to the increases in greenhouse gases (Arblaster and Meehl, 2006).

It is implied that the future change in the annular modes leads to modifications of the future change in various fields such as surface temperatures, precipitation and sea ice with regional features similar to those for the modes of natural variability (e.g., Hurrell et al., 2003). For instance, the surface warming in winter would be intensified in northern Eurasia and most of North America while weakened in the western North Atlantic, and winter precipitation would increase in northern Europe while decreasing in southern Europe. The atmospheric circulation change would also affect the ocean circulations. Sakamoto et al. (2005) simulate an intensification of the Kuroshio Current but no shift in the Kuroshio Extension in response to an AO-like circulation change for the 21st century. However, Sato et al. (2006) simulate a northward shift of the Kuroshio Extension, which leads to a strong warming off the eastern coast of Japan.

In summary, the future changes in the extratropical circulation variability are likely to be characterised by increases in positive phases of both the NAM and the SAM. The response in the NAM to anthropogenic forcing might not be distinct from the larger multi-decadal internal variability in the first half of the 21st century. The change in the SAM would appear earlier than in the NAM since stratospheric ozone depletion acts as an additional forcing. The positive trends in annular modes would influence the regional changes in temperature, precipitation and other fields, similar to those that accompany the NAM and the SAM in the present climate, but would be superimposed on the global-scale changes in a future warmer climate.

10.3.6 Future Changes in Weather and Climate Extremes

Projections of future changes in extremes rely on an increasingly sophisticated set of models and statistical techniques. Studies assessed in this section rely on multi-member ensembles (three to five members) from single models, analyses of multi-model ensembles ranging from 8 to 15 or more AOGCMs, and a perturbed physics ensemble with a single mixed-layer model with over 50 members. The discussion here is intended to identify general characteristics of changes in extremes in a global context. Chapter 3 provides a definition of weather and climate extremes, and Chapter 11 addresses changes in extremes for specific regions.

10.3.6.1 Precipitation Extremes

A long-standing result from global coupled models noted in the TAR is a projected increase in the chance of summer drying in the mid-latitudes in a future warmer climate with associated increased risk of drought. This is shown in Figure 10.12, and has been documented in the more recent generation of models (Burke et al., 2006; Meehl et al., 2006b; Rowell and Jones, 2006). For example, Wang (2005) analyse 15 recent AOGCMs and show that in a future warmer climate, the models simulate summer dryness in most parts of the northern subtropics and mid-latitudes, but with a large range in the amplitude of summer dryness across models. Droughts associated with this summer drying could result in regional vegetation die-offs (Breshears et al., 2005) and contribute to an increase in the percentage of land area experiencing drought at any one time, for example, extreme drought increasing from 1% of present-day land area to 30% by the end of the century in the A2 scenario (Burke et al., 2006). Drier soil conditions can also contribute to more severe heat waves as discussed in Section 10.3.6.2 (Brabson et al., 2005).

Associated with the risk of drying is a projected increase in the chance of intense precipitation and flooding. Although somewhat counter-intuitive, this is because precipitation is projected to be concentrated into more intense events, with longer periods of little precipitation in between. Therefore, intense and heavy episodic rainfall events with high runoff amounts are interspersed with longer relatively dry periods with increased evapotranspiration, particularly in the subtropics

Frequently Asked Question 10.1

Are Extreme Events, Like Heat Waves, Droughts or Floods, Expected to Change as the Earth's Climate Changes?

Yes; the type, frequency and intensity of extreme events are expected to change as Earth's climate changes, and these changes could occur even with relatively small mean climate changes. Changes in some types of extreme events have already been observed, for example, increases in the frequency and intensity of heat waves and heavy precipitation events (see FAQ 3.3).

In a warmer future climate, there will be an increased risk of more intense, more frequent and longer-lasting heat waves. The European heat wave of 2003 is an example of the type of extreme heat event lasting from several days to over a week that is likely to become more common in a warmer future climate. A related aspect of temperature extremes is that there is likely to be a decrease in the daily (diurnal) temperature range in most regions. It is also likely that a warmer future climate would have fewer frost days (i.e., nights where the temperature dips below freezing). Growing season length is related to number of frost days, and has been projected to increase as climate warms. There is likely to be a decline in the frequency of cold air outbreaks (i.e., periods of extreme cold lasting from several days to over a week) in NH winter in most areas. Exceptions could occur in areas with the smallest reductions of extreme cold in western North America, the North Atlantic and southern Europe and Asia due to atmospheric circulation changes.

In a warmer future climate, most Atmosphere-Ocean General Circulation Models project increased summer dryness and winter wetness in most parts of the northern middle and high latitudes. Summer dryness indicates a greater risk of drought. Along with the risk of drying, there is an increased chance of intense precipitation and flooding due to the greater water-holding capacity of a warmer atmosphere. This has already been observed and is projected to continue because in a warmer world, precipitation tends to be concentrated into more intense events, with longer periods of little precipitation in between. Therefore, intense and heavy downpours would be interspersed with longer relatively dry periods. Another aspect of these projected changes is that wet extremes are projected to become more severe in many areas where mean precipitation is expected to increase, and dry extremes are projected to become more severe in areas where mean precipitation is projected to decrease.

In concert with the results for increased extremes of intense precipitation, even if the wind strength of storms in a future climate did not change, there would be an increase in extreme rainfall intensity. In particular, over NH land, an increase in the likelihood of very wet winters is projected over much of central and northern Europe due to the increase in intense precipitation during storm events, suggesting an increased chance of flooding over Europe and other mid-latitude regions due to more intense rainfall and snowfall events producing more runoff. Similar results apply for summer precipitation, with implications for more flooding in the Asian monsoon region and other tropical areas. The increased risk of floods in a number of major river basins in a future warmer climate has been related to an increase in river discharge with an increased risk of future intense storm-related precipitation events and flooding. Some of these changes would be extensions of trends already underway.

There is evidence from modelling studies that future tropical cyclones could become more severe, with greater wind speeds and more intense precipitation. Studies suggest that such changes may already be underway; there are indications that the average number of Category 4 and 5 hurricanes per year has increased over the past 30 years. Some modelling studies have projected a decrease in the number of tropical cyclones globally due to the increased stability of the tropical troposphere in a warmer climate, characterised by fewer weak storms and greater numbers of intense storms. A number of modelling studies have also projected a general tendency for more intense but fewer storms outside the tropics, with a tendency towards more extreme wind events and higher ocean waves in several regions in association with those deepened cyclones. Models also project a poleward shift of storm tracks in both hemispheres by several degrees of latitude.

as discussed in Section 10.3.6.2 in relation to Figure 10.19 (Frei et al., 1998; Allen and Ingram, 2002; Palmer and Räisänen, 2002; Christensen and Christensen, 2003; Beniston, 2004; Christensen and Christensen, 2004; Pal et al., 2004; Meehl et al., 2005a). However, increases in the frequency of dry days do not necessarily mean a decrease in the frequency of extreme high rainfall events depending on the threshold used to define such events (Barnett et al., 2006). Another aspect of these changes has been related to the mean changes in precipitation, with wet extremes becoming more severe in many areas where mean precipitation increases, and dry extremes where the mean precipitation decreases (Kharin and Zwiers, 2005; Meehl et al., 2005a; Räisänen, 2005a; Barnett et al., 2006). However, analysis of the 53-member perturbed physics ensemble indicates that the change in the frequency of extreme precipitation at an individual location can be difficult to estimate definitively due to model parametrization uncertainty (Barnett et al., 2006). Some specific regional aspects of these changes in precipitation extremes are discussed further in Chapter 11.

Climate models continue to confirm the earlier results that in a future climate warmed by increasing greenhouse gases, precipitation intensity (e.g., proportionately more precipitation per precipitation event) is projected to increase over most regions (Wilby and Wigley, 2002; Kharin and Zwiers, 2005; Meehl et al., 2005a; Barnett et al., 2006), and the increase in precipitation extremes is greater than changes in mean precipitation (Kharin and Zwiers, 2005). As discussed in Chapter 9, this is related to the fact that the energy budget of the atmosphere constrains increases in large-scale mean precipitation, but extreme precipitation relates to increases in moisture content and thus the nonlinearities involved with the Clausius-Clapeyron relationship such that, for a given increase in temperature, increases in extreme precipitation can be more than the mean precipitation increase (e.g., Allen and Ingram, 2002). Additionally, time scale can play a role whereby increases in the frequency of seasonal mean rainfall extremes can be greater than the increases in the frequency of daily extremes (Barnett et al., 2006). The increase in mean and extreme precipitation in various regions has been attributed to contributions from both dynamic and thermodynamic processes associated with global warming (Emori and Brown, 2005). The greater increase in extreme precipitation compared to the mean is attributed to the greater thermodynamic effect on the extremes due to increases in water vapour, mainly over subtropical areas. The thermodynamic effect is important nearly everywhere, but changes in circulation also contribute to the pattern of precipitation intensity changes at middle and high latitudes (Meehl et al., 2005a). Kharin and Zwiers (2005) show that changes in both the location and scale of the extreme value distribution produce increases in precipitation extremes substantially greater than increases in annual mean precipitation. An increase in the scale parameter from the gamma distribution represents an increase in precipitation intensity, and various regions such as the NH land areas in winter showed particularly high values of increased scale parameter (Semenov and Bengtsson, 2002; Watterson and Dix, 2003). Time-slice simulations with a higher-resolution model (~1°) show similar results using changes in the gamma distribution, namely increased extremes in the hydrological cycle (Voss et al., 2002). However, some regional decreases are also projected such as over the subtropical oceans (Semenov and Bengtsson, 2002).

A number of studies have noted the connection between increased rainfall intensity and an implied increase in flooding. McCabe et al. (2001) and Watterson (2005) show a projected increase in extreme rainfall intensity with the extra-tropical surface lows, particularly over NH land, with an implied increase in flooding. In a multi-model analysis of the CMIP models, Palmer and Räisänen (2002) show an increased likelihood of very wet winters over much of central and northern Europe due to an increase in intense precipitation associated with mid-latitude storms, suggesting more floods across Europe (see also Chapter 11). They found similar results for summer precipitation with implications for greater flooding in the Asian monsoon region in a future warmer climate. Similarly, Milly et al. (2002), Arora and Boer (2001) and Voss et al. (2002) relate the increased risk of floods in a number of major river basins in a future warmer climate to an increase in spring river discharge related to increased winter snow depth in some regions. Christensen and Christensen (2003) conclude that there could be an increased risk of summer flooding in Europe.

Globally averaged time series of the Frich et al. (2002) indices in the multi-model analysis of Tebaldi et al. (2006) show simulated increases in precipitation intensity during the 20th century continuing through the 21st century (Figure 10.18a,b), along with a somewhat weaker and less consistent trend of increasing dry periods between rainfall events for all scenarios (Figure 10.18c,d). Part of the reason for these results is shown in the geographic maps for these quantities, where precipitation intensity increases almost everywhere, but particularly at middle and high latitudes where mean precipitation also increases (Meehl et al., 2005a; compare Figure 10.18b to Figure 10.9). However, in Figure 10.18d, there are regions of increased runs of dry days between precipitation events in the subtropics and lower mid-latitudes, but decreased runs of dry days at higher mid-latitudes and high latitudes where mean precipitation increases (compare Figure 10.9 with Figure 10.18d). Since there are areas of both increases and decreases in consecutive dry days between precipitation events in the multi-model average (Figure 10.9), the global mean trends are smaller and less consistent across models as shown in Figure 10.18. Consistency of response in a perturbed physics ensemble with one model shows only limited areas of increased frequency of wet days in July, and a larger range of changes in precipitation extremes relative to the control ensemble mean in contrast to the more consistent response of temperature extremes (Section 10.6.3.2), indicating a less consistent response for precipitation extremes in general compared to temperature extremes (Barnett et al., 2006). Analysis of the Frich et al. (2002) precipitation indices in a 20-km resolution global model shows similar results to those in Figure 10.18, with particularly large increases in precipitation intensity in South Asia and West Africa (Kamiguchi et al., 2005).

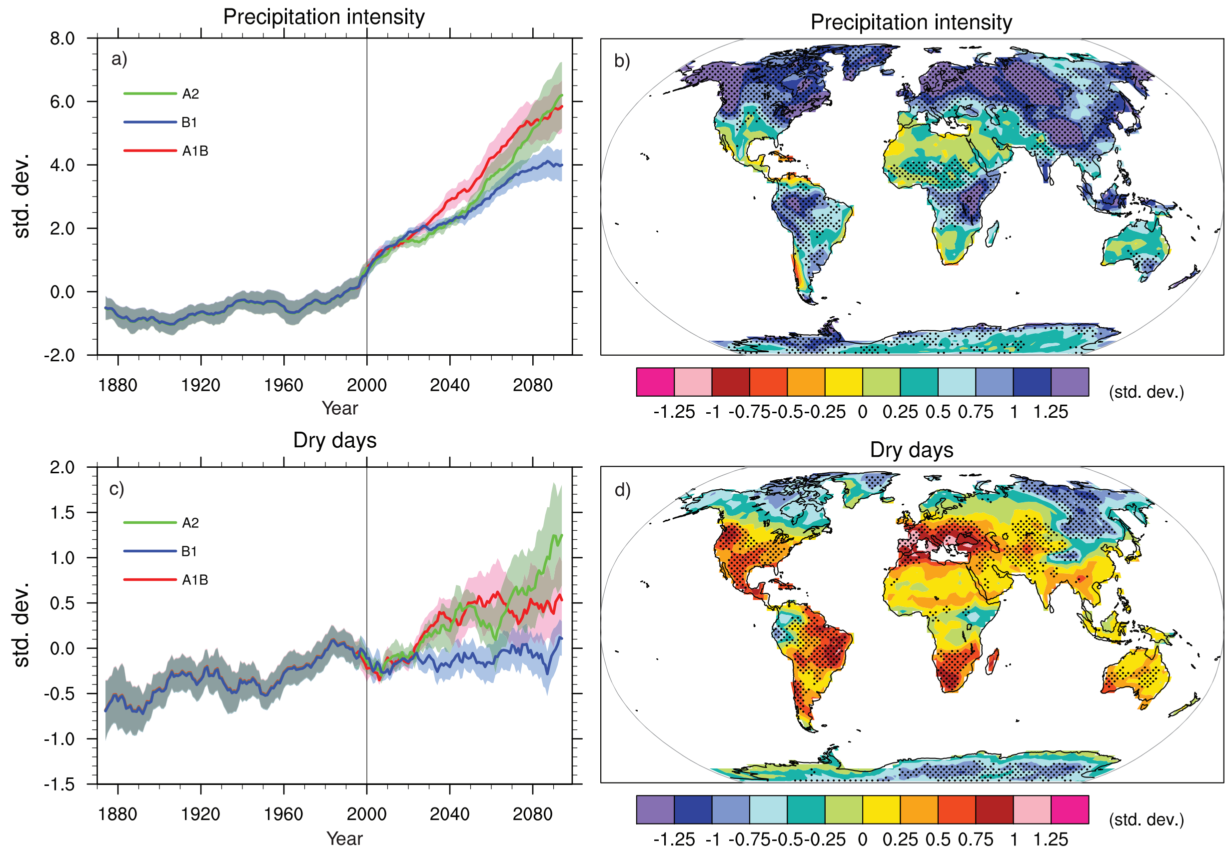


Figure 10.18. *Changes in extremes based on multi-model simulations from nine global coupled climate models, adapted from Tebaldi et al. (2006). (a) Globally averaged changes in precipitation intensity (defined as the annual total precipitation divided by the number of wet days) for a low (SRES B1), middle (SRES A1B) and high (SRES A2) scenario. (b) Changes in spatial patterns of simulated precipitation intensity between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario. (c) Globally averaged changes in dry days (defined as the annual maximum number of consecutive dry days). (d) Changes in spatial patterns of simulated dry days between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario. Solid lines in (a) and (c) are the 10-year smoothed multi-model ensemble means; the envelope indicates the ensemble mean standard deviation. Stippling in (b) and (d) denotes areas where at least five of the nine models concur in determining that the change is statistically significant. Extreme indices are calculated only over land following Frich et al. (2002). Each model's time series was centred on its 1980 to 1999 average and normalised (rescaled) by its standard deviation computed (after de-trending) over the period 1960 to 2099. The models were then aggregated into an ensemble average, both at the global and at the grid-box level. Thus, changes are given in units of standard deviations.*

10.3.6.2 Temperature Extremes

The TAR concluded that there was a very likely risk of increased high temperature extremes (and reduced risk of low temperature extremes) with more extreme heat episodes in a future climate. The latter result has been confirmed in subsequent studies (Yonetani and Gordon, 2001). Kharin and Zwiers (2005) show in a single model that future increases in temperature extremes follow increases in mean temperature over most of the world except where surface properties change (melting snow, drying soil). Furthermore, they show that in most instances warm extremes correspond to increases in daily maximum temperature, but cold extremes warm up faster than daily minimum temperatures, although this result is less consistent when model parameters are varied in a perturbed physics ensemble where there are increased daily temperature maxima for nearly the entire land surface. However, the range in magnitude of increases was substantial indicating a sensitivity to model formulations (Clark et al., 2006).

Weisheimer and Palmer (2005) examine changes in extreme seasonal (DJF and JJA) temperatures in 14 models for three scenarios. They show that by the end of 21st century, the probability of such extreme warm seasons is projected to rise in many areas. This result is consistent with the perturbed physics ensemble where, for nearly all land areas, extreme JJA temperatures were at least 20 times and in some areas 100 times more frequent compared to the control ensemble mean, making these changes greater than the ensemble spread.

Since the TAR, possible future cold air outbreaks have been studied. Vavrus et al. (2006) analyse seven AOGCMs run with the A1B scenario, and define a cold air outbreak as two or more consecutive days when the daily temperatures are at least two standard deviations below the present-day winter mean. For a future warmer climate, they document a 50 to 100% decline in the frequency of cold air outbreaks in NH winter in most areas compared to the present, with the smallest reductions occurring in western North America, the North Atlantic and southern Europe and Asia due to atmospheric circulation changes associated with the increase in greenhouse gases.

No studies at the time of the TAR specifically documented changes in heat waves (very high temperatures over a sustained period of days, see Chapter 3). Several recent studies address possible future changes in heat waves explicitly, and find an increased risk of more intense, longer-lasting and more frequent heat waves in a future climate (Meehl and Tebaldi, 2004; Schär et al., 2004; Clark et al., 2006). Meehl and Tebaldi (2004) show that the pattern of future changes in heat waves, with greatest intensity increases over western Europe, the Mediterranean and the southeast and western USA, is related in part to base state circulation changes due to the increase in greenhouse gases. An additional factor leading to extreme heat is drier soils in a future warmer climate (Brabson et al., 2005; Clark et al., 2006). Schär et al. (2004), Stott et al. (2004) and Beniston (2004) use the European 2003 heat wave as an example of the types of heat waves that are likely to become more common in a future warmer climate. Schär et al. (2004) note that the increase in the frequency of extreme warm conditions is also associated with a change in interannual variability, such that the statistical distribution of mean summer temperatures is not merely shifted towards warmer conditions but also becomes wider. A multi-model ensemble shows that heat waves are simulated to have been increasing over the latter part of the 20th century, and are projected to increase globally and over most regions (Figure 10.19; Tebaldi et al., 2006), although different model parameters can contribute to the range in the magnitude of this response (Clark et al., 2006).

A decrease in DTR in most regions in a future warmer climate was reported in the TAR, and is substantiated by more recent studies (e.g., Stone and Weaver, 2002; also discussed in relation to Figure 10.11b and in Chapter 11). For a quantity related to the DTR, the TAR concluded that it would be likely that a future warmer climate would also be characterised by a decrease in the number of frost days, although there were no studies at that time from global coupled climate models that addressed this issue explicitly. It has since been shown that there would indeed be decreases in frost days in a future warmer climate in the extratropics (Meehl et al., 2004a), with the pattern of the decreases dictated by the changes in atmospheric circulation due to the increase in greenhouse gases (Meehl et al., 2004a). Results from a nine-member multi-model ensemble show simulated decreases in frost days for the 20th century continuing into the 21st century globally and in most regions (Figure 10.19). A quantity related to frost days in many mid- and high-latitude areas, particularly in the NH, is growing season length as defined by Frich et al. (2002), and this has been projected to increase in future climate (Tebaldi et al., 2006). This result is also shown in a nine-member multi-model ensemble where the simulated increase in growing season length in the 20th century continues into the 21st century globally and in most regions (Figure 10.19). The globally averaged extremes indices in Figures 10.18 and 10.19 have non-uniform changes across the scenarios compared to the more consistent relative increases in Figure 10.5 for globally averaged temperature. This indicates that patterns that scale well by radiative forcing for temperature (e.g., Figure 10.8) would not scale for extremes.

10.3.6.3 Tropical Cyclones (Hurricanes)

Earlier studies assessed in the TAR showed that future tropical cyclones would likely become more severe with greater wind speeds and more intense precipitation. More recent modelling experiments have addressed possible changes in tropical cyclones in a warmer climate and generally confirmed those earlier results. These studies fall into two categories: those with model grid resolutions that only roughly represent some aspects of individual tropical cyclones, and those with model grids of sufficient resolution to reasonably simulate individual tropical cyclones.

In the first category, a number of climate change experiments with global models have started to simulate some characteristics of individual tropical cyclones, although classes of models with 50 to 100 km resolution or lower cannot accurately simulate observed tropical cyclone intensities due to the limitations of the relatively coarse grid spacing (e.g., Yoshimura et al., 2006). A study with roughly 100-km grid spacing shows a decrease in tropical cyclone frequency globally and in the North Pacific but a regional increase over the North Atlantic and no significant changes in maximum intensity (Sugi et al., 2002). Yoshimura et al. (2006) use the same model but different SST patterns and two different convection schemes, and show a decrease in the global frequency of relatively weak tropical cyclones but no significant change in the frequency of intense storms. They also show that the regional changes are dependent on the SST pattern, and precipitation near the storm centres could increase in the future. Another study using a 50 km resolution model confirms this dependence on SST pattern, and also shows a consistent increase in precipitation intensity in future tropical cyclones (Chauvin et al., 2006). Another global modelling study with roughly a 100-km grid spacing finds a 6% decrease in tropical storms globally and a slight increase in intensity, with both increases and decreases regionally related to the El Niño-like base state response in the tropical Pacific to increased greenhouse gases (McDonald et al., 2005). Another study with the same resolution model indicates decreases in tropical cyclone frequency and intensity but more mean and extreme precipitation from the tropical cyclones simulated in the future in the western north Pacific (Hasegawa and Emori, 2005). An AOGCM analysis with a coarser-resolution atmospheric model (T63, or about 200-km grid spacing) shows little change in overall numbers of tropical storms in that model, but a slight decrease in medium-intensity storms in a warmer climate (Bengtsson et al., 2006). In a global warming simulation with a coarse-resolution atmospheric model (T42, or about 300-km grid spacing), the frequency of global tropical cyclone occurrence did not change significantly, but the mean intensity of the global tropical cyclones increased significantly (Tsutsui, 2002). Thus, from this category of coarser-grid models that can only represent rudimentary aspects of tropical cyclones, there is no consistent evidence for large changes in either frequency or intensity of these models' representation of tropical cyclones, but there is a consistent response of more intense precipitation from future storms in a warmer climate. Also note that the

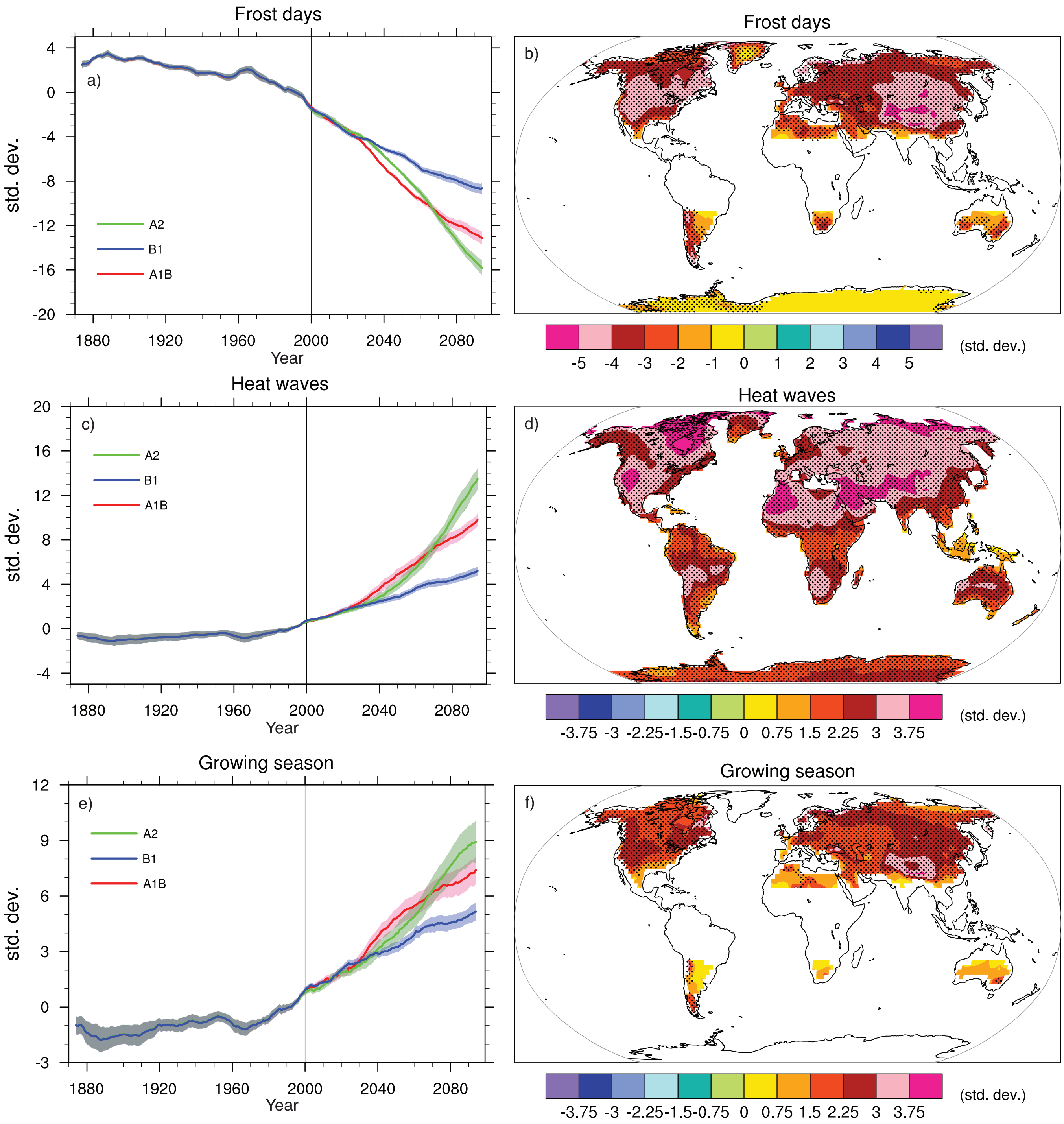


Figure 10.19. *Changes in extremes based on multi-model simulations from nine global coupled climate models, adapted from Tebaldi et al. (2006). (a) Globally averaged changes in the frost day index (defined as the total number of days in a year with absolute minimum temperature below 0°C) for a low (SRES B1), middle (SRES A1B) and high (SRES A2) scenario. (b) Changes in spatial patterns of simulated frost days between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario. (c) Globally averaged changes in heat waves (defined as the longest period in the year of at least five consecutive days with maximum temperature at least 5°C higher than the climatology of the same calendar day). (d) Changes in spatial patterns of simulated heat waves between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario. (e) Globally averaged changes in growing season length (defined as the length of the period between the first spell of five consecutive days with mean temperature above 5°C and the last such spell of the year). (f) Changes in spatial patterns of simulated growing season length between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario. Solid lines in (a), (c) and (e) show the 10-year smoothed multi-model ensemble means; the envelope indicates the ensemble mean standard deviation. Stippling in (b), (d) and (f) denotes areas where at least five of the nine models concur in determining that the change is statistically significant. Extreme indices are calculated only over land. Frost days and growing season are only calculated in the extratropics. Extremes indices are calculated following Frich et al. (2002). Each model's time series was centred around its 1980 to 1999 average and normalised (rescaled) by its standard deviation computed (after de-trending) over the period 1960 to 2099. The models were then aggregated into an ensemble average, both at the global and at the grid-box level. Thus, changes are given in units of standard deviations.*

decreasing tropical precipitation in future climate in Yoshimura et al. (2006) is for SSTs held fixed as atmospheric CO_2 is increased, a situation that does not occur in any global coupled model.

In the second category, studies have been performed with models that have been able to credibly simulate many aspects of tropical cyclones. For example, Knutson and Tuleya (2004) use a high-resolution (down to 9 km) mesoscale hurricane model to simulate hurricanes with intensities reaching about 60 to 70 m s^{-1}, depending on the treatment of moist convection in the model. They use mean tropical conditions from nine global climate models with increased CO_2 to simulate tropical cyclones with 14% more intense central pressure falls, 6% higher maximum surface wind speeds and about 20% greater near-storm rainfall after an idealised 80-year buildup of CO_2 at 1% yr^{-1} compounded (warming given by TCR shown for models in Chapter 8). Using a multiple nesting technique, an AOGCM was used to force a regional model over Australasia and the western Pacific with 125-km grid resolution, with an embedded 30-km resolution model over the south-western Pacific (Walsh et al., 2004). At that 30-km resolution, the model is able to closely simulate the climatology of the observed tropical cyclone lower wind speed threshold of 17 m s^{-1}. Tropical cyclone occurrence (in terms of days of tropical cyclone activity) is slightly greater than observed, and the somewhat weaker than observed pressure gradients near the storm centres are associated with lower than observed maximum wind speeds, likely due to the 30-km grid spacing that is too coarse to capture extreme pressure gradients and winds. For 3 × atmospheric CO_2 in that model configuration, the simulated tropical cyclones experienced a 56% increase in the number of storms with maximum wind speed greater than 30 m s^{-1} and a 26% increase in the number of storms with central pressures less than 970 hPa, with no large changes in frequency and movement of tropical cyclones for that southwest Pacific region. It should also be noted that ENSO fluctuations have a strong impact on patterns of tropical cyclone occurrence in the southern Pacific (Nguyen and Walsh, 2001), and that uncertainty with respect future ENSO behaviour (Section 10.3.5.1) contributes to uncertainty with respect to tropical cyclones (Walsh, 2004).

In another experiment with a high resolution global model that is able to generate tropical cyclones that begin to approximate real storms, a global 20-km grid atmospheric model was run in time slice experiments for a present-day 10-year period and a 10-year period at the end of the 21st century for the A1B scenario to examine changes in tropical cyclones. Observed climatological SSTs were used to force the atmospheric model for the 10-year period at the end of the 20th century, time-mean SST anomalies from an AOGCM simulation for the future climate were added to the observed SSTs and atmospheric composition was changed in the model to be consistent with the A1B scenario. At that resolution, tropical cyclone characteristics, numbers and tracks were relatively well simulated for present-day climate, although simulated wind speed intensities were somewhat weaker than observed intensities (Oouchi et al., 2006). In that study, tropical cyclone frequency decreased 30% globally (but increased about 34% in the North Atlantic). The strongest tropical cyclones with extreme surface winds increased in number while weaker storms decreased. The tracks were not appreciably altered, and maximum peak wind speeds in future simulated tropical cyclones increased by about 14% in that model, although statistically significant increases were not found in all basins. As noted above, the competing effects of greater stabilisation of the tropical troposphere (less storms) and greater SSTs (the storms that form are more intense) likely contribute to these changes except for the tropical North Atlantic where there are greater SST increases than in the other basins in that model. Therefore, the SST warming has a greater effect than the vertical stabilisation in the Atlantic and produces not only more storms but also more intense storms there. However, these regional changes are largely dependent on the spatial pattern of future simulated SST changes (Yoshimura et al., 2006).

Sugi et al. (2002) show that the global-scale reduction in tropical cyclone frequency is closely related to weakening of tropospheric circulation in the tropics in terms of vertical mass flux. They note that a significant increase in dry static stability in the tropical troposphere and little increase in tropical precipitation (or convective heating) are the main factors contributing to the weakening of the tropospheric circulation. Sugi and Yoshimura (2004) investigate a mechanism of this tropical precipitation change. They show that the effect of CO_2 enhancement (without changing SST conditions, which is not realistic as noted above) is a decrease in mean precipitation (Sugi and Yoshimura, 2004) and a decrease in the number of tropical cyclones as simulated in an atmospheric model with about 100 km resolution (Yoshimura and Sugi, 2005). Future changes in the large-scale steering flow as a mechanism to deduce possible changes in tropical cyclone tracks in the western North Pacific (Wu and Wang, 2004) were analysed to show different shifts at different times in future climate change experiments along with a dependence of such shifts on the degree of El Niño-like mean climate change in the Pacific (see Section 10.3.5).

A synthesis of the model results to date indicates that, for a future warmer climate, coarse-resolution models show few consistent changes in tropical cyclones, with results dependent on the model, although those models do show a consistent increase in precipitation intensity in future storms. Higher-resolution models that more credibly simulate tropical cyclones project some consistent increase in peak wind intensities, but a more consistent projected increase in mean and peak precipitation intensities in future tropical cyclones. There is also a less certain possibility of a decrease in the number of relatively weak tropical cyclones, increased numbers of intense tropical cyclones and a global decrease in total numbers of tropical cyclones.

10.3.6.4 Extratropical Storms and Ocean Wave Height

The TAR noted that there could be a future tendency for more intense extratropical storms, although the number of storms could be less. A more consistent result that has emerged more

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Arctic sea ice forecasts point to lower-than-average season ahead

Spring has arrived in the Arctic. After peaking at 15.21 million square kilometers (5.87 million square miles) in the second week of March, Arctic sea ice extent has declined through the month of April. April extent has not fallen below the lowest April extent on record, but it is still below the long-term average.

Taken together, an assessment of the available evidence, detailed below, points to another extreme September sea ice minimum. Could the North Pole be ice free this melt season? Given that this region is currently covered with first-year ice, that seems quite possible.

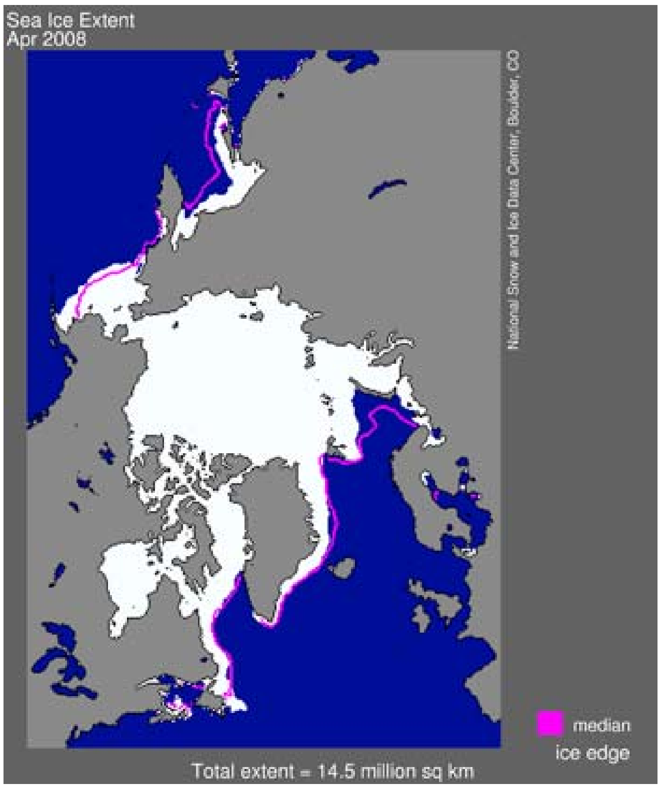
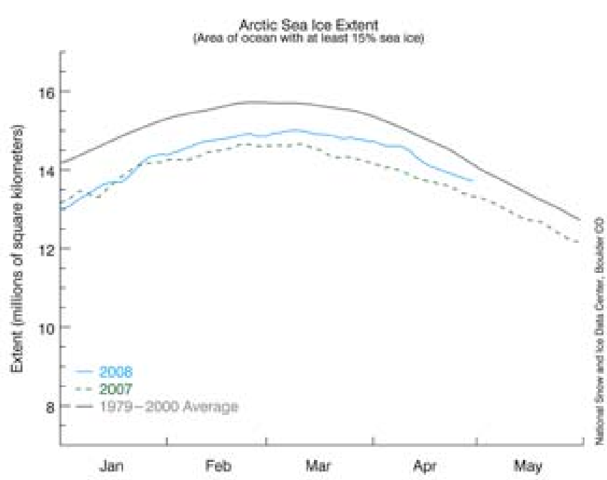


Figure 1. Arctic sea ice extent for April 2008 was 14.49 million square kilometers (5.59 million square miles). The magenta line shows the median ice extent for March from 1979 to 2000. Data Note
—Credit: National Snow and Ice Data Center

See High Resolution Image

Overview of conditions

For the month of April, Arctic sea ice extent stood at 14.49 million square kilometers (5.59 million square miles), which is 0.61 million square kilometers (0.24 million square miles) greater than April 2007, but is still 0.51 million square kilometers (0.20 million square miles) less than the 1979 to 2000 average for April.



Conditions in context

Although there is more ice than this time last year, the average decline rate through the month of April was 6,000 square kilometers per day (2,300 square

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State of the Cryosphere: Sea Ice
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Related Resources

Sea Ice Outlook Report

This report, updated monthly during the summer melt season, synthesizes scientific projections concerning the September 2008 minimum. From the Study of Environmental Arctic Change.

NSIDC Scientist Discusses Sea Ice

Mark Serreze gave the Nye Lecture at AGU in 2007; he talked about Arctic sea ice. Click on the link above and scroll to "C24A Nye Lecture."

Figure 2. Daily sea ice extent; the blue line indicates 2008; the black line indicates extent from 1979 to 2000; the dotted line shows extent from December 2006 through April 2007.
—Credit: National Snow and Ice Data Center

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faster than last April.

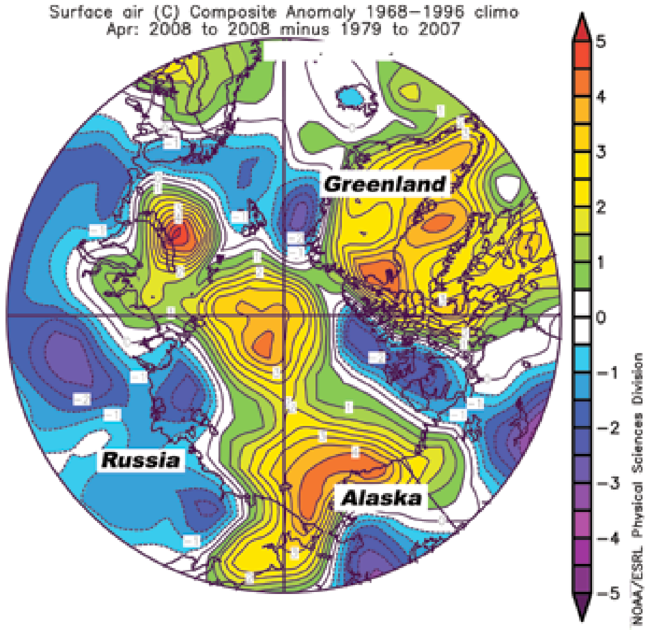

Figure 3. The spatial pattern of surface air temperature anomalies for April 2008, expressed with respect to the average for 1979 to 2007, shows unusually high temperatures over the Arctic Ocean and peripheral seas.
—Credit: From National Snow and Ice Data Center courtesy Climate Diagnostic Center

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Faster decline reflects warmer Arctic

At least part of the explanation for this fairly rapid decline lies in the warm conditions that characterized April over the Arctic Ocean and peripheral seas. Anomalies over some regions exceed 5 degrees Celsius (9 degrees Fahrenheit). For the most part, this unusual warmth is consistent with shifts in atmospheric circulation that bring warm air into the region. The distinct hot spot near Novaya Zemlya, in the upper left quadrant of Figure 3, overlies an open water area where heat is being released to the atmosphere. In past years, this area tended to be ice covered in April, preventing this heat release.

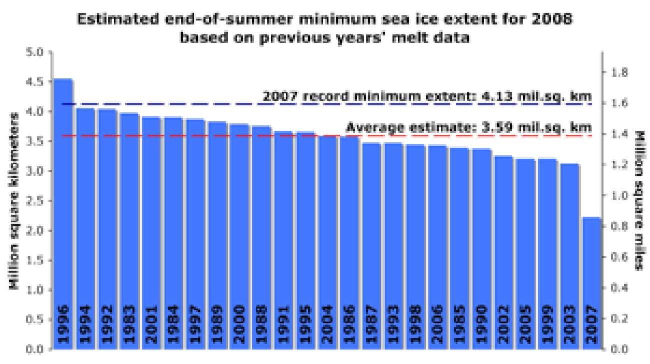

Figure 4. This bar plot shows estimates of sea ice extent at the 2008 September minimum based on known ice survival rates. The blue dotted line indicates the record-breaking minimum extent of 2007; the red dotted line shows the mean estimate based on all years between 1983 and 2007.
—Credit: National Snow and Ice Data Center

See High Resolution Image

Estimating September extent based on past conditions

As discussed in our April analysis, the ice cover this spring shows an unusually large proportion of young, thin first-year ice; about 30% of first-year ice typically survives the summer melt season, while 75% of the older ice survives. For a simple estimate of the likelihood of breaking last year's September

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record, we can apply survival rates from past years to this year's April ice cover. This gives us 25 different estimates, one for each year that we have reliable ice-age data (see Figure 4). To avoid beating the September 2007 record low, more than 50% of this year's first-year ice would have to survive; this has only happened once in the last 25 years, in 1996. If we apply the survival rates averaged over all years to current conditions, the end-of-summer extent would be 3.59 million square kilometers (1.39 million square miles). With survival rates similar to those in 2007, the minimum for the 2008 season would be only 2.22 million square kilometers (0.86 million square miles). By comparison the record low extent, set last September, was 4.28 million square kilometers (1.65 million square miles).

Forecasting September extent with climate predictors

Sheldon Drobot at the Center for Astrodynamics Research at the University of Colorado at Boulder and colleagues have developed a sophisticated forecasting technique. The forecast considers sea ice extent, ice age, summer and winter temperatures, cloudiness, the phase of the Atlantic Oscillation, and climate trends as predictors (see the papers cited below for details; visit the Arctic Oscillation Index). As reported last month, the Arctic Oscillation was in its positive phase through the winter season, associated with a wind pattern helping to flush thick ice out of the Arctic, leaving thinner ice. This is one of the factors helping to set the stage for pronounced ice losses this summer. Drobot predicts a 59% chance of a new record minimum this year; read the press release. Todd Arbetter of the U.S. National Ice Center tells us that his group is working to implement a version of Drobot's analysis scheme for operational forecasting.

Ronald Lindsay of the University of Washington's Applied Physics Laboratory and collaborators recently published results from their own ice prediction system, based on a retrospective analysis of the modeled state of the ice and ocean system (see the paper cited below for details). The model is successful in explaining around 75% of the year-to-year variations for the past few decades; for 2008, the model implies a very low, but not extreme, sea ice minimum. Lindsay cautions that sea ice conditions are now changing so rapidly that predictions based on relationships developed from the past 50 years of data may no longer apply.

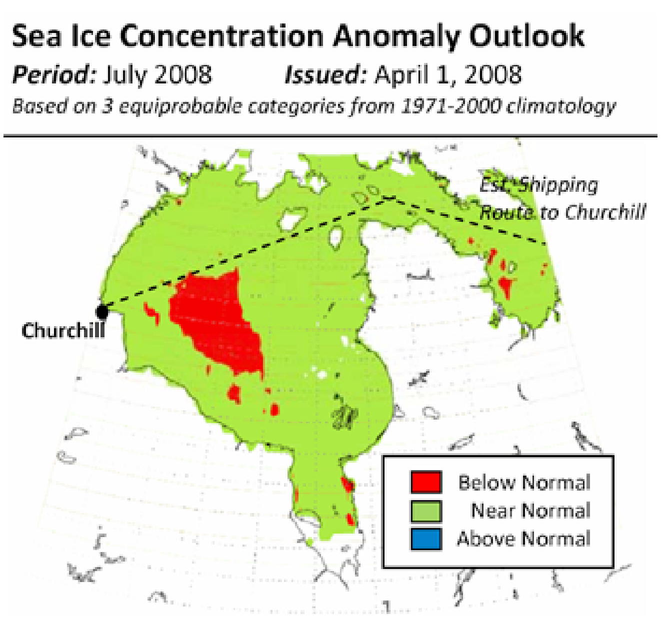

Figure 5. This image shows probable ice conditions in the Hudson Bay for July 2008; the colored area is the bay and white indicates land masses. Green shows near-normal ice conditions; red shows below average; blue shows above average.
—Credit: From National Snow and Ice Data Center courtesy A.Tivy

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Regional shipping forecasts

Marine transportation in the Arctic is expected to increase as ice extent decreases. However, the viability of shipping through the Northwest Passage in the Canadian Arctic Islands, the Northern Sea Route along the Eurasian coast and in other areas such as Hudson Bay depend on local ice conditions, which can be highly variable. Adrienne Tivy at the University of Calgary and colleagues have investigated the variables that affect shipping in Hudson Bay. They found that the date on which shipping routes open across Hudson Bay to Churchill is most strongly correlated with sea surface temperatures between January and March and atmospheric pressure patterns in the East Atlantic in January. This year, Adrienne Tivy and colleagues predict that shipping to Churchill in a non-ice-strengthened vessel will be possible on July 16, 15 days earlier than the long-term mean of July 31. They estimate below-normal ice concentrations in the southwestern bay, but near-normal conditions elsewhere.

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Projected climate change impact on oceanic acidification

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Published: 27 June 2006

Carbon Balance and Management 2006, **1**:2 doi:10.1186/1750-0680-1-2

This article is available from: http://www.cbmjournal.com/content/1/1/2

Received: 06 March 2006
Accepted: 27 June 2006

Abstract

Background: Anthropogenic CO_2 uptake by the ocean decreases the pH of seawater, leading to an 'acidification' which may have potential detrimental consequences on marine organisms [1]. Ocean warming or circulation alterations induced by climate change has the potential to slowdown the rate of acidification of ocean waters by decreasing the amount of CO_2 uptake by the ocean [2]. However, a recent study showed that climate change affected the decrease in pH insignificantly [3]. Here, we examine the sensitivity of future oceanic acidification to climate change feedbacks within a coupled atmosphere-ocean model and find that ocean warming dominates the climate change feedbacks.

Results: Our results show that the direct decrease in pH due to ocean warming is approximately equal to but opposite in magnitude to the indirect increase in pH associated with ocean warming (ie reduced DIC concentration of the upper ocean caused by lower solubility of CO_2).

Conclusion: As climate change feedbacks on pH approximately cancel, future oceanic acidification will closely follow future atmospheric CO_2 concentrations. This suggests the only way to slowdown or mitigate the potential biological consequences of future ocean acidification is to significantly reduce fossil-fuel emissions of CO_2 to the atmosphere.

Background

Rising atmospheric CO_2 concentrations via fossil fuel emissions will lead to an increase in oceanic CO_2 via thermodynamic equilibration. Carbon chemistry in seawater undergoes the following equilibrium reactions as CO_2 enters the ocean.

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow HCO_3^- + H^+ \Leftrightarrow CO_3^{2-} + 2H^+ \quad (1)$$

The pH of seawater is defined by the amount of H+ ions available: $pH = -\log_{10}[H^+]$. Increasing CO_2 concentrations in the surface ocean via anthropogenic CO_2 uptake will have implications for oceanic pH. As shown in equation (1), when CO_2 dissolves in water it forms a weak acid (H_2CO_3), dissociates to bicarbonate generating hydrogen ions (H+), which makes the ocean less basic (pH decreases). Using an ocean-only model forced with atmospheric CO_2 projections (IS92a), Caldeira and Wickett [4]predicted a pH drop of 0.4 units by the year 2100 and a further decline of 0.7 by the year 2300.

Future acidification (lowering of pH) may adversely impact marine biota, but our present understanding of the potential biological response is limited [1]. It is recognised however that a decrease in pH will alter the acid-base balance with the cells of marine organisms [1]. Marine organisms regulate intercellular pH by the metabolic interconversion of acids and bases, the passive chemical buffering of intra- and extra-cellular fluids, and the active ion transport (e.g. proton transport by extra-cellular respiratory proteins such as hemoglobin) [5]. Acid-base imbalances in marine organisms can lead to the dissolution of exoskeletal components such as calcareous shells, metabolic suppression, reduced protein synthesis and reduced activity [6,7]. Experiments to determine the likely response of marine organisms to pH changes have induced large changes in pH under laboratory conditions (>1) [8-13]. Little is known on what the gradual long-term effects of pH lowering will be on marine organisms. As pH changes have the potential to directly impact marine biota it is important to understand the magnitude of these changes under elevated CO_2 levels and global warming.

Projections of future decreases in pH have been obtained from an ocean-only model that has not considered the effect of climate change feedbacks on the carbon chemistry of the ocean [4]. Recently, a study explored the role that climate change plays on the extent of ocean acidification [3]. Using three separate climate models they found climate change to insignificantly impact the projected future decreases of pH. However there was no investigation into this outcome even though the same models used predict large reductions in oceanic CO_2 uptake due to climate change in association with temperature, circulation and biological feedbacks [2]. In this study we use a climate model to examine, partition and discuss the dominating climate change feedbacks controlling the future surface ocean pH.

Results and discussion

Changes in surface pH reflect changes in the speciation of carbon within the ocean and are a function of temperature, salinity, alkalinity and DIC concentrations. With climate change, the model projects an average surface temperature (SST) to warm from 18°C to about 21.5°C by the year 2100 (Figure 1b) while the globally averaged sea surface salinity (SSS) freshens from 34.71 to 34.53. The salinity normalized Alkalinity remained nearly constant at an average global concentration of 2270 μmol/kg. With climate change, we project by 2100 that the surface

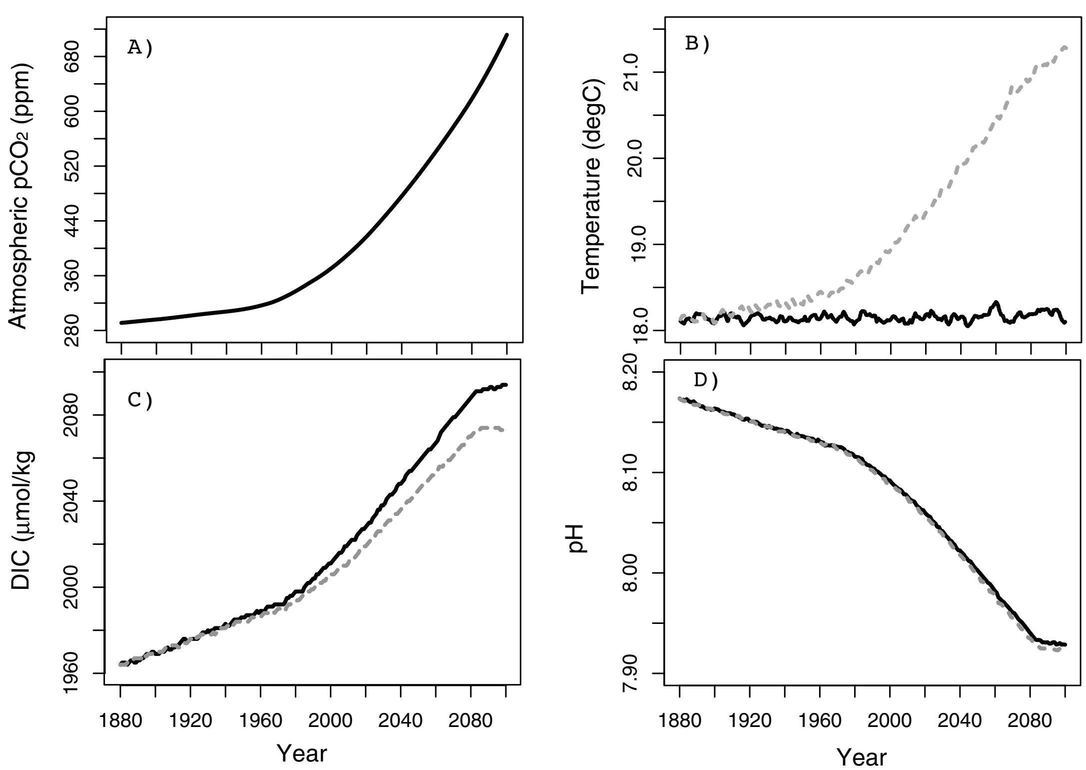

Figure 1
A) IS92a atmospheric CO_2 projections used by our model; B) globally average sea surface temperature from the control experiment (solid line) and climate change experiment (dashed line); C) globally averaged Dissolved Inorganic Carbon (DIC) concentration (μmol/kg); D) globally averaged pH.

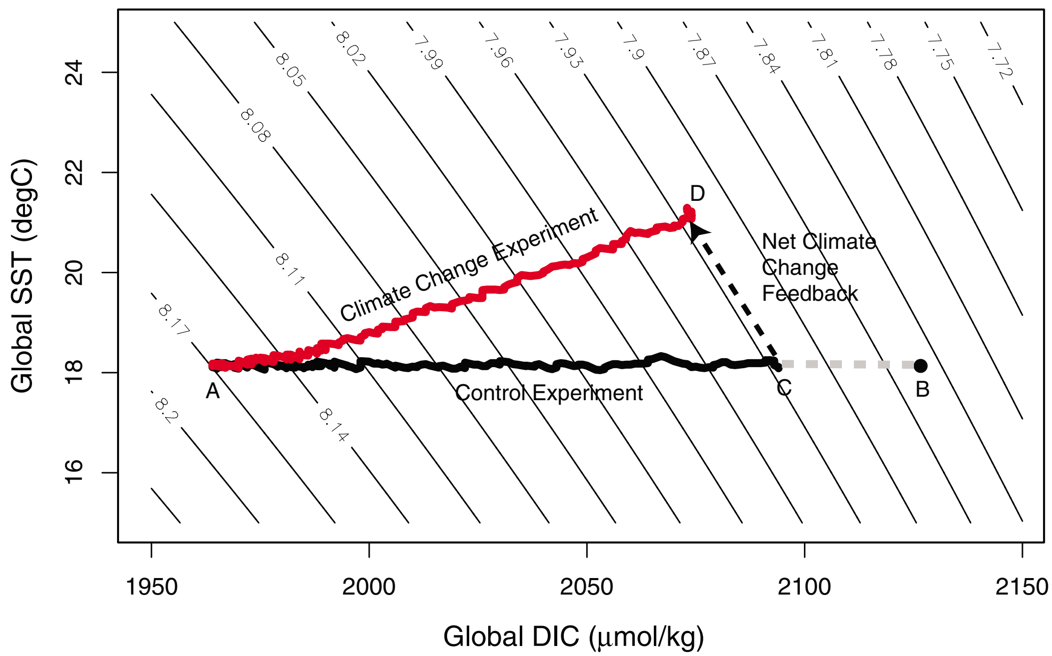

Figure 2
Evolution of mean surface pH in relation to DIC and sea surface temperature for both the control experiment (solid black line) and climate change experiment (solid red line). The *net* climate change feedback is shown as the dashed black vector between the control and climate change experiments. Point A is the initial state in the year 1880 before industrialization. Point B is the pH state (~7.82) in the year 2100 if the ocean absorbed atmospheric CO_2 under equilibrium proportions. Point C is the pH state (~7.93) in the year 2100 for the control experiment and is equivalent to an oceanic steady state solution. Point D is the pH state (~7.93) for the year 2100 under climate change, and includes feedbacks such as circulation, biological production and temperature.

ocean DIC concentration is 18% less than the control experiment (reduction in DIC growth from 135 µmol/kg to 110 µmol/kg; see Figure 1c). The reduced growth in DIC concentration with climate change largely reflects reduced solubility of CO_2 in the surface water due to the warming. We find pH decreases to be insensitive to climate change with virtually no difference between the transient and control experiment (Figure 1d). For both experiments, the globally averaged pH is projected to decrease from 8.17 in the year 1880 to about 7.91 by 2100.

The insensitivity of pH to climate change is associated with compensating effects related to the ocean warming feedback. Figure 2 better illustrates the influence of DIC and sea surface temperature (SST) on pH in relation to the evolution of both the control and climate change experiments from the model. The evolution of pH from 1880 to 2100 for the control experiment is illustrated by line A-C, while line A-D in Figure 2 is the evolution of the climate change experiment. In the control experiment, there is no change in SST while oceanic uptake of anthropogenic CO_2 increases DIC concentration (by ~135 µmol/kg), which consequently lowers pH considerably. Under climate change, SST increases while DIC concentration increases to a lesser extent than for the control (by ~110 µmol/kg). The difference between points C and D shows the net affect of climate change on pH. For pH, point C and D (net climate change feedback) lie almost exactly on contours of constant pH, therefore implying that climate change has no net affect on projected declining pH.

The solubility driven reductions in the growth of surface DIC concentration due to warming increase pH by a magnitude that is almost equal to pH decline directly associated with ocean warming, which cause the two affects to almost cancel each other. In Figure 2, the lines of constant pH are almost parallel to slope of the $\left(\frac{\partial DIC}{\partial SST}\right)\Big\|_{ALK,Sal,pCO2=constant}$. As a consequence, the projected global pH decline of the climate change experiment does not differ from the projection made with the control experiment.

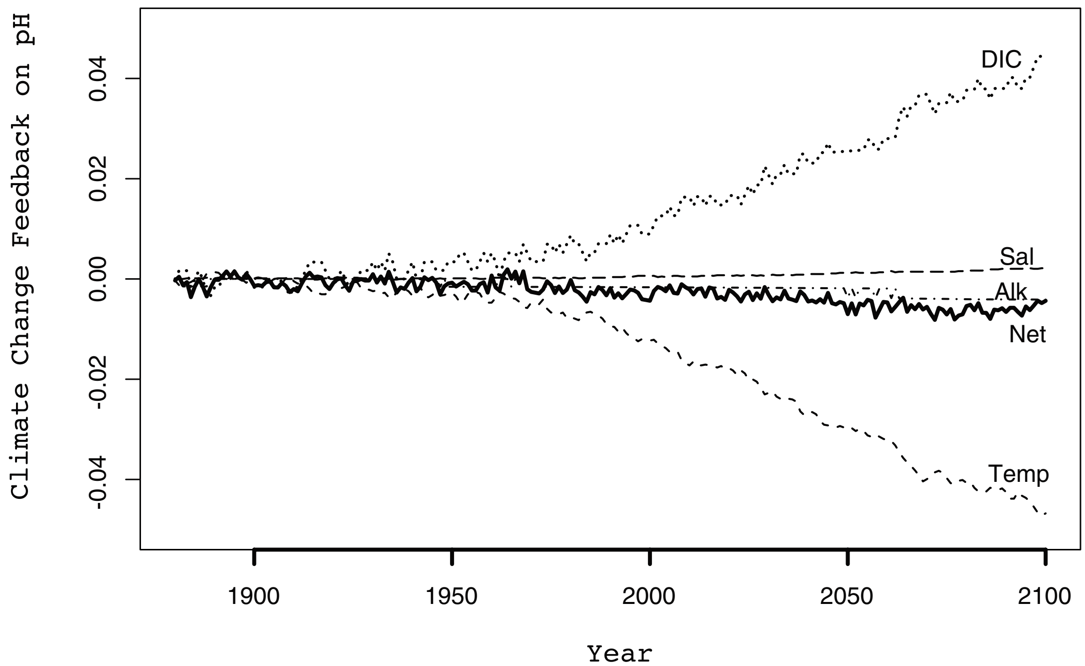

Figure 3
Net climate change effects on pH between 1880 and 2100 due to various controlling parameters. Negative pH change implies that climate change will amplify the reduction in pH from the control simulation, while a positive pH implies that climate change will buffer (or reduce) the decline in pH from the control simulation. Solid line represents the overall net climate change feedback while the dashed lines indicate changes due to DIC (which are solubility driven), direct effects of Temperature (Temp), Alkalinity (Alk) and Salinity (Sal).

To investigate the importance of different water properties changes on global-averaged pH, we compare the change in pH between the control experiment and climate change experiment for each individual water property change (ie. $\left(\frac{\partial pH(SST, Sal, DIC, ALK)}{\partial SST}\right)\Big|_{Sal, ALK, DIC = control\,experiment}$). Future variations in salinity and alkalinity have little effect on pH, while the direct effects of ocean warming (SST) and indirect effects on DIC (solubility induced changes) dominate (Figure 3). For pH, the negative feedback associated with a reduction in growth of surface DIC concentrations due to solubility is offset by the positive feedback associated with the direct effects of ocean warming (Figure 3). The overall net climate change feedback impact on pH is small. However, as discussed earlier climate models show different sensitivities and it is unclear whether this result is unique to the CSIRO climate model. There is circumstantial evidence to suggest this phenomena may be independent of the type of climate model used. The IPSL climate model has a lower sensitivity (~3.6°C) but was found to undergo similar pH insensitivity as to the CSIRO climate model in Orr et al. (2005). Analysis on models with a broad range of sensitivities will further elucidate if our results are more indicative of climate models in general.

The CO_2 biological pump within our simulations changed considerably with carbon export decreasing with climate change [2]. These changes would also lead to changes in pH within the water column however in the surface ocean, biologically mediated pH changes were found to be negligible.

Figure 4a shows the zonal evolution of pH in the surface ocean up to the year 2100. Both the pH distribution along with it decline is zonally relatively uniform, decreasing from about 8.2 to 7.9 although the Arctic Ocean is more basic (~8.3). Figure 4b shows the zonal evoution of pH associated with the net climate change feedback. There is very little variation in the magnitude and structure of the meridional change in pH due to climate change. In the Arctic Ocean (>60°N) however, there is a positive feedback and a faint positive feedback in the high Southern Ocean (>65°S) beyond the year 2070. For these regions, climate change reduces sea-ice extent thereby allowing more absorption of anthropogenic CO_2 independent of

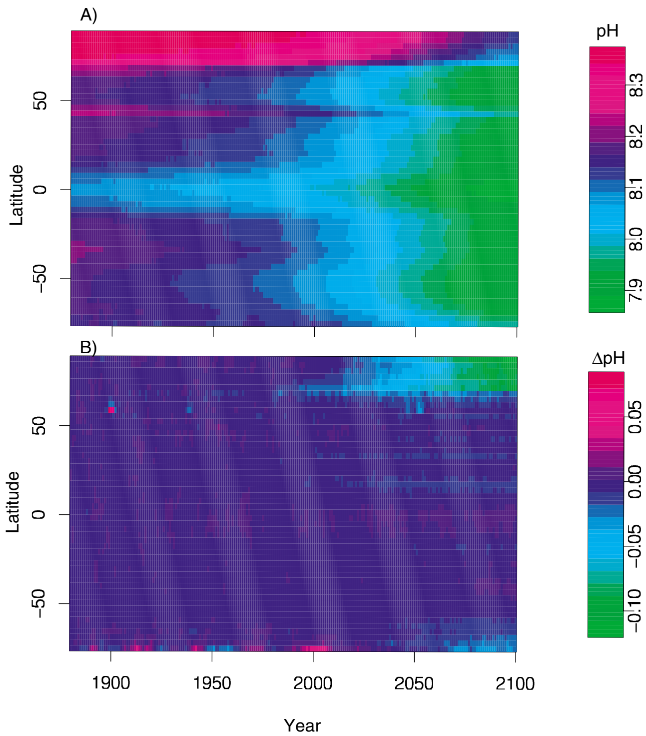

Figure 4
A) Zonally averaged temporal evolution of surface ocean pH from the climate change experiment up to the year 2100; B) Simulated zonally averaged evolution of net climate change feedback on surface ocean pH.

ocean warming which reduces pH beyond that of other parts of the ocean.

Conclusion

Our study confirms previous suggestions that climate change feedbacks do not influence the projected decline in pH. This insensitivity to climate change occurs because the decrease in pH due to warming is nearly equal to but opposite in magnitude to the pH increase associated with reduced growth of DIC concentration in the upper ocean caused by reduced solubility of CO_2 with ocean warming (Figure 2). Therefore, projections that neglect climate change [4] provide a reasonable estimate of the future pH change. Future projections of ocean acidification will therefore mainly be dependent on the future level of atmospheric CO_2. The consequences of a small but sustained decrease in oceanic pH on marine phytoplankton are virtually unknown. It will be important for marine ecologists in the future to better understand the sensitivities of phytoplankton growth to pH in particular, so as to better quantify the likely future biological changes at the regional and global scale.

Methods

Model

The coupled atmosphere-ice-ocean carbon cycle model developed by the Commonwealth Scientific Industrial Research Organisation (CSIRO) was used for this study [14]. Details of the model are described elsewhere [2]. Climate change feedbacks were quantified by comparing two separate climate model experiments. The 'control' experiment did not include the warming effects of elevated greenhouse gases in the atmosphere (no radiative forcing) while the 'climate change' experiment explicitly includes the radiative forcing of greenhouse gases in the atmosphere. For both experiments atmospheric CO_2 levels increased according to observations between 1880 to 1995 then followed IS92a projections until the year 2100 [15]. Differing climate models maintain differing sensitivities to anthropogenic climate forcing. The sensitivity is defined as the global annual temperature change associated with a doubling of atmospheric CO_2. The sensitivity of the CSIRO Mark II climate model is 4.3°C [16], and is at the higher end of global model sensitivities [15].

Authors' contributions

BIM initiated the study and RJM developed the carbon cycle model. BIM analysed the model output, provided the main interpretations for the paper and wrote a draft manuscript. RJM provided further interpretations and approved the final version.

Acknowledgements

We acknowledge the constructive suggestions of the editor, Christopher Sabine, Mark Baird and three anonymous reviewers. B.I.M was supported through a grant from the Australian Research Council while R.J.M was supported through the Australian Greenhouse Office Climate Change Program.

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May 5, 2008

Arctic sea ice forecasts point to lower-than-average season ahead

Spring has arrived in the Arctic. After peaking at 15.21 million square kilometers (5.87 million square miles) in the second week of March, Arctic sea ice extent has declined through the month of April. April extent has not fallen below the lowest April extent on record, but it is still below the long-term average.

Taken together, an assessment of the available evidence, detailed below, points to another extreme September sea ice minimum. Could the North Pole be ice free this melt season? Given that this region is currently covered with first-year ice, that seems quite possible.

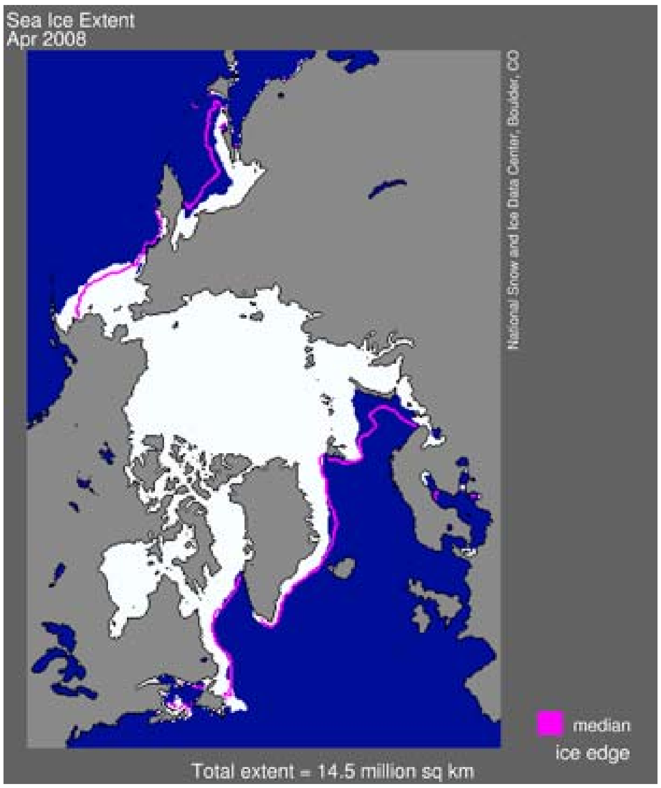
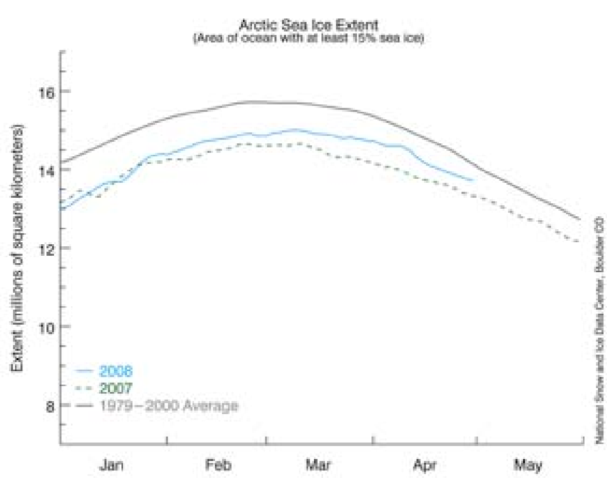


Figure 1. Arctic sea ice extent for April 2008 was 14.49 million square kilometers (5.59 million square miles). The magenta line shows the median ice extent for March from 1979 to 2000. Data Note
—Credit: National Snow and Ice Data Center

See High Resolution Image

Overview of conditions

For the month of April, Arctic sea ice extent stood at 14.49 million square kilometers (5.59 million square miles), which is 0.61 million square kilometers (0.24 million square miles) greater than April 2007, but is still 0.51 million square kilometers (0.20 million square miles) less than the 1979 to 2000 average for April.



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Conditions in context

Although there is more ice than this time last year, the average decline rate through the month of April was 6,000 square kilometers per day (2,300 square

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This report, updated monthly during the summer melt season, synthesizes scientific projections concerning the September 2008 minimum. From the Study of Environmental Arctic Change.

NSIDC Scientist Discusses Sea Ice

Mark Serreze gave the Nye Lecture at AGU in 2007; he talked about Arctic sea ice. Click on the link above and scroll to "C24A Nye Lecture."

faster than last April.

Figure 2. Daily sea ice extent; the blue line indicates 2008; the black line indicates extent from 1979 to 2000; the dotted line shows extent from December 2006 through April 2007.
—Credit: National Snow and Ice Data Center

See High Resolution Image

Faster decline reflects warmer Arctic

At least part of the explanation for this fairly rapid decline lies in the warm conditions that characterized April over the Arctic Ocean and peripheral seas. Anomalies over some regions exceed 5 degrees Celsius (9 degrees Fahrenheit). For the most part, this unusual warmth is consistent with shifts in atmospheric circulation that bring warm air into the region. The distinct hot spot near Novaya Zemlya, in the upper left quadrant of Figure 3, overlies an open water area where heat is being released to the atmosphere. In past years, this area tended to be ice covered in April, preventing this heat release.

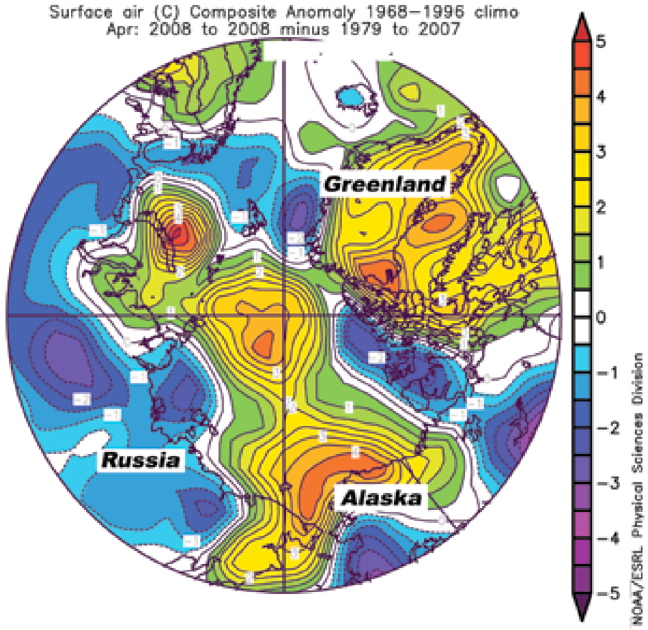

Figure 3. The spatial pattern of surface air temperature anomalies for April 2008, expressed with respect to the average for 1979 to 2007, shows unusually high temperatures over the Arctic Ocean and peripheral seas.
—Credit: From National Snow and Ice Data Center courtesy Climate Diagnostic Center

See High Resolution Image

Estimating September extent based on past conditions

As discussed in our April analysis, the ice cover this spring shows an unusually large proportion of young, thin first-year ice; about 30% of first-year ice typically survives the summer melt season, while 75% of the older ice survives. For a simple estimate of the likelihood of breaking last year's September

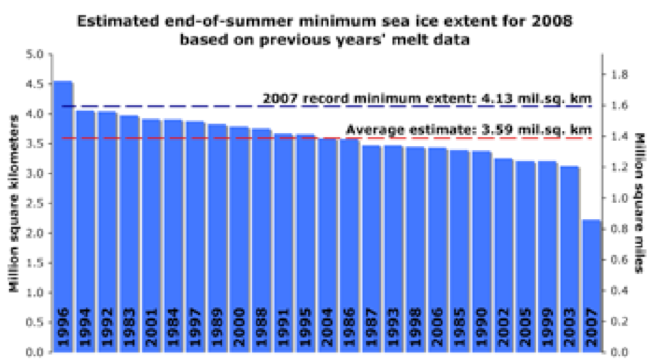

Figure 4. This bar plot shows estimates of sea ice extent at the 2008 September minimum based on known ice survival rates. The blue dotted line indicates the record-breaking minimum extent of 2007; the red dotted line shows the mean estimate based on all years between 1983 and 2007.
—Credit: National Snow and Ice Data Center

See High Resolution Image

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This gives us 25 different estimates, one for each year that we have reliable ice-age data (see Figure 4). To avoid beating the September 2007 record low, more than 50% of this year's first-year ice would have to survive; this has only happened once in the last 25 years, in 1996. If we apply the survival rates averaged over all years to current conditions, the end-of-summer extent would be 3.59 million square kilometers (1.39 million square miles). With survival rates similar to those in 2007, the minimum for the 2008 season would be only 2.22 million square kilometers (0.86 million square miles). By comparison the record low extent, set last September, was 4.28 million square kilometers (1.65 million square miles).

Forecasting September extent with climate predictors

Sheldon Drobot at the Center for Astrodynamics Research at the University of Colorado at Boulder and colleagues have developed a sophisticated forecasting technique. The forecast considers sea ice extent, ice age, summer and winter temperatures, cloudiness, the phase of the Atlantic Oscillation, and climate trends as predictors (see the papers cited below for details; visit the Arctic Oscillation Index). As reported last month, the Arctic Oscillation was in its positive phase through the winter season, associated with a wind pattern helping to flush thick ice out of the Arctic, leaving thinner ice. This is one of the factors helping to set the stage for pronounced ice losses this summer. Drobot predicts a 59% chance of a new record minimum this year; read the press release. Todd Arbetter of the U.S. National Ice Center tells us that his group is working to implement a version of Drobot's analysis scheme for operational forecasting.

Ronald Lindsay of the University of Washington's Applied Physics Laboratory and collaborators recently published results from their own ice prediction system, based on a retrospective analysis of the modeled state of the ice and ocean system (see the paper cited below for details). The model is successful in explaining around 75% of the year-to-year variations for the past few decades; for 2008, the model implies a very low, but not extreme, sea ice minimum. Lindsay cautions that sea ice conditions are now changing so rapidly that predictions based on relationships developed from the past 50 years of data may no longer apply.

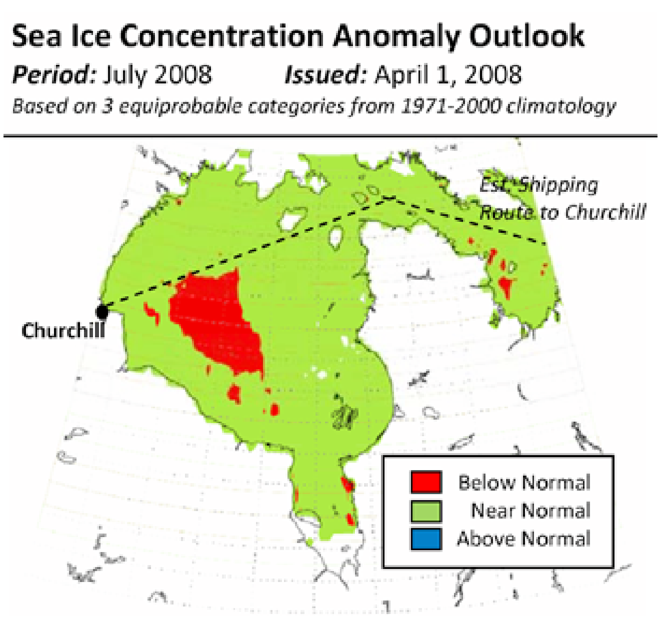

Figure 5. This image shows probable ice conditions in the Hudson Bay for July 2008; the colored area is the bay and white indicates land masses. Green shows near-normal ice conditions; red shows below average; blue shows above average.
—Credit: From National Snow and Ice Data Center courtesy A.Tivy

See High Resolution Image

Regional shipping forecasts

Marine transportation in the Arctic is expected to increase as ice extent decreases. However, the viability of shipping through the Northwest Passage in the Canadian Arctic Islands, the Northern Sea Route along the Eurasian coast and in other areas such as Hudson Bay depend on local ice conditions, which can be highly variable. Adrienne Tivy at the University of Calgary and colleagues have investigated the variables that affect shipping in Hudson Bay. They found that the date on which shipping routes open across Hudson Bay to Churchill is most strongly

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correlated with sea surface temperatures between January and March and atmospheric pressure patterns in the East Atlantic in January. This year, Adrienne Tivy and colleagues predict that shipping to Churchill in a non-ice-strengthened vessel will be possible on July 16, 15 days earlier than the long-term mean of July 31. They estimate below-normal ice concentrations in the southwestern bay, but near-normal conditions elsewhere.

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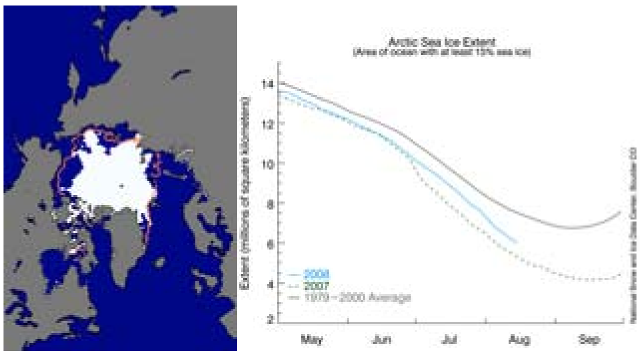

Sea ice data updated daily, with one-day lag: extent (left), time series (right). Orange line in extent image and gray line in timeseries show normal extent for the day shown from 1979 to 2000. Click for high-resolution versions. To learn more about the data used, see About the data. —*Credit: National Snow and Ice Data Center*

Arctic sea ice reflects sunlight, keeping the polar regions cool and moderating global climate. According to scientific measurements, Arctic sea ice has declined dramatically over at least the past thirty years, with the most extreme decline seen in the summer melt season.

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NSIDC Scientist Discusses Sea I

Northwest Passage opens

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The pace of sea ice loss sharply quickened in the past ten days, triggered by a series of strong storms that broke up thin ice in the Beaufort and Chukchi Seas. Amundsen's historic Northwest Passage is opening up; the wider and deeper route through Parry Channel is currently still clogged with ice.

Note: Analysis updates, unless otherwise noted, now show a single-day *extent value for Figure 1, as opposed to the standard* monthly average*. While monthly average extent images are more accurate in understanding long-term changes, the daily images are helpful in monitoring sea ice conditions in near-real time.*

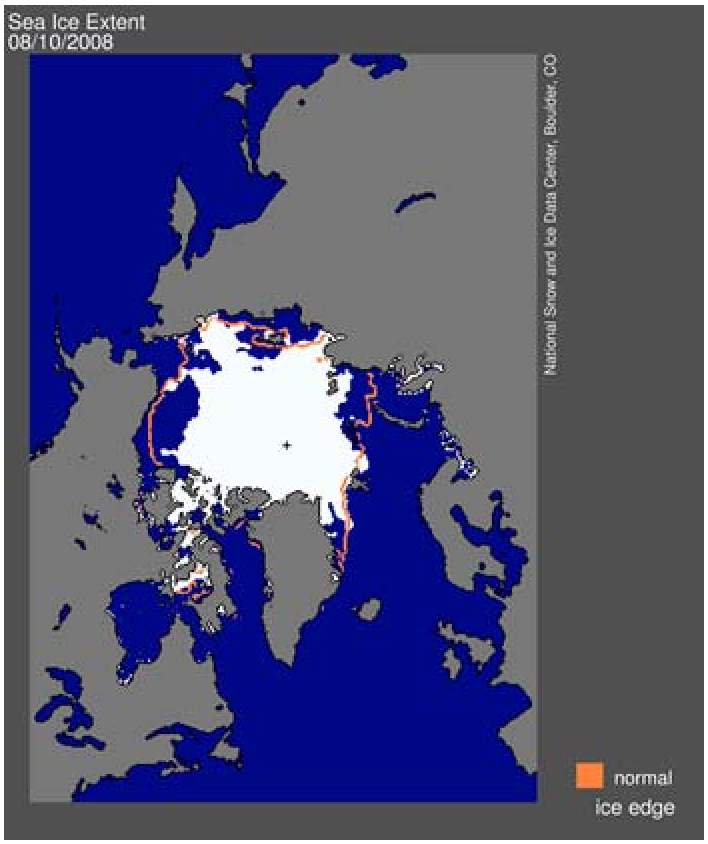
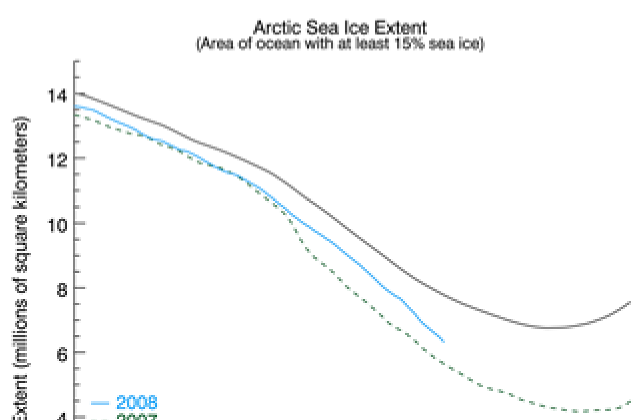


Figure 1. Daily Arctic sea ice extent for August 10, 2008, was 6.54 million square kilometers (2.52 million square miles). The orange line shows the 1979 to 2000 average extent for that day. The black cross indicates the geographic North Pole. Sea Ice Index data. [About the data].
—Credit: National Snow and Ice Data Center

[High-resolution image]

Overview of conditions

Arctic sea ice extent on August 10 was 6.54 million square kilometers (2.52 million square miles), a decline of 1 million square kilometers (390,000 square miles) since the beginning of the month. Extent is now within 780,000 square kilometers (300,000 square miles) of last year's value on the same date and is 1.50 million square kilometers (580,000 square miles) below the 1979 to 2000 average.



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Conditions in context

Ice extent has begun to decline sharply. The decline rate surged to -113,000 square

Mark Serreze gave the Nye Lecture at AGU in 2007; he talked about Arctic se ice. Click on the link above and scroll tc "C24A Nye Lecture."

gray line indicates extent from 1979 to 2000; the dotted green line shows extent for 2007. Sea Ice Index data.
—Credit: National Snow and Ice Data Center

[High-resolution Image](#)

on August 7 and as of August 10 was -103,000 square kilometers per day. This compares to the long-term average decline of -76,000 square kilometers per day for this time of year. Normally, the peak decline rate is in early July.

Many of the areas now seeing a rapid retreat saw an early melt onset (see [July 2, 2008](#)); this helped set the stage for rapid retreat ([July 17](#) and [April 7](#)). However, the more fundamental issue is that these regions started the melt season covered with thin first-year ice, which is especially vulnerable to melting out completely. Thin ice is also vulnerable to breakup by winds; the last ten days have seen a windy, stormy pattern that has accelerated the ice loss.

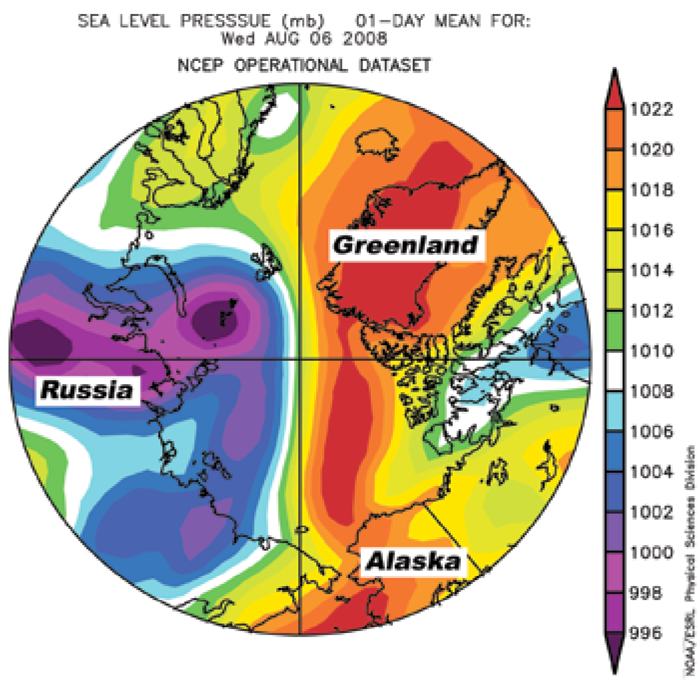


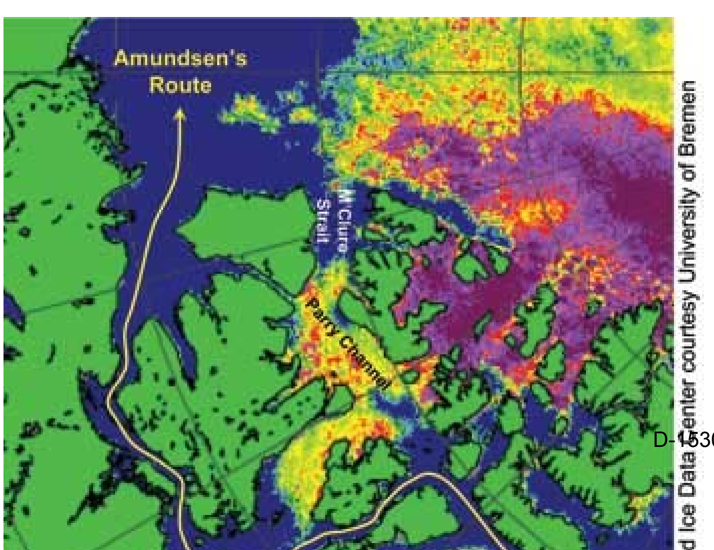
Figure 3. Sea-level pressure for August 8, 2008, shows a weather pattern favoring ice melt. Areas of high pressure are shown in yellow and red; areas of low pressure are shown in blue and purple.
—Credit: From National Snow and Ice Data Center courtesy Climate Diagnostic Center

[High-resolution image](#)

Storms trigger increased melt

A series of storms north of Alaska and Siberia in late July and early August have helped break up the thin ice and have brought warm southerly winds into the region.

Subsequently, a pattern has developed with high pressure over the Beaufort Sea and low pressure over the Laptev and East Siberian Seas (Figure 3). In accord with [Buys Ballot's Law](#), this pattern has brought southerly winds to the region, enhancing melt, breaking up ice, and pushing the ice edge northward.



Opening of Amundsen's Northwest Passage

The Northwest Passage that Roald Amundsen navigated with great difficulty starting in 1903 is

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concentration on August 10, 2008, over the Northwest Passage region. The yellow line indicates Amundsen's historic route through the passage. NASA AMSR-E data.
—Credit: From National Snow and Ice Data Center courtesy University of Bremen

High-resolution image

opening for the second year in a row, as shown in the AMSR-E sea ice product from the University of Bremen (Figure 4).

The most recent operational analysis from the Canadian Ice Service and the U.S. National Ice Center on August 8 showed a small section of Amundsen's historic path still blocked by a 50-kilometer (31-mile) stretch of sea ice, although that should melt within the next few days.

Amundsen's route requires sailing through treacherous narrow and shallow channels, making it impractical for deep-draft commercial ships. The more important northern route, through the wide and deep Parry Channel, is still ice-clogged. The northern route opened in mid-August last year; it may still open up before the end of this year's melt season.

For previous analysis, please see the drop-down menu under Archives in the right navigation at the top of this page.

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The Scientific Consensus on Climate Change

Naomi Oreskes

Policy-makers and the media, particularly in the United States, frequently assert that climate science is highly uncertain. Some have used this as an argument against adopting strong measures to reduce greenhouse gas emissions. For example, while discussing a major U.S. Environmental Protection Agency report on the risks of climate change, then–EPA administrator Christine Whitman argued, "As [the report] went through review, there was less consensus on the science and conclusions on climate change" (*1*). Some corporations whose revenues might be adversely affected by controls on carbon dioxide emissions have also alleged major uncertainties in the science (*2*). Such statements suggest that there might be substantive disagreement in the scientific community about the reality of anthropogenic climate change. This is not the case.

Without substantial disagreement, scientists find human activities are heating the Earth's surface.

The scientific consensus is clearly expressed in the reports of the Intergovernmental Panel on Climate Change (IPCC). Created in 1988 by the World Meteorological Organization and the United Nations Environmental Programme, IPCC's purpose is to evaluate the state of climate science as a basis for informed policy action, primarily on the basis of peer-reviewed and published scientific literature (*3*). In its most recent assessment, IPCC states unequivocally that the consensus of scientific opinion is that Earth's climate is being affected by human activities: "Human activities … are modifying the concentration of atmospheric constituents … that absorb or scatter radiant energy. … [M]ost of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations" [p. 21 in (*4*)].

IPCC is not alone in its conclusions. In recent years, all major scientific bodies in the United States whose members' expertise bears directly on the matter have issued similar statements. For example, the National Academy of Sciences report, *Climate Change Science: An Analysis of Some Key Questions*, begins: "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise" [p. 1 in (*5*)]. The report explicitly asks whether the IPCC assessment is a fair summary of professional scientific thinking, and answers yes: "The IPCC's conclusion that most of the observed warming of the last 50 years is likely to have been due to the increase in greenhouse gas concentrations accurately reflects the current thinking of the scientific community on this issue" [p. 3 in (*5*)].

Others agree. The American Meteorological Society (*6*), the American Geophysical Union (*7*), and the American Association for the Advancement of Science (AAAS) all have issued statements in recent years concluding that the evidence for human modification of climate is compelling (*8*).

The drafting of such reports and statements involves many opportunities for comment, criticism, and revision, and it is not likely that they would diverge greatly from the opinions of the societies' members. Nevertheless, they might downplay legitimate dissenting opinions. That hypothesis was tested by analyzing 928 abstracts, published in refereed scientific journals between 1993 and 2003, and listed in the ISI database with the keywords "climate change" (*9*).

The 928 papers were divided into six categories: explicit endorsement of the consensus position, evaluation of impacts, mitigation proposals, methods, paleoclimate analysis, and rejection of the consensus position. Of all the papers, 75% fell into the first three categories, either explicitly or implicitly accepting the consensus view; 25% dealt with methods or paleoclimate, taking no position on current anthropogenic climate change. Remarkably, none of the papers disagreed with the consensus position.

Admittedly, authors evaluating impacts, developing methods, or studying paleoclimatic change might believe that current climate change is natural. However, none of these papers argued that point.

This analysis shows that scientists publishing in the peer-reviewed literature agree with IPCC, the National Academy of Sciences, and the public statements of their professional societies. Politicians, economists, journalists, and others may have the impression of confusion, disagreement, or discord among climate scientists, but that impression is incorrect.

The scientific consensus might, of course, be wrong. If the history of science teaches anything, it is humility, and no one can be faulted for failing to act on what is not known. But our grandchildren will surely blame us if they find that we understood the reality of anthropogenic climate change and failed to do anything about it.

Many details about climate interactions are not well understood, and there are ample grounds for continued research to provide a better basis for understanding climate dynamics. The question of what to do about climate change is also still open. But there is a scientific consensus on the reality of anthropogenic climate change. Climate scientists have repeatedly tried to make this clear. It is time for the rest of us to listen.

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9. The first year for which the database consistently published abstracts was 1993. Some abstracts were deleted from our analysis because, although the authors had put "climate change" in their key words, the paper was not about climate change.

10. This essay is excerpted from the 2004 George Sarton Memorial Lecture, "Consensus in science: How do we know we're not wrong," presented at the AAAS meeting on 13 February 2004. I am grateful to AAAS and the History of Science Society for their support of this lectureship; to my research assistants S. Luis and G. Law; and to D. C. Agnew, K. Belitz, J. R. Fleming, M. T. Greene, H. Leifert, and R. C. J. Somerville for helpful discussions.

10.1126/science.1103618

D-1532

Published by AAAS

ERRATUM

Post date 21 January 2005

Essays: "The scientific consensus on climate change" by N. Oreskes (3 Dec. 2004, p. 1686). The final sentence of the fifth paragraph should read "That hypothesis was tested by analyzing 928 abstracts, published in refereed scientific journals between 1993 and 2003, and listed in the ISI database with the keywords 'global climate change' (*9*)." The keywords used were "global climate change," not "climate change."

http://www.latimes.com/news/opinion/la-oe-oreskes24jul24,0,823343.story?coll=la-opinion-rightrail
From the Los Angeles Times

Global Warming -- Signed, Sealed and Delivered

Scientists agree: The Earth is warming, and human activities are the principal cause.

By Naomi Oreskes
NAOMI ORESKES is a history of science professor at UC San Diego.

July 24, 2006

AN OP-ED article in the Wall Street Journal a month ago claimed that a published study affirming the existence of a scientific consensus on the reality of global warming had been refuted. This charge was repeated again last week, in a hearing of the House Committee on Energy and Commerce.

I am the author of that study, which appeared two years ago in the journal Science, and I'm here to tell you that the consensus stands. The argument put forward in the Wall Street Journal was based on an Internet posting; it has not appeared in a peer-reviewed journal — the normal way to challenge an academic finding. (The Wall Street Journal didn't even get my name right!)

My study demonstrated that there is no significant disagreement within the scientific community that the Earth is warming and that human activities are the principal cause.

Papers that continue to rehash arguments that have already been addressed and questions that have already been answered will, of course, be rejected by scientific journals, and this explains my findings. Not a single paper in a large sample of peer-reviewed scientific journals between 1993 and 2003 refuted the consensus position, summarized by the National Academy of Sciences, that "most of the observed warming of the last 50 years is likely to have been due to the increase in greenhouse gas concentrations."

Since the 1950s, scientists have understood that greenhouse gases produced by burning fossil fuels could have serious effects on Earth's climate. When the 1980s proved to be the hottest decade on record, and as predictions of climate models started to come true, scientists increasingly saw global warming as cause for concern.

In 1988, the World Meteorological Assn. and the United Nations Environment Program joined forces to create the Intergovernmental Panel on Climate Change to evaluate the state of climate science as a basis for informed policy action. The panel has issued three assessments (1990, 1995, 2001), representing the combined expertise of 2,000 scientists from more than 100 countries, and a fourth report is due out shortly. Its conclusions — global warming is occurring, humans have a major role in it — have been ratified by scientists around the world in published scientific papers, in statements issued by professional scientific societies and in reports of the National Academy of Sciences, the British Royal Society and many other national and royal academies of science worldwide. Even the Bush administration accepts the fundamental findings. As President Bush's science advisor, John Marburger III, said last year in a speech: "The climate is changing; the Earth is warming."

To be sure, there are a handful of scientists, including MIT professor Richard Lindzen, the author of the Wall Street Journal editorial, who disagree with the rest of the scientific community. To a historian of science like me, this is not surprising. In any scientific community, there are always some individuals who simply refuse to accept new ideas and evidence. This is especially true when the new evidence strikes at their core beliefs and values.

Earth scientists long believed that humans were insignificant in comparison with the vastness of geological time and the power of geophysical forces. For this reason, many were reluctant to accept that humans had become a force of nature, and it took decades for the present understanding to be achieved. Those few who refuse to accept it are not ignorant, but they are stubborn. They are not unintelligent, but they are stuck on details that cloud the larger issue. Scientific communities include tortoises and hares, mavericks and mules.

A historical example will help to make the point. In the 1920s, the distinguished Cambridge geophysicist Harold Jeffreys rejected the idea of continental drift on the grounds of physical impossibility. In the 1950s, geologists and geophysicists began to accumulate overwhelming evidence of the reality of continental motion, even though the physics of it was poorly understood. By the late 1960s, the theory of plate tectonics was on the road to near-universal acceptance.

Yet Jeffreys, by then Sir Harold, stubbornly refused to accept the new evidence, repeating his old arguments about the impossibility of the thing. He was a great man, but he had become a scientific mule. For a while, journals continued to publish Jeffreys' arguments, but after a while he had nothing new to say. He died denying plate tectonics. The scientific debate was over.

So it is with climate change today. As American geologist Harry Hess said in the 1960s about plate tectonics, one can quibble about the details, but the overall picture is clear.

Yet some climate-change deniers insist that the observed changes might be natural, perhaps caused by variations in solar irradiance or other forces we don't yet understand. Perhaps there are other explanations for the receding glaciers. But "perhaps" is not evidence.

The greatest scientist of all time, Isaac Newton, warned against this tendency more than three centuries ago. Writing in "Principia Mathematica" in 1687, he noted that once scientists had successfully drawn conclusions by "general induction from phenomena," then those conclusions had to be held as "accurately or very nearly true notwithstanding any contrary hypothesis that may be imagined…. "

Climate-change deniers can imagine all the hypotheses they like, but it will not change the facts nor "the general induction from the phenomena."

None of this is to say that there are no uncertainties left — there are always uncertainties in any live science. Agreeing about the reality and causes of current global warming is not the same as agreeing about what will happen in the future. There is continuing debate in the scientific community over the likely rate of future change: not "whether" but "how much" and "how soon." And this is precisely why we need to act today: because the longer we wait, the worse the problem will become, and the harder it will be to solve.

ARTICLES

Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms

James C. Orr[1], Victoria J. Fabry[2], Olivier Aumont[3], Laurent Bopp[1], Scott C. Doney[4], Richard A. Feely[5], Anand Gnanadesikan[6], Nicolas Gruber[7], Akio Ishida[8], Fortunat Joos[9], Robert M. Key[10], Keith Lindsay[11], Ernst Maier-Reimer[12], Richard Matear[13], Patrick Monfray[1]†, Anne Mouchet[14], Raymond G. Najjar[15], Gian-Kasper Plattner[7,9], Keith B. Rodgers[1,16]†, Christopher L. Sabine[5], Jorge L. Sarmiento[10], Reiner Schlitzer[17], Richard D. Slater[10], Ian J. Totterdell[18]†, Marie-France Weirig[17], Yasuhiro Yamanaka[8] & Andrew Yool[18]

Today's surface ocean is saturated with respect to calcium carbonate, but increasing atmospheric carbon dioxide concentrations are reducing ocean pH and carbonate ion concentrations, and thus the level of calcium carbonate saturation. Experimental evidence suggests that if these trends continue, key marine organisms—such as corals and some plankton—will have difficulty maintaining their external calcium carbonate skeletons. Here we use 13 models of the ocean–carbon cycle to assess calcium carbonate saturation under the IS92a 'business-as-usual' scenario for future emissions of anthropogenic carbon dioxide. In our projections, Southern Ocean surface waters will begin to become undersaturated with respect to aragonite, a metastable form of calcium carbonate, by the year 2050. By 2100, this undersaturation could extend throughout the entire Southern Ocean and into the subarctic Pacific Ocean. When live pteropods were exposed to our predicted level of undersaturation during a two-day shipboard experiment, their aragonite shells showed notable dissolution. Our findings indicate that conditions detrimental to high-latitude ecosystems could develop within decades, not centuries as suggested previously.

Ocean uptake of CO_2 will help moderate future climate change, but the associated chemistry, namely hydrolysis of CO_2 in seawater, increases the hydrogen ion concentration $[H^+]$. Surface ocean pH is already 0.1 unit lower than preindustrial values. By the end of the century, it will become another 0.3–0.4 units lower[1,2] under the IS92a scenario, which translates to a 100–150% increase in $[H^+]$. Simultaneously, aqueous CO_2 concentrations $[CO_2(aq)]$ will increase and carbonate ion concentrations $[CO_3^{2-}]$ will decrease, making it more difficult for marine calcifying organisms to form biogenic calcium carbonate ($CaCO_3$). Substantial experimental evidence indicates that calcification rates will decrease in low-latitude corals[3–5], which form reefs out of aragonite, and in phytoplankton that form their tests (shells) out of calcite[6,7], the stable form of $CaCO_3$. Calcification rates will decline along with $[CO_3^{2-}]$ owing to its reaction with increasing concentrations of anthropogenic CO_2 according to the following reaction:

$$CO_2 + CO_3^{2-} + H_2O \rightarrow 2HCO_3^- \quad (1)$$

These rates decline even when surface waters remain supersaturated with respect to $CaCO_3$, a condition that previous studies have predicted will persist for hundreds of years[4,8,9].

Recent predictions of future changes in surface ocean pH and carbonate chemistry have primarily focused on global average conditions[1,2,10] or on low latitude regions[4], where reef-building corals are abundant. Here we focus on future surface and subsurface changes in high latitude regions where planktonic shelled pteropods are prominent components of the upper-ocean biota in the Southern Ocean, Arctic Ocean and subarctic Pacific Ocean[11–15]. Recently, it has been suggested that the cold surface waters in such regions will begin to become undersaturated with respect to aragonite only when atmospheric CO_2 reaches 1,200 p.p.m.v., more than four times the preindustrial level ($4 \times CO_2$) of 280 p.p.m.v. (ref. 9). In contrast, our results suggest that some polar and subpolar surface waters will become undersaturated at $\sim 2 \times CO_2$, probably within the next 50 years.

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Changes in carbonate

We have computed modern-day ocean carbonate chemistry from observed alkalinity and dissolved inorganic carbon (DIC), relying on data collected during the CO_2 Survey of the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS). These observations are centred around the year 1994, and have recently been provided as a global-scale, gridded data product GLODAP (ref. 16; see Supplementary Information). Modern-day surface $[CO_3^{2-}]$ varies meridionally by more than a factor of two, from average concentrations in the Southern Ocean of 105 μmol kg^{-1} to average concentrations in tropical waters of 240 μmol kg^{-1} (Fig. 1). Low $[CO_3^{2-}]$ in the Southern Ocean is due to (1) low surface temperatures and CO_2-system thermodynamics, and (2) large amounts of upwelled deep water, which contain high $[CO_2(aq)]$ from organic matter remineralization. These two effects reinforce one another, yielding a high positive correlation of present-day $[CO_3^{2-}]$ with temperature (for example, $R^2 = 0.92$ for annual mean surface maps). Changes in $[CO_3^{2-}]$ and $[CO_2(aq)]$ are also inextricably linked to changes in other carbonate chemistry variables (Supplementary Fig. S1).

We also estimated preindustrial $[CO_3^{2-}]$ from the same data, after subtracting data-based estimates of anthropogenic DIC (ref. 17) from the modern DIC observations and assuming that preindustrial and modern alkalinity fields were identical (see Supplementary Information). Relative to preindustrial conditions, invasion of anthropogenic CO_2 has already reduced modern surface $[CO_3^{2-}]$ by more than 10%, that is, a reduction of 29 μmol kg^{-1} in the tropics and 18 μmol kg^{-1} in the Southern Ocean. Nearly identical results were found when, instead of the data-based anthropogenic CO_2 estimates, we used simulated anthropogenic CO_2, namely the median from 13 models that participated in the second phase of the Ocean Carbon-Cycle Model Intercomparison Project, or OCMIP-2 (Fig. 1c).

To quantify future changes in carbonate chemistry, we used simulated DIC from ocean models that were forced by two atmospheric CO_2 scenarios: the Intergovernmental Panel on Climate Change (IPCC) IS92a 'continually increasing' scenario (788 p.p.m.v. in the year 2100) and the IPCC S650 'stabilization' scenario (563 p.p.m.v. in the year 2100) (Fig. 1). Simulated perturbations in DIC relative to 1994 (the GLODAP reference year) were added to the modern DIC data; again, alkalinity was assumed to be constant. To provide a measure of uncertainty, we report model results as the OCMIP median $\pm$ 2σ. The median generally outperformed

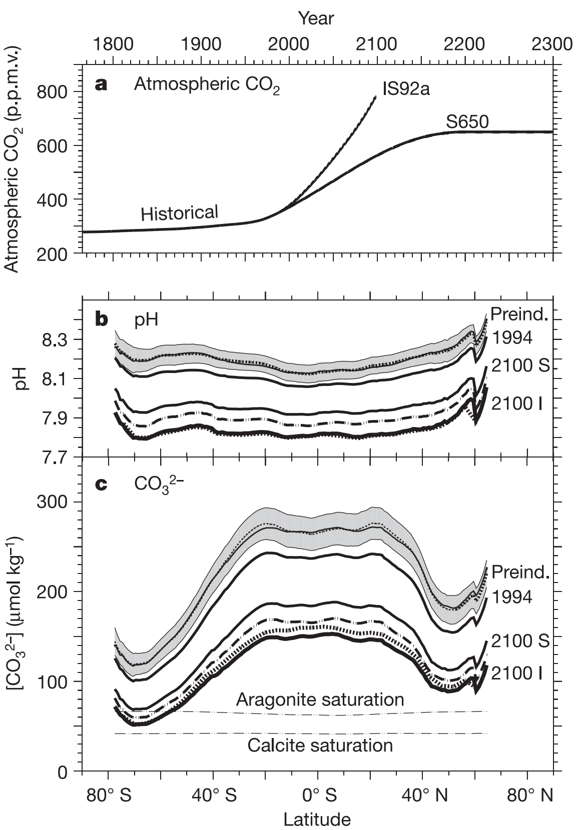

Figure 1 | Increasing atmospheric CO_2 and decreasing surface ocean pH and $[CO_3^{2-}]$. **a**, Atmospheric CO_2 used to force 13 OCMIP models over the industrial period ('Historical') and for two future scenarios: IS92a ('I' in **b** and **c**) and S650 ('S' in **b** and **c**). **b**, **c**, Increases in atmospheric CO_2 lead to reductions in surface ocean pH (**b**) and surface ocean $[CO_3^{2-}]$ (**c**). Results are given as global zonal averages for the 1994 data and the preindustrial ('Preind.') ocean. The latter were obtained by subtracting data-based anthropogenic DIC (ref. 17) (solid line in grey-shaded area), as well as by subtracting model-based anthropogenic DIC (OCMIP median, dotted line in grey-shaded area; OCMIP range, grey shading). Future results for the year 2100 come from the 1994 data plus the simulated DIC perturbations for the two scenarios; results are also shown for the year 2300 with S650 (thick dashed line). The small effect of future climate change simulated by the IPSL climate–carbon model is added as a perturbation to IS92a in the year 2100 (thick dotted line); two other climate–carbon models, PIUB-Bern and Commonwealth Scientific and Industrial Research Organisation (CSIRO), show similar results (Fig. 3a). The thin dashed lines indicating the $[CO_3^{2-}]$ for sea water in equilibrium with aragonite and calcite are nearly flat, revealing weak temperature sensitivity.

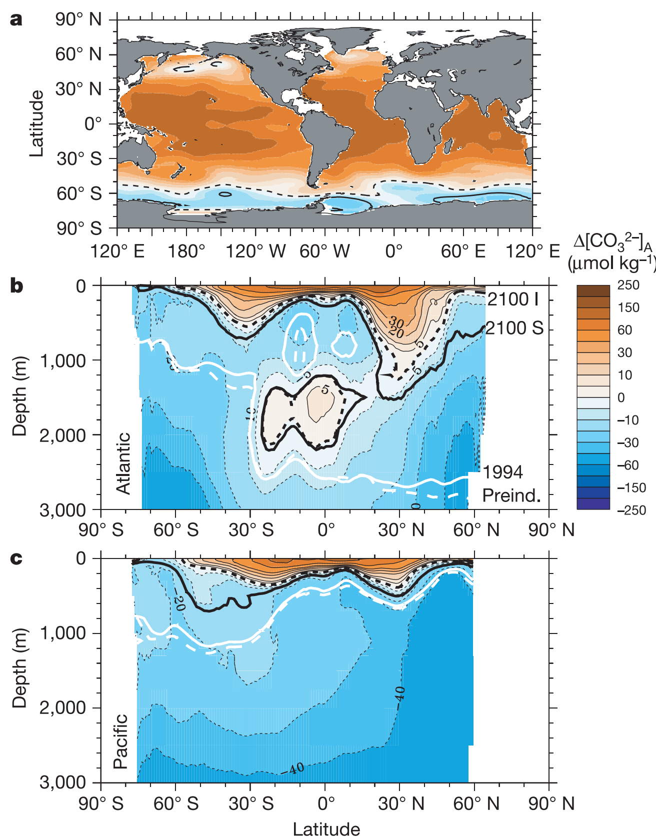

Figure 2 | The aragonite saturation state in the year 2100 as indicated by $\Delta[CO_3^{2-}]_A$. The $\Delta[CO_3^{2-}]_A$ is the *in situ* $[CO_3^{2-}]$ minus that for aragonite-equilibrated sea water at the same salinity, temperature and pressure. Shown are the OCMIP-2 median concentrations in the year 2100 under scenario IS92a: **a**, surface map; **b**, Atlantic; and **c**, Pacific zonal averages. Thick lines indicate the aragonite saturation horizon in 1765 (Preind.; white dashed line), 1994 (white solid line) and 2100 (black solid line for S650; black dashed line for IS92a). Positive $\Delta[CO_3^{2-}]_A$ indicates supersaturation; negative $\Delta[CO_3^{2-}]_A$ indicates undersaturation.

individual models in OCMIP model–data comparison (Supplementary Fig. S2). By the year 2100, as atmospheric CO_2 reaches 788 p.p.m.v. under the IS92a scenario, average tropical surface $[CO_3^{2-}]$ declines to $149 \pm 14\,\mu mol\,kg^{-1}$. This is a 45% reduction relative to preindustrial levels, in agreement with previous predictions[4,8]. In the Southern Ocean (all waters south of 60° S), surface concentrations dip to $55 \pm 5\,\mu mol\,kg^{-1}$, which is 18% below the threshold where aragonite becomes undersaturated ($66\,\mu mol\,kg^{-1}$).

These changes extend well below the sea surface. Throughout the Southern Ocean, the entire water column becomes undersaturated with respect to aragonite. During the twenty-first century, under the IS92a scenario, the Southern Ocean's aragonite saturation horizon (the limit between undersaturation and supersaturation) shoals from its present average depth of 730 m (Supplementary Fig. S3) all the way to the surface (Fig. 2). Simultaneously, in a portion of the subarctic Pacific, the aragonite saturation horizon shoals from depths of about 120 m to the surface. In the North Atlantic, surface waters remain saturated with respect to aragonite, but the aragonite saturation horizon shoals dramatically; for example, north of 50° N it shoals from 2,600 m to 115 m. The greater erosion in the North Atlantic is due to deeper penetration and higher concentrations of anthropogenic CO_2, a tendency that is already evident in present-day data-based estimates[17,18] and in models[19,20] (Supplementary Figs S4 and S5). Less pronounced changes were found for the calcite saturation horizon. For example, in the year 2100 the average calcite saturation horizon in the Southern Ocean stays below 2,200 m. Nonetheless, in 2100 surface waters of the Weddell Sea become slightly undersaturated with respect to calcite.

In the more conservative S650 scenario, the atmosphere reaches $2 \times CO_2$ in the year 2100, 50 years later than with the IS92a scenario. In 2100, Southern Ocean surface waters generally remain slightly supersaturated with respect to aragonite. However, the models also simulate that the Southern Ocean's average aragonite saturation horizon will have shoaled from 730 m to 60 m, and that the entire water column in the Weddell Sea will have become undersaturated (Fig. 2). In the north, all surface waters remain saturated under the S650 scenario. North of 50° N, the annual average aragonite saturation horizon shoals from 140 m to 70 m in the Pacific, whereas it shoals by 2,000 m to 610 m in the North Atlantic. Therefore, under either scenario the OCMIP models simulated large changes in surface and subsurface $[CO_3^{2-}]$. Yet these models account for only the direct geochemical effect of increasing atmospheric CO_2 because they were all forced with prescribed modern-day climate conditions.

In addition to this direct geochemical effect, ocean $[CO_3^{2-}]$ is also altered by climate variability and climate change. To quantify the added effect of future climate change, we analysed results from three atmosphere–ocean climate models that each included an ocean carbon-cycle component (see Supplementary Information). These three models agree that twenty-first century climate change will cause a general increase in surface ocean $[CO_3^{2-}]$ (Fig. 3), mainly because most surface waters will be warmer. However, the models also agree that the magnitude of this increase in $[CO_3^{2-}]$ is small, typically counteracting less than 10% of the decrease due to the geochemical effect. High-latitude surface waters show the smallest increases in $[CO_3^{2-}]$, and even small reductions in some cases. Therefore, our analysis suggests that physical climate change alone will not substantially alter high-latitude surface $[CO_3^{2-}]$ during the twenty-first century.

Climate also varies seasonally and interannually, whereas our previous focus has been on annual changes. To illustrate how climate variability affects surface $[CO_3^{2-}]$, we used results from an ocean carbon-cycle model forced with the daily National Centers for Environmental Prediction (NCEP) reanalysis fields[21] over 1948–2003 (see Supplementary Information). These fields are observationally based and vary on seasonal and interannual timescales. Simulated interannual variability in surface ocean $[CO_3^{2-}]$ is negligible when compared with the magnitude of the anthropogenic decline (Fig. 3b). Seasonal variability is also negligible except in the high latitudes, where surface $[CO_3^{2-}]$ varies by about $\pm 15\,\mu mol\,kg^{-1}$

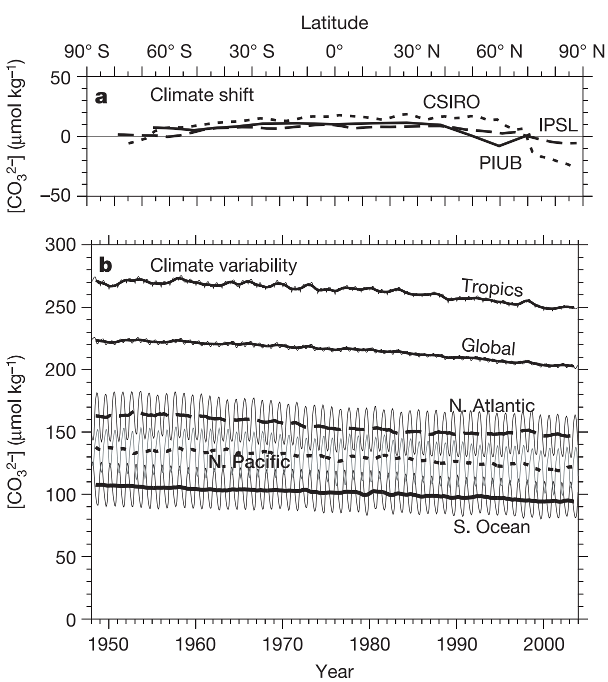

Figure 3 | Climate-induced changes in surface $[CO_3^{2-}]$. a, The twenty-first century shift in zonal mean surface ocean $[CO_3^{2-}]$ due to climate change alone, from three atmosphere–ocean climate models—CSIRO-Hobart (short dashed line), IPSL-Paris (long dashed line) and PIUB-Bern (solid line)—that each include an ocean carbon-cycle component (see Supplementary Information). **b**, The regional-scale seasonal and interannual variability is simulated by an ocean carbon-cycle model forced with reanalysed climate forcing.

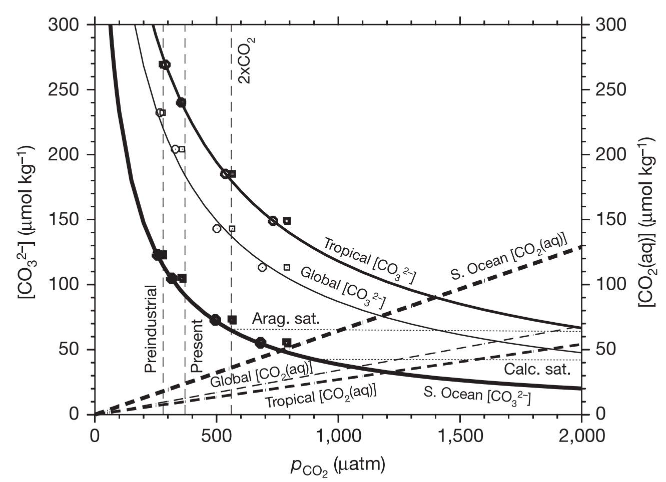

Figure 4 | Key surface carbonate chemistry variables as a function of p_{CO_2}. Shown are both $[CO_3^{2-}]$ (solid lines) and $[CO_2(aq)]$ (dashed lines) for average surface waters in the tropical ocean (thick lines), the Southern Ocean (thickest lines) and the global ocean (thin lines). Solid and dashed lines are calculated from the thermodynamic equilibrium approach. For comparison, open symbols are for $[CO_3^{2-}]$ from our non-equilibrium, model-data approach versus seawater p_{CO_2} (open circles) and atmospheric p_{CO_2} (open squares); symbol thickness corresponds with line thickness, which indicates the regions for area-weighted averages. The nearly flat, thin dotted lines indicate the $[CO_3^{2-}]$ for seawater in equilibrium with aragonite ('Arag. sat.') and calcite ('Calc. sat.').

when averaged over large regions. This is smaller than the twenty-first-century's transient change (for example, ~50 μmol kg^{-1} in the Southern Ocean). However, high-latitude surface waters do become substantially less saturated during winter, because of cooling (resulting in higher [CO_2(aq)]) and greater upwelling of DIC-enriched deep water, in agreement with previous observations in the North Pacific[22]. Thus, high-latitude undersaturation will be first reached during winter.

Our predicted changes may be compared to those found in earlier studies, which focused on surface waters in the tropics[8] and in the subarctic Pacific[22,23]. These studies assumed thermodynamic equilibrium between CO_2 in the atmosphere and the surface waters at their *in situ* alkalinity, temperature and salinity. If, in the equilibrium approach, the p_{CO_2} is taken only to represent seawater p_{CO_2}, then the results agree with our non-equilibrium approach when the sets of carbonate chemistry constants are identical (Fig. 4). However, assuming equilibrium with the atmosphere leads to the prediction that future undersaturation will occur too soon (at lower atmospheric CO_2 levels), mainly because the anthropogenic transient in the ocean actually lags that in the atmosphere. For example, with the equilibrium approach, we predict that average surface waters in the Southern Ocean become undersaturated when atmospheric CO_2 is 550 p.p.m.v. (in the year 2050 under IS92a), whereas our non-equilibrium approach, which uses models and data, indicates that undersaturation will occur at 635 p.p.m.v. (in the year 2070). Despite these differences, both approaches indicate that the Southern Ocean surface waters will probably become undersaturated with respect to aragonite during this century. Conversely, both of these approaches disagree with a recent assessment[9] that used a variant of the standard thermodynamic equilibrium approach, where an incorrect input temperature was used inadvertently.

Uncertainties

The three coupled climate–carbon models show little effect of climate change on surface [CO_3^{2-}] (compare Fig. 3a to Fig. 1) partly because air–sea CO_2 exchange mostly compensates for the changes in surface DIC caused by changes in marine productivity and circulation. In subsurface waters where such compensation is lacking, these models could under- or over-predict how much [CO_3^{2-}] will change as a result of changes in overlying marine productivity. However, the models project a consistent trend, which only worsens the decline in subsurface [CO_3^{2-}]; that is, all coupled climate models predict increased evaporation in the tropics and increased precipitation in the high latitudes[24]. This leads to greater upper ocean stratification in the high latitudes, which in turn decreases nutrients (but not to zero) and increases light availability (owing to more shallow mixed layers). Thus, at $2 \times CO_2$ there is a 10% local increase in surface-to-deep export of particulate organic carbon (POC) in the Southern Ocean using the Institut Pierre Simon Laplace (IPSL)-Paris model[25]. Subsequent remineralization of this exported POC within the thermocline would increase DIC, which would only exacerbate the decrease in high-latitude subsurface [CO_3^{2-}]. For the twenty-first century, these uncertainties appear small next to the anthropogenic DIC invasion (see Supplementary Information).

The largest uncertainty by far, and the only means to limit the future decline in ocean [CO_3^{2-}], is the atmospheric CO_2 trajectory. To better characterize uncertainty due to CO_2 emissions, we compared the six illustrative IPCC Special Reports on Emission Scenarios (SRES) in the reduced complexity, Physics Institute University of Bern (PIUB)-Bern model. Under the moderate SRES B2 scenario, average Southern Ocean surface waters in that model become undersaturated with respect to aragonite when atmospheric CO_2 reaches 600 p.p.m.v. in the year 2100 (Fig. 5). For the three higher-emission SRES scenarios (A1FI, A2 and A1B), these waters become undersaturated sooner (between the years 2058 and 2073); for the two lower-emission scenarios (A1T and B1), these waters remain slightly supersaturated in 2100. Thus, if atmospheric CO_2 rises above 600 p.p.m.v., most Southern Ocean surface waters will become undersaturated with respect to aragonite. Yet, even below this level, the Southern Ocean's aragonite saturation horizon will shoal substantially (Fig. 2). For a given atmospheric CO_2 scenario, predicted changes in surface ocean [CO_3^{2-}] are much more certain than the related changes in climate. The latter depend not only on the model response to CO_2 forcing, but also on poorly constrained physical processes, such as those associated with clouds.

Ocean CO_2 uptake

With higher levels of anthropogenic CO_2 and lower surface [CO_3^{2-}], the change in surface ocean DIC per unit change in atmospheric CO_2 (μmol kg^{-1} per p.p.m.v.) will be about 60% lower in the year 2100 (under IS92a) than it is today. Simultaneously, the CO_3^{2-}/CO2(aq) ratio will decrease from 4:1 to 1:1 in the Southern Ocean (Fig. 4). These decreases are due to the well-understood anthropogenic reduction in buffer capacity[26], already accounted for in ocean carbon-cycle models.

On the other hand, reduced export of $CaCO_3$ from the high latitudes would increase surface [CO_3^{2-}], thereby increasing ocean CO_2 uptake and decreasing atmospheric CO_2. Owing to this effect, ocean CO_2 uptake could increase by 6–13 petagrams (Pg) C over the twenty-first century, based on one recent model study[27] that incorporated an empirical, CO_2-dependant relationship for calcification[7]. Rates of calcification could decline even further, to zero, if waters actually became undersaturated with respect to both aragonite and calcite. We estimate that the total shutdown of high-latitude aragonite production would lead to, at most, a 0.25 Pg C yr^{-1} increase in ocean CO_2 uptake, assuming that 1 Pg C yr^{-1} of $CaCO_3$ is exported globally[28], that up to half of that is aragonite[9,29], and that perhaps half of all aragonite is exported from the high latitudes. The actual increase in ocean CO_2 uptake could be much lower because the aragonite fraction of the $CaCO_3$ may be only 0.1 based on low-latitude sediment traps[30], and the latitudinal distribution of aragonite export is uncertain. Thus, increased CO_2 uptake from reduced export of aragonite will provide little compensation for decreases in ocean CO_2 uptake due to reductions in buffer capacity. Of greater concern are potential biological impacts due to future undersaturation.

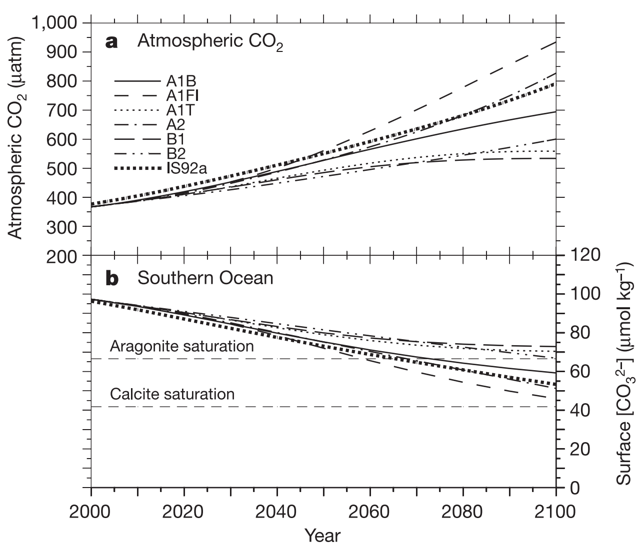

Figure 5 | Average surface [CO_3^{2-}] in the Southern Ocean under various scenarios. Time series of average surface [CO_3^{2-}] in the Southern Ocean for the PIUB-Bern reduced complexity model (see Fig. 3 and Supplementary Information) under the six illustrative IPCC SRES scenarios. The results for the SRES scenarios A1T and A2 are similar to those for the non-SRES scenarios S650 and IS92a, respectively.

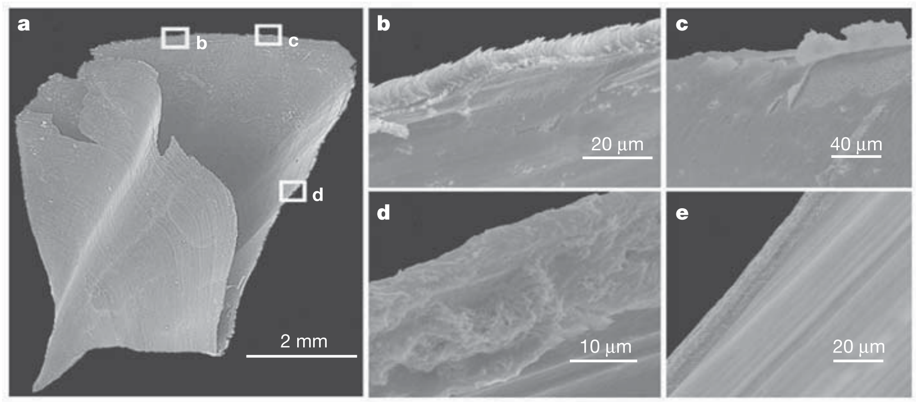

Figure 6 | Shell dissolution in a live pteropod. a–d, Shell from a live pteropod, *Clio pyramidata*, collected from the subarctic Pacific and kept in water undersaturated with respect to aragonite for 48 h. The whole shell (**a**) has superimposed white rectangles that indicate three magnified areas: the shell surface (**b**), which reveals etch pits from dissolution and resulting exposure of aragonitic rods; the prismatic layer (**c**), which has begun to peel back, increasing the surface area over which dissolution occurs; and the aperture region (**d**), which reveals advanced shell dissolution when compared to a typical *C. pyramidata* shell not exposed to undersaturated conditions (**e**).

Biological impacts

The changes in seawater chemistry that we project to occur during this century could have severe consequences for calcifying organisms, particularly shelled pteropods: the major planktonic producers of aragonite. Pteropod population densities are high in polar and subpolar waters. Yet only five species typically occur in such cold water regions and, of these, only one or two species are common at the highest latitudes[31]. High-latitude pteropods have one or two generations per year[12,15,32], form integral components of food webs, and are typically found in the upper 300 m where they may reach densities of hundreds to thousands of individuals per m^3 (refs 11, 13–15). In the Ross Sea, for example, the prominent subpolar–polar pteropod *Limacina helicina* sometimes replaces krill as the dominant zooplankton, and is considered an overall indicator of ecosystem health[33]. In the strongly seasonal high latitudes, sedimentation pulses of pteropods frequently occur just after summer[15,34]. In the Ross Sea, pteropods account for the majority of the annual export flux of both carbonate and organic carbon[34,35]. South of the Antarctic Polar Front, pteropods also dominate the export flux of $CaCO_3$ (ref. 36).

Pteropods may be unable to maintain shells in waters that are undersaturated with respect to aragonite. Data from sediment traps indicate that empty pteropod shells exhibit pitting and partial dissolution as soon as they fall below the aragonite saturation horizon[22,36,37]. *In vitro* measurements confirm such rapid pteropod shell dissolution rates[38]. New experimental evidence suggests that even the shells of live pteropods dissolve rapidly once surface waters become undersaturated with respect to aragonite[9]. Here we show that when the live subarctic pteropod *Clio pyramidata* is subjected to a level of undersaturation similar to what we predict for Southern Ocean surface waters in the year 2100 under IS92a, a marked dissolution occurs at the growing edge of the shell aperture within 48 h (Fig. 6). Etch pits formed on the shell surface at the apertural margin (which is typically ~7-µm-thick) as the <1-µm exterior (prismatic layer) peeled back (Fig. 6c), exposing the underlying aragonitic rods to dissolution. Fourteen individuals were tested. All of them showed similar dissolution along their growing edge, even though they all remained alive. If *C. pyramidata* cannot grow its protective shell, we would not expect it to survive in waters that become undersaturated with respect to aragonite.

If the response of other high-latitude pteropod species to aragonite undersaturation is similar to that of *C. pyramidata*, we hypothesize that these pteropods will not be able to adapt quickly enough to live in the undersaturated conditions that will occur over much of the high-latitude surface ocean during the twenty-first century. Their distributional ranges would then be reduced both within the water column, disrupting vertical migration patterns, and latitudinally, imposing a shift towards lower-latitude surface waters that remain supersaturated with respect to aragonite. At present, we do not know if pteropod species endemic to polar regions could disappear altogether, or if they can make the transition to live in warmer, carbonate-rich waters at lower latitudes under a different ecosystem. If pteropods are excluded from polar and subpolar regions, their predators will be affected immediately. For instance, gymnosomes are zooplankton that feed exclusively on shelled pteropods[33,39]. Pteropods also contribute to the diet of diverse carnivorous zooplankton, myctophid and nototheniid fishes[40–42], North Pacific salmon[43,44], mackerel, herring, cod and baleen whales[45].

Surface dwelling calcitic plankton, such as foraminifera and coccolithophorids, may fare better in the short term. However, the beginnings of high-latitude calcite undersaturation will only lag that for aragonite by 50–100 years. The diverse benthic calcareous organisms in high-latitude regions may also be threatened, including cold-water corals which provide essential fish habitat[46]. Cold-water corals seem much less abundant in the North Pacific than in the North Atlantic[46], where the aragonite saturation horizon is much deeper (Fig. 2). Moreover, some important taxa in Arctic and Antarctic benthic communities secrete magnesian calcite, which can be more soluble than aragonite. These include gorgonians[46], coralline red algae and echinoderms (sea urchins)[47]. At $2 \times CO_2$, juvenile echinoderms stopped growing and produced more brittle and fragile exoskeletons in a subtropical six-month manipulative experiment[48]. However, the responses of high-latitude calcifiers to reduced $[CO_3^{2-}]$ have generally not been studied. Yet experimental evidence from many lower-latitude, shallow-dwelling calcifiers reveals a reduced ability to calcify with a decreasing carbonate saturation state[9]. Given that at $2 \times CO_2$, calcification rates in some shallow-dwelling calcareous organisms may decline by up to 50% (ref. 9), some calcifiers could have difficulty surviving long enough even to experience undersaturation. Certainly, they have not experienced undersaturation for at least the last 400,000 years[49], and probably much longer[50].

Changes in high-latitude seawater chemistry that will occur by the end of the century could well alter the structure and biodiversity of polar ecosystems, with impacts on multiple trophic levels. Assessing these impacts is impeded by the scarcity of relevant data.

Received 15 June; accepted 29 July 2005.

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Supplementary Information is linked to the online version of the paper at www.nature.com/nature.

Acknowledgements We thank M. Gehlen for discussions, and J.-M. Epitalon, P. Brockmann and the Ferret developers for help with analysis. All but the climate simulations were made as part of the OCMIP project, which was launched in 1995 by the Global Analysis, Integration and Modelling (GAIM) Task Force of the International Geosphere–Biosphere Programme (IGBP) with funding from NASA (National Aeronautics and Space Administration). OCMIP-2 was supported by the European Union Global Ocean Storage of Anthropogenic Carbon (EU GOSAC) project and the United States JGOFS Synthesis and Modeling Project funded through NASA. The interannual simulation was supported by the EU Northern Ocean Carbon Exchange Study (NOCES) project, which is part of OCMIP-3.

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Acc. No. 0592 *Los Angeles Times article and attachment* can be viewed on the docket: http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0593 and 0593.1 *Letter from New York State Department of Transportation* are duplicates of Acc. No. 0588 can be viewed on the docket: http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

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Program Rules

Let's Refuel America Program
Official Program Rules

PROGRAM PERIOD:

May 7, 2008 through July 31, 2008

PROGRAM TYPE:

Refer to latest version of the Incentive Program Rules Manual (previously referred to as the Gold Book) and Incentive Summary Communications.

PROGRAM DESCRIPTION:

This special Let's Refuel America Program is offered to eligible retail consumers who purchase or lease an eligible vehicle and take delivery during the program period. This special Let's Refuel America Program is an alternative to the traditional incentive offers of Consumer Cash/Lease Cash and/or APR. This offer consists of a specific number of price-protected gallons of fuel at $2.99 per gallon* for regular 87 octane unleaded, E85, or diesel purchases, per vehicle in addition to a Let's Refuel America Bonus Cash Program (amounts vary from $0 to $3,000 by vehicle, as listed in the Model Eligibility section).

This program also contains the following elements:

1. The eligible consumer must have a valid MasterCard or Visa credit card to participate in this program. No debit cards or other credit cards are permitted in this program.
   Check card eligibility can be determined as follows:
   1. Card has a Visa or MasterCard logo on the face
   2. Visa cards begin with the number 4 and MasterCards begin with the number 5. No other prefix card number should be

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site(http://refuelamerica.pricelock.com) or by calling the Let's Refuel America Enrollment Center (1-800-866-4656) before August 31, 2008.

14. The Let's Refuel America program contains a $400 maximum fuel charge per day without pre-authorization.
15. If an eligible consumer exceeds the maximum gallon allotment during a tank fill-up, the program will cover the entire fill-up at $2.99 per gallon, unless the consumer has exceeded the total program fuel allotment. The Let's Refuel America card will not function for future fuel purchases until the next annual gallon allotment is replenished (if applicable – i.e. if time still remains in the program).
16. Only fuel purchases in the United States are eligible for this program.
17. Fuel purchases at marinas are ineligible for this program.

This program is an alternative to traditional incentive programs. Consumers who select this offer will not be eligible for the traditional consumer/lease cash, subvented APR rates, or Compass/Patriot retail cash (39C8V). Dealers must have each consumer sign an acknowledgement form indicating the programs that the customer has selected. (See Dealer Responsibility section below.) Select compatible programs are identified in the Program Compatibility section of these rules.

DEALERS WILL BE REQUIRED TO CLAIM THE LET'S REFUEL AMERICA BONUS CASH PROGRAM ID 38C96 TO ALLOW THE LET'S REFUEL AMERICA GAS CARD TO BE VALIDATED FOR ACTIVATION, EVEN IF THE DOLLAR VALUE IS $0 (ZERO).

PARTICIPATING DEALERS:

All franchised Chrysler LLC U.S. dealers who agree to abide by these Official Program Rules are eligible to participate.

MODEL ELIGIBILITY:

Eligible vehicles must be delivered during the program start and end dates indicated.

Eligible Models:
All new, unused 2008 & 2009 MY Chrysler, Jeep, and Dodge vehicles listed in the "Let's Refuel America Eligibility and Bonus Cash Chart" below are eligible for this Let's Refuel America incentive offer:
Note: All SRT models, Sprinter, Viper, Crossfire, Wrangler, Wrangler Unlimited, Ram Chassis Cab, and Challenger models are ineligible to participate in this program.

*The gallon allotment calculation used to determine three years of gas at $2.99 per gallon is as follows: 12,000 miles driven per year multiplied by 3 years, divided by the vehicle's adjusted combined EPA City/Highway average miles per gallon (MPG) (average MPG calculated via average of all body models MPG within each nameplate). Please refer to attached matrix to view individual nameplate average MPG and program gallon allotment.
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2008/2009 MY Let's Refuel America Eligibility & Incentive Option Chart

Let's Refuel America eligible models	Let's Refuel America Bonus Cash Program 38C96	Average MPG by model utilized for Let's Refuel America program calculations	Total allotted Let's Refuel America program gallons
Small Car			
Dodge Caliber	$0	24	1,500
Chrysler PT Cruiser	$1,000	22	1,636
Chrysler PT Convertible	$0	22	1,636
Mid-size Car			
Dodge Avenger	$0	21	1,714
Chrysler Sebring Sedan	$0	21	1,714
Chrysler Sebring Convertible	$1,000	21	1,714
Large Car			
Dodge Charger	$500	18	2,000
Dodge Charger RT	$1,000	18	2,000
Chrysler 300C	$2,000	17	2,118
Chrysler 300	$500	20	1,800
Dodge Magnum	$1,000	18	2,000
Dodge Magnum RT	$1,500	18	2,000
Family			
Dodge Grand Caravan	$500	19	1,895
Chrysler Town & Country	$500	19	1,895
Chrysler Pacifica	$500	17	2,118
Dodge Journey	$0	20	1,800
Small SUV			

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Jeep Compass	$0	24	1,500
Jeep Patriot	$0	23	1,565
Mid-size SUV			
Jeep Liberty	$0	18	2,000
Dodge Nitro	$0	18	2,000
Large SUV			
Jeep Grand Cherokee	$2,000	16	2,250
Jeep Commander	$2,000	15	2,400
Dodge Durango	$2,000	15	2,400
Chrysler Aspen	$2,000	15	2,400
Mid-size Truck			
Dodge Dakota Club Cab	$1,000	16	2,250
Dodge Dakota Quad Cab	$1,000	16	2,250
Light Duty Truck			
Dodge Ram Regular Cab	$3,000	15	2,400
Dodge Ram Quad Cab	$3,000	15	2,400
Dodge Ram Mega Cab	$3,000	15	2,400
Heavy Duty Truck			
Dodge Ram HD Regular Cab	$2,000	15	2,400
Dodge Ram HD Quad Cab	$2,000	15	2,400
Dodge Ram HD Mega Cab	$2,000	15	2,400

PROGRAM COMPATIBILITY:

This program is compatible with the following program types, providing the vehicle meets all program eligibility requirements:

- Chrysler LLC Employee Advantage/Employee Choice program
- Dealership Employee Purchase program
- Friends and Family program
- Chrysler LLC Affiliate Rewards programs
- Chrysler LLC Affinity programs
- Automobility program
- All other TDM programs
- Chrysler LLC/Dealership Employee Bonus Cash programs
- National and/or Regional Lease Rate programs
- National and/or Regional Lease Loyalty programs

Incompatible programs:

- National and/or Regional Consumer Cash Allowance programs
- National and/or Regional APR programs
- National and/or Regional Lease Cash programs
- Compass/Patriot Retail Cash

PROGRAM PERIOD:

June 3, 2008 through July 31, 2008

2007 MODEL ELIGIBILITY

Eligible vehicles must be delivered during the program start and end dates indicated.

Eligible Models:

All 2007 MY Chrysler, Jeep, and Dodge vehicles listed in the ¡°Let's Refuel America Eligibility and Incentive Option Chart¡± below are eligible for this Let's Refuel America incentive offer:

Note: All SRT models, Sprinter, Viper, Crossfire, Wrangler, Wrangler Unlimited, Ram Chassis Cab, and Challenger models are ineligible to participate in this program.

2007 MY Let’s Refuel America Eligibility & Incentive Option Chart

Let's Refuel America eligible models	Let's Refuel America Bonus Cash Program 40C77	Average MPG by model utilized for Let's Refuel America program calculations	Total allotted Let's Refuel America program gallons
Small Car			
Dodge Caliber	$0	24	1,500
Chrysler PT Cruiser	$2,000	22	1,636
Chrysler PT Convertible	$0	22	1,636
Mid-size Car			
Chrysler Sebring Sedan	$1,000	21	1,714
Large Car			
Dodge Charger	$1,500	18	2,000
Dodge Charger RT	$2,500	18	2,000
Chrysler 300C	$2,500	17	2,118
Chrysler 300	$1,500	20	1,800
Dodge Magnum	$1,500	18	2,000
Dodge Magnum RT	$2,500	18	2,000
Family			
Dodge Caravan/Grand Caravan	$1,500	19	1,895
Chrysler Town & Country	$1,500	19	1,895
Chrysler Pacifica	$1,500	17	2,118
Small SUV			
Jeep Compass	$500	24	1,500
Jeep Patriot	$500	23	1,565
Mid-size SUV			
Jeep Liberty	$2,500	18	2,000
Dodge Nitro	$500	18	2,000
Large SUV			
Jeep Grand Cherokee	$2,000	16	2,250
Jeep Commander	$2,000	15	2,400
Dodge Durango	$2,000	15	2,400
Chrysler Aspen	$2,000	15	2,400
Mid-size Truck			
Dodge Dakota	$1,750	16	2,250
Light Duty Truck			
Dodge Ram Regular Cab	$3,500	15	2,400
Dodge Ram Quad Cab	$3,500	15	2,400
Dodge Ram Mega Cab	$3,500	15	2,400
Heavy Duty Truck			
Dodge Ram HD Regular Cab	$4,500	15	2,400
Dodge Ram HD Quad Cab	$4,500	15	2,400
Dodge Ram HD Mega Cab	$4,500	15	2,400

KCRA.com

Chrysler Plan Locks In 3 Years Of $2.99 Gas

Plan Available On New Cars Bought By June 2

POSTED: 10:16 am PDT May 6, 2008
UPDATED: 10:24 am PDT May 6, 2008

Chrysler announced Tuesday a plan could have an impact on how much money drivers spend on gas.

In what the automaker is calling its own economic stimulus package, Chrysler is offering a gas price protection policy that will eliminate further increases at the pump.

The "Let's Refuel America" program gives new-car buyers a gas card that immediately lowers their gas price to $2.99 per gallon, and keeps it there for three years. The offer is available at 3,511 U.S. Chrysler, Jeep and Dodge dealerships through June 2, 2008, and is available on vehicles ranging from popular new compacts, crossovers and minivans to full-size diesel-powered pickup trucks.

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- **Commute:** Cut Your Costs

"Today we are proud to introduce an unprecedented program to help put customers' minds at ease and do something to help working people who are worried about the volatility of fuel prices and vehicle cost of ownership," said Chrysler vice-chairman and president Jim Press. "The Let's Refuel America Price Guarantee puts money in your pocket today, and allows our customers to better manage their fuel expenses. And you can't get it anywhere else besides a Chrysler, Jeep or Dodge dealership."

Press said Chrysler's lineup includes five models that get 28 miles-per-gallon or better on the highway: Chrysler Sebring, Chrysler Sebring Convertible, Dodge Avenger, Jeep Compass, Jeep Patriot and Dodge Caliber.

In February, Chrysler created the industry's first Customer Advisory Board to encourage a direct dialogue with customers and gather insight and feedback, which helped steer the automaker to this program. The panel found that 76 percent are "very concerned" or "extremely concerned" about fuel prices, and 83 percent of the community responded that fuel prices will affect their summer vacation plans.

The offer is valid with 87 octane regular unleaded fuel, E85 fuel or diesel fuel only, depending upon purchased vehicle. There is a yearly allotment of gallons available at the discounted price.

If mid-grade or premium unleaded fuel is purchased, the customer will be billed for the $2.99 plus $.15

per gallon for mid-grade (88-89 octane) or plus $.30 for premium (90-94 octane).

The following vehicles are eligible for the Let's Refuel America program:

Small/Compact Car

Dodge Caliber, Chrysler PT Cruiser, Chrysler PT Cruiser Convertible

Mid-size Car

Dodge Avenger, Chrysler Sebring, Chrysler Sebring Convertible

Large Car

Dodge Charger, Chrysler 300, Dodge Magnum

Crossover

Dodge Journey

Minivan

Dodge Grand Caravan, Chrysler Town and Country

Compact SUV Jeep Patriot, Jeep Compass

Mid-size SUV

Dodge Nitro, Jeep Liberty

Large SUV

Jeep Grand Cherokee, Jeep Commander, Dodge Durango, Chrysler Aspen

Pickup Truck

Dodge Dakota, Dodge Ram, Dodge Ram HD

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August 14, 2008

THE BRYANT PARK PROJECT from NPR NEWS

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Economy

Analyst: Big Three Still Lag on Fuel Efficiency

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Yoshikazu Tsuno

A Toyota Prius at the company's showroom in Tokyo. AFP/Getty Images

The Bryant Park Project, June 11, 2008 · Toyota plans to ship some 180,000 Priuses to the United States this year, but the Japanese automaker, as well as other manufacturers of hybrids, won't even come close to meeting America's voracious demand. In fact, demand is so far outstripping supply that overall hybrid sales actually fell last month because dealers had so much trouble getting them onto their lots.

At the same time, Detroit's Big Three automakers have faced new troubles, as consumers turn their backs on oversize gas guzzlers. GM recently announced it would shut down four pickup and SUV plants and conduct a "strategic review" of the Hummer.

U.S. auto manufacturers not only have made poor decisions in recent years, says Jalopnik.com's Ray Wert, they have traditionally failed to plan for the long term, while their Japanese rivals look much further to the future.

But even now, says Wert, Detroit hasn't gotten the message that consumers, suffering from rising gas prices, want more fuel-efficient cars. "If I were working at GM," he says, "I'd say we need to jettison Hummer, we need to take a look at whether or not we need to have GMC still exist, we need to cut down to one large SUV, one pickup truck and focus the rest of our [research and development] on more fuel-efficient vehicles."

Even now, American manufacturers are making more fuel-efficient cars overseas than they are selling here. Most run on diesel, which Wert says American consumers have not embraced. It may at first appear more expensive at the pump, where it costs more per gallon, but Wert points out that in the end it's much cheaper, because diesel can get 60 to 70 miles to the gallon. But, he adds, there aren't enough diesel stations in most of the U.S., and, he observes, "There's still a perception among American consumers that diesel smells."

Wert also notes that the U.S. automakers are looking at innovations for the future. GM is working on the Chevy Volt, scheduled to hit the market in 2010, which will be a gas/electric hybrid plug-in, meaning that it will literally plug into regular home electric sockets. Toyota is also working on a hybrid plug-in version of the Prius.

GM and Honda are also both working on a hydrogen fuel cell car. The car should get 80 miles to the gallon, but one problem would be creating a network of hydrogen fueling stations.

So, for now, is a hybrid the best option for people who want to save gas? Wert says hybrids might be the most effectively marketed option, but not necessarily the cheapest. Many used cars might get decent gas mileage at half the cost of a new Prius. And, additionally, he points out that for consumers driven by green concerns, "If you're driving a car, you're not using an environmentally friendly product."

D-1551

August 14, 2008

Business

Ford Shifts Production Focus To Smaller Cars

by Dustin Dwyer

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Dustin Dwyer/NPR

Production at the Michigan Truck Plant in Wayne, Mich., is shifting from sport utility vehicles to small cars.

All Things Considered, July 24, 2008 · Ford Motor Co. posted an $8.7 billion loss for the second quarter on Thursday — the worst quarterly performance in the company's 105-year history and another sign of the U.S. auto industry's woes.

Most of the loss came from one-time charges, but the loss on operations was still more than $1 billion. Consumers hit by high gas prices and falling home values have shied away from trucks and sport utility vehicles, Ford's mainstay. In response, Ford announced a new plan Thursday to focus more on smaller, fuel-efficient cars.

Ford has a lineup of small cars in Europe that's ideally suited for where the U.S. market seems to be headed. Ford CEO Alan Mulally said six of those small European models would be sold in the U.S. starting in 2010. He called the move a strategic decision based on environmental changes and customer demand.

"And to get that full product line, Ford plans major changes to its manufacturing operations in the U.S.," he said at the Michigan Truck Plant in Wayne, just outside of Dearborn. The plant has been making trucks since 1964.

"Ford stopped production here a month ago because this plant builds big SUVs, and people aren't buying big SUVs right now," Mulally said. "So the plan is to take this plant and switch it over and make small cars here instead."

Ford also plans to shift production to smaller vehicles at a plant in Louisville, Ky., and one in Cuautitlan, Mexico.

According to David Cole of the Center for Automotive Research, there is one factor that could complicate Ford's plan: "We really don't know what the price of fuel could be in a year. It could be $5 a gallon, it could be $2 a gallon, and so one of the business imperatives for companies like Ford ... is to do everything possible to become more flexible and agile."

Cole says that even if Ford moves quickly, it could take the company more than a year to switch out its truck plants.

"And, in part, it's not governed by how fast you can get people in the plant and move stuff around," he says. "You've got to depend on tooling. You've got to depend on manufacturing equipment that might have to be ordered. And you may have to wait in line with other people that are trying to order the same kind of thing. It's a huge challenge."

When Ford switches its truck plants, Mulally said, it will design them to be even more flexible going forward, so that the next time the market shifts, Ford can be quicker to respond.

Dustin Dwyer reports for Michigan Radio.

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Hybrid SUVs Are Missing in Action

March 31, 2008 from All Things Considered

MICHEL NORRIS, host: Say you care about the environment, but you also have a large family or lots of stuff to haul. If you're looking for a new car, you might consider a hybrid SUV as the perfect solution.

But as NPR's Elizabeth Shogren found out, good luck trying to find one.

(Soundbite of Ford Escape ad)

KERMIT THE FROG: (Singing) It's not that easy being green.

ELZABETH SHOGREN: In this TV ad, Kermit the Frog mountain bikes along a rocky trail, kayaks through white water, and struggles to climb up a steep mountain. But at the top, he comes across a shiny SUV.

(Soundbite of Ford Escape ad)

KERMIT THE FROG: Hmm, I guess it is easy being green.

Unidentified Man: The 36-mile-per-gallon Ford Escape hybrid.

SHOGREN: Mike Warden(ph) might disagree with that. He and his wife recently went looking to buy an Escape hybrid at a Ford dealership in Colorado Springs, Colorado.

Mr. MIKE WARDEN (Resident, Colorado): And after we had been there for about two hours after the test drive, and looking at the different colors, and going through all the options, you know, I finally ask, well, can we get a price on the one that we'd like to order.

SHOGREN: The dealer didn't have any hybrids in stock. So ordering was the only option. The salesman disappeared for 15 or 20 minutes to speak with his manager and returned with some news.

Mr. WARDEN: Oh, I forgot to tell you, all Escapes we order have a $5,000 dollar mark-up for the dealer. And at that point, you know, we said okay, thanks, and left.

SHOGREN: Warden and his wife wanted to save money on gas and help the environment by buying a hybrid. But with the mark-up, the price would have hit $37,000, $11,000 more than the gasoline version.

Mr. WARDEN: Whatever gas savings we'd get with the hybrid, it would probably take longer than we would own that vehicle to make that money back from the mark-up.

SHOGREN: Warden went to Internet chatrooms and found that his experience was hardly unique. Dealers across the country are jacking up the price of Escapes and other hybrid SUVs, the same way they would put premiums on fancy sports cars. Would-be hybrid buyers also tell stories of waiting months for cars they've ordered and giving up in frustration.

Mr. CHRISTIAN FACKRELL (Manager, Jerry's Ford in Annandale, Virginia): Unfortunately, they don't make any nonprofit car dealerships.

SHOGREN: Christian Fackrell, a manager at Jerry's Ford in Annandale, Virginia, a suburb of Washington, is unapologetic about the mark-ups his dealership puts on hybrid Escapes.

Mr. FACKRELL: Right now it's $3,995.

SHOGREN: Almost $4,000. By contrast, the dealer is offering discounts of several thousand dollars on almost every other vehicle, including the gasoline Escape. Jerry's is a big dealership, so Fackrell says he has an easier time than most getting hybrids on his lot. Still, he only gets a few a month, and customers end up ordering about half of the hybrid Escapes the dealer sells. That isn't true for any other car. Fackrell wishes Ford would make more hybrids.

Mr. FACKRELL: If there was an abundance of them, I'm sure they would sell like hotcakes.

SHOGREN: But Said Deep, a Ford spokesman, says the company has no plans to significantly increase production.

Mr. SAID DEEP (Spokesman, Ford Motor Company): The factory that makes them in Kansas is running at two shifts and working Saturdays to kind of keep up with demand.

SHOGREN: Deep says in the first two months of this year, hybrid sales were up 12 percent. Still, the hybrids only make up about 10 percent of all Escapes sold. And it's not just the Ford hybrids that are scarce. If you don't live in California, you have almost no chance of finding a Saturn Vue Green Line - that company's hybrid SUV.

Company spokesman Michael Morrissey says most dealers have been out of stock since last fall because the company is having supply problems with the hybrid battery.

Mr. MORESI (Spokesman, Saturn): And that's one of the growing pains. When you have hybrids that are relatively new technology, there's only so much manufacturing capacity of hybrid batteries in the world right now.

SHOGREN: Hybrids may be hard to find, but that's not keeping car companies from flooding the airwaves with ads.

(Soundbite of hybrid ad)

Unidentified Man: Right! And are hybrids big?

Unidentified Child: No.

Unidentified Man: They're teensy-weensy, aren't they?

Unidentified Group: Yes.

Unidentified man: Wrong. This is America's first full-sized hybrid SUV: Chevy Tahoe.

SHOGREN: GM has been pushing the Tahoe and its sister hybrid, the Yukon, during the Super Bowl and March Madness. The company says they're great for P.R.

The fact that we've gotten such good press on the vehicle and it's lifting the image for the entire company.

SHOGREN: But Chevy spokesman Mark Closson(ph) admits you won't find them at most dealership even if you are willing to shell out upwards of $60,000.

Mr. MARK CLOSSON (Spokesman, Chevy): We've taken a really different approach about the distribution with this vehicle.

SHOGREN: There are only about 1,500 hybrid Tahoes to share across the country. So, only a small fraction of Chevy dealers have been allotted one. Customers can come in for a test drive, but they can't expect to drive one home anytime soon.

Elizabeth Shogren, NPR News.

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FEATURES

Chevrolet Tahoe Hybrid Named 2008 Green Car of the Year®

By Green Car Journal Editors

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First Full-Size Hybrid SUV Achieves 30 Percent Fuel Efficiency Increase Over Standard Model

LOS ANGELES, Calif., Nov. 15, 2007 – The 2008 Chevrolet Tahoe Hybrid – the first General Motors vehicle to use the company's all-new two-mode hybrid system – has been named *Green Car Journal's 2008 Green Car of the Year®*. The award was presented at a press conference this morning at the Los Angeles Auto Show.

"This is a milestone in many respects," says *Green Car Journal* editor and publisher Ron Cogan. "People don't think 'green' when SUVs are concerned, and for generally good reason since SUVs often get poor fuel economy compared to most other vehicles. Chevrolet's Tahoe Hybrid changes this dynamic with a fuel efficiency improvement of up to 30 percent compared to similar vehicles equipped with a standard V-8."

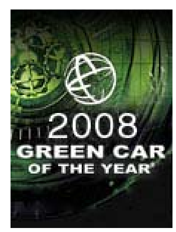
According to the EPA's 2008 estimated fuel economy ratings, Chevrolet's achievement is even more apparent during city driving where a large percentage of SUVs spend their time every day. In this environment, the 6.0-liter two-mode hybrid Tahoe achieves 50 percent better fuel economy than a Tahoe powered by a standard 5.3-liter V-8. What's equally eye-opening is that the Tahoe's 21 mpg city fuel efficiency rating is the same as that of the city EPA rating for the four-cylinder Toyota Camry sedan.

"We're thrilled to receive this recognition from *Green Car Journal* for our Chevrolet Tahoe Hybrid," says Ed Peper, Chevrolet general manager. "We've felt that the Tahoe Hybrid represents the best of both worlds – the great utility you'd expect from a Tahoe with fuel economy on par with today's mid-size cars. It's satisfying to receive this validation from such an authority on environmentally-friendly vehicles."

The Chevrolet Tahoe Hybrid was selected in a majority vote by a jury of high-profile environmental and industry leaders, along with four *Green Car Journal* editors. Invited jurors this year included Carroll Shelby, Jay Leno, Carl Pope (Sierra Club), Christopher Flavin (Worldwatch Institute), Jonathan Lash (World Resources Institute), and Jean-Michel Cousteau (Ocean Futures Society).

"GM promised they would use hybrid technology, and use it where it would make the most difference – on their biggest vehicles. They have delivered with the Chevy Tahoe," says Carl Pope, executive director of the Sierra Club, pointing out that this vehicle ends the argument that efficiency and vehicle choice are incompatible. He adds that automakers should now make their entire fleets fuel efficient as fast as they can retool.

The Tahoe Hybrid is the industry's first application of hybrid technology in a full-size SUV. While a few vehicles with V-6 and V-8 engines are offered with hybrid options, most hybrid technology is incorporated into mid-size or smaller vehicles with four-cylinder engines because this is where big fuel economy gains are most readily achieved. It's a different challenge to achieve meaningful mpg increases on large vehicles of greater weight where substantial cargo hauling and



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towing may be needed, and larger engines are required for the job. For instance, the Tahoe Hybrid features seating for up to eight passengers, a 60 cubic foot cargo volume with the second and third row seats folded, the ability to carry up to 1400 pounds of cargo, and a tow rating of up to 6,200 pounds.

"The importance of GM's accomplishment can't be overstated," says Cogan. "For years, consumers have been buying SUVs in increasing numbers because of their functionality, making them the number one class of vehicle on the market. The problem has been obvious: With larger vehicles generally comes poorer fuel economy because of greater size and curb weight. An 'equalizer' has been needed…and the two-mode hybrid system in the Tahoe is clearly that equalizer."

Along with the Tahoe Hybrid, the jury considered 2008 Green Car of the Year nominees including the Chevrolet Malibu Hybrid, Mazda Tribute Hybrid, Nissan Altima Hybrid, and the Saturn Aura Hybrid. Dozens of 2008 model year vehicles using all technologies and fuels were considered by the *Green Car Journal* staff in narrowing down the field to five nominees.

Along with their considerable achievements in raising the bar in environmental performance, each of those making the final cut had to meet the requirement of being on sale and widely available to the public by Jan. 1, 2008. "Newness" was also a factor in the nomination process, with nominees ideally in the earlier phases of their production cycle rather than near the end. Other factors that weigh in on the decision making include production volume and the likelihood of a candidate vehicle's environmentally-focused technologies leading to further implementation in other vehicles.

To read more about why the 2008 Chevrolet Tahoe Hybrid was selected by the Green Car of the Year jury, check out Ron Cogan's **Green Car of the Year forum on eHow**. You can exchange with him directly and start a discussion with other users.

About Green Car of the Year®
The GCOY award is an important part of *Green Car Journal's* mission to showcase environmental progress in the auto industry. Since 1992, *Green Car Journal* has focused on the intersection of automobiles, energy, and environment, first with an industry newsletter and then with an award-winning auto enthusiast magazine. Today, the magazine is considered the premier source of information on high fuel efficiency, low emission, advanced technology, and alternative fuel vehicles. Green Car of the Year® is a registered trademark of *Green Car Journal* and RJ Cogan Specialty Publications Group, Inc. For more information visit **www.greencar.com**.

About the LA Auto Show
For the second consecutive year, the LA Auto Show will be held in the fall. The show opens for media only Nov. 14 and 15. Public days run from Nov. 16-25 including Thanksgiving Day. For general information visit **www.LAautoshow.com**.

The 2008 Tahoe Hybrid is available with better fuel economy then any of his competitors.(1) So why mess with a good thing? To make it better, of course. Seems the *Green Car Journal* agrees — they've named the 2008 Chevy Tahoe Hybrid(2) the Green Car of the Year®.(3)

America's first full-size hybrid SUV(4) is available in two- or four-wheel drive and provides the power and capability you expect from a utility vehicle while delivering efficiency you never imagined. Its hybrid propulsion system is designed to operate in three ways: electric power, engine power, or any combination of electric and engine power. When you need the extra muscle of Tahoe's Vortec V8, it kicks in seamlessly. When you need to conserve, two small and lightweight 60 kW motors get the job done.

And here's the big finish: When you pair the two-mode technology with our Active Fuel Management system, the Tahoe Hybrid offers up to 50% better city fuel economy over the non-hybrid Tahoe.(5) That's one hardworking hybrid.

"With larger vehicles generally comes poorer fuel economy because of greater size and curb weight. An 'equalizer' has been needed...and the two-mode hybrid system in the Tahoe Hybrid is clearly that equalizer."
— Ron Cogan, Green Car Journal, Editor and Publisher

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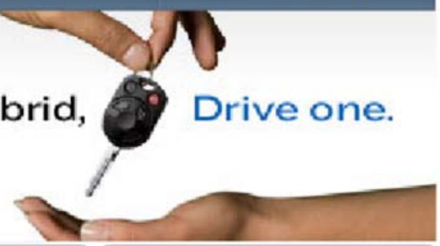

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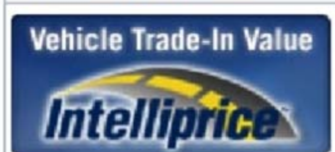

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2008 Ford Escape Hybrid - The guilt-free SUV

By Dan Lyons autoMedia.com

Chocolate without the calories. Beer without the belly. Given the choice, we'd all like to be able to indulge without consequences. But the reality is that sometimes we have to compromise. In recent years, many drivers have wished they could keep their big SUVs, but their monthly gas bills argued otherwise. So, reluctantly, they moved down in size to economize. These days, technology adds to our options, so the compromising needn't be so demoralizing. Case in point—the Ford Escape Hybrid.

Ford has recently introduced the 2008 version of its popular compact SUV, and it's available with three powertrains. In addition to a 2.3-liter four-cylinder and 3.0-liter V-6, Ford also offers a hybrid-powered model. This Escape is a full hybrid, meaning it is capable of running completely on electric power up to about 25 mph. As your speed increases, the 70 kw electric motor is joined by a 2.3-liter Atkinson cycle four-cylinder gas engine. The combined 155 horsepower is more than enough to handle daily driving situations—everything from city shuffling to highway cruising. Unlike some hybrids, Escape's power flow is seamless. There's no sudden silence when you stop, no abrupt pickup when the gas motor chimes in. The Continuously Variable Transmission (CVT) holds up its end of the driveline nicely, getting the power to the pavement efficiently. And efficiency with fuel is key to Escape Hybrid's popularity.

2008 EPA estimates for fuel efficiency are 34 city/30 highway for the front-wheel-drive Escape, making it—along with cousins Mazda Tribute Hybrid 2WD and Mercury Mariner Hybrid FWD—the most fuel-efficient SUV in the country, according to www.fueleconomy.gov. A 4-wheeldrive version is also available, with mileage estimates of 29/27. Our FWD test vehicle netted 30 mpg in mixed, city/highway driving. We know a lot of SUV drivers who would trade their eyeteeth (and their payment books) for a steady diet of 30 mpg.

Escape's available Intelligent 4WD system is geared toward allweather driving rather than all-terrain travel. It's an on-demand setup, requiring no driver input. The system monitors wheel slip and directs engine torque from front to rear as necessary to maximize traction. The Escape has a firm (but not harsh) ride and a stable feel going down the road. New for 2008 is a speed sensitive, electronic power steering unit that doles out just enough boost to keep steering effort easy, without losing feel. All Escape models benefit from "right-size" dimensions. Former drivers of larger utes will be pleasantly surprised with the ease with which Escape can be threaded through tight quarters. Visibility is generally good in all directions, though drivers must take into account the back seat head restraints when sizing up their rear view.

"Utility" is an SUVs middle name. The squared off shape of the traditional sport-ute form is a people and cargo friendly design. Escape fills the bill, on both scores. Swing up the split, lift gate door and you've got a generous, 27.8 cubic feet of cargo capacity, expandable to as much as 66 cubic feet, with both rear seats folded forward. Liftover height in back is low. Rear seat head rests must be popped off before folding. Up front, Escape has enough room to easily seat six footers. With a little legroom compromise between rows, Escape will also fit a couple of six footers in the back row. There's plenty of spots for onboard storage, including molded door pockets, a small glove box, various cubbyholes and an oversized, covered center console big enough to hold a laptop computer. Cloth seating on the Escape Hybrid is also eco-friendly, made from 100% post-industrial material.

Controls and switchgear are within arm's reach. HVAC controls are located low on the dashboard center stack. They're activated by means of three rheostats, flanked by a series of small buttons. Big hands or winter gloves will test your accuracy when changing settings while driving. The new interior design for 2008 includes a centered, dash top display with digital readouts for sound system, climate control and outdoor temperature. Standard features include side air curtains and airbags, four-wheel-disc antilock brakes, a tire pressure monitoring system and MP3 capability for your sound system. Among the available options are a Navigation/Energy Monitoring system, moon roof and a 320 sound system with a 6-disc, in-dash CD changer and Sirius satellite radio capability.

All of the above is wrapped in a fresh, sheetmetal skin for '08. While much of the SUV market is trending toward softer styling, Ford took a different approach with Escape. They've tugged the design more in line with Ford's truck division, with sharper angles and a higher beltline. Freed from the body side moldings of earlier models, Escape looks cleaner and uncluttered.

Escape Hybrid puts economy and utility together in a compact, efficient package. Prices start at $25,740 for a base model with frontwheel drive, while all-wheel-drive versions will start at $27,490. Although the purchase price of a hybrid is higher than its gas powered equivalent, the up-charge for technology may be offset in part by tax breaks and insurance discounts. In fact, if you meet eligibility requirements, Escape Hybrid buyers can qualify for a $3,000 federal income tax credit. Check with www.fueleconomy.gov for complete details.

The day-to-day discount is measured in improved mileage and the realization that you're no longer on a first name basis with the cashier at the local gas station. But, the tipping point for many people doesn't come down to money. It's the satisfaction factor—knowing you're doing a little more by using a little less.

*EPA-estimated 34 city/30 hwy mpg with FWD 2.3L I4 engine and 4-Speed Automatic (CVT) transmission.

www.fueleconomy.gov

Acc. No. 0597

model year 2008

Fuel Economy Guide

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
U.S. Environmental Protection Agency

EPA

DOE/EE-0321

CONTENTS

USING THE FUEL ECONOMY GUIDE

The U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) produce the Fuel Economy Guide to help car buyers choose the most fuel-efficient vehicle that meets their needs. The guide is published in print and on the Web at www.fueleconomy.gov. For additional print copies, please send your request to EERE Information Center, 20440 Century Boulevard, Suite 150, Germantown, MD 20874.

Fuel Economy Estimates

Each vehicle in this guide has two fuel economy estimates:

- A city estimate that represents urban driving, in which a vehicle is started in the morning (after being parked all night) and driven in stop-and-go traffic
- A highway estimate that represents a mixture of rural and interstate highway driving in a warmed-up vehicle, typical of longer trips in free-flowing traffic

These fuel economy estimates are based on laboratory testing. All vehicles are tested in the same manner to allow fair comparisons.

New Estimates Effective This Year!

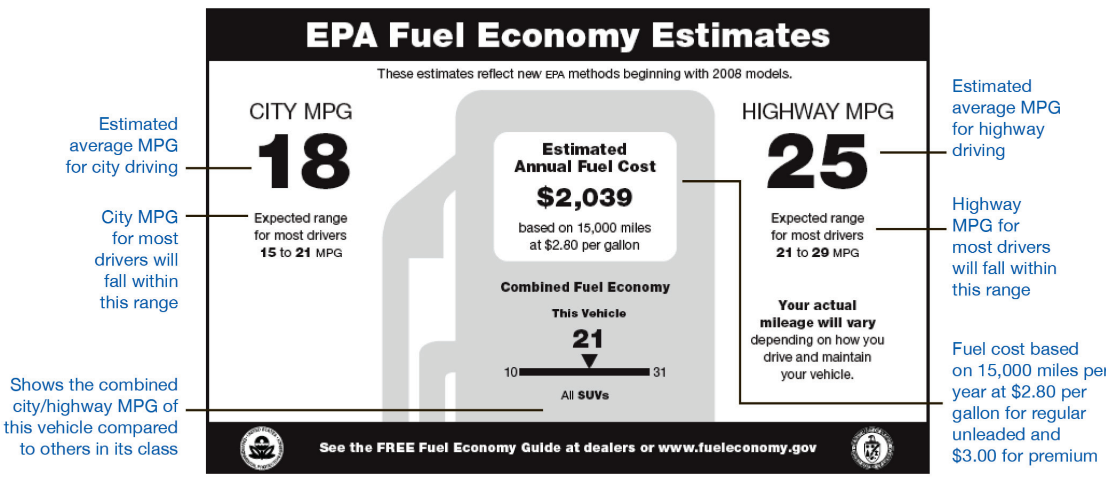
EPA has revised its methods for estimating MPG to better represent current real-world driving conditions. Beginning with 2008 model year vehicles, city and highway estimates will account for more aggressive driving (higher speeds and faster acceleration), air conditioner use, and cold temperature operation. Details about the new methodology are available at www.epa.gov/fueleconomy.

Comparing New and Old Estimates

The new testing methods cause MPG estimates for 2008 (and later) model year vehicles to be noticeably lower than those for previous years, even though the actual fuel economy you would achieve may be the same. This makes it difficult to directly compare 2008 (and later) model year vehicles with older models. A tool for comparing the new estimates with those of older vehicles is available at www.fueleconomy.gov.

Sample Fuel Economy Label

(Attached to New Vehicle Window)



Check the fuel economy label on the vehicle at the dealer showroom for its specific fuel economy (mpg) ratings. The ratings may vary slightly from the values in this guide because of engine and fuel system differences not listed here.

Annual Fuel Cost Estimates

This guide provides fuel cost estimates for each vehicle. The estimates are based on the assumptions that you travel 15,000 miles per year (55% under city driving conditions and 45% under highway conditions) and that fuel costs $3.96/gallon for regular unleaded gasoline and $4.21/gallon for premium. Cost-per-gallon assumptions for vehicles that use other fuel types are discussed at the beginning of those vehicle sections. The fuel costs are updated weekly in order to reflect current national average fuel prices. Visit www.fueleconomy.gov. to personalize fuel costs based on current fuel prices and your driving habits.

Your Fuel Economy Will Vary

Fuel economy is not a fixed number it varies significantly based on where you drive, how you drive, and other factors. Thus, it is impossible for one set of estimates to predict fuel economy precisely for all drivers in all environments.

For example, the following factors can lower your vehicle's fuel economy:

- Aggressive driving (hard acceleration and braking)
- Excessive idling, accelerating, and braking in stop-and-go traffic
- Cold weather (engines are more efficient when warmed up)
- Driving with a heavy load or the air conditioner running
- Improperly tuned engine, dirty air filter, under-inflated tires

In addition, small variations in vehicle manufacturing can cause MPG variations in the same make and model, and some vehicles don't attain maximum fuel economy until they are "broken in" (around 3,000–5,000 miles).

So, please remember that the EPA ratings are a useful tool for comparing vehicles when car buying, but they may not accurately predict the MPG you will get. This is also true for annual fuel cost estimates. For more information on fuel economy ratings and factors that affect fuel economy, visit www.fueleconomy.gov.

UNDERSTANDING THE GUIDE LISTINGS

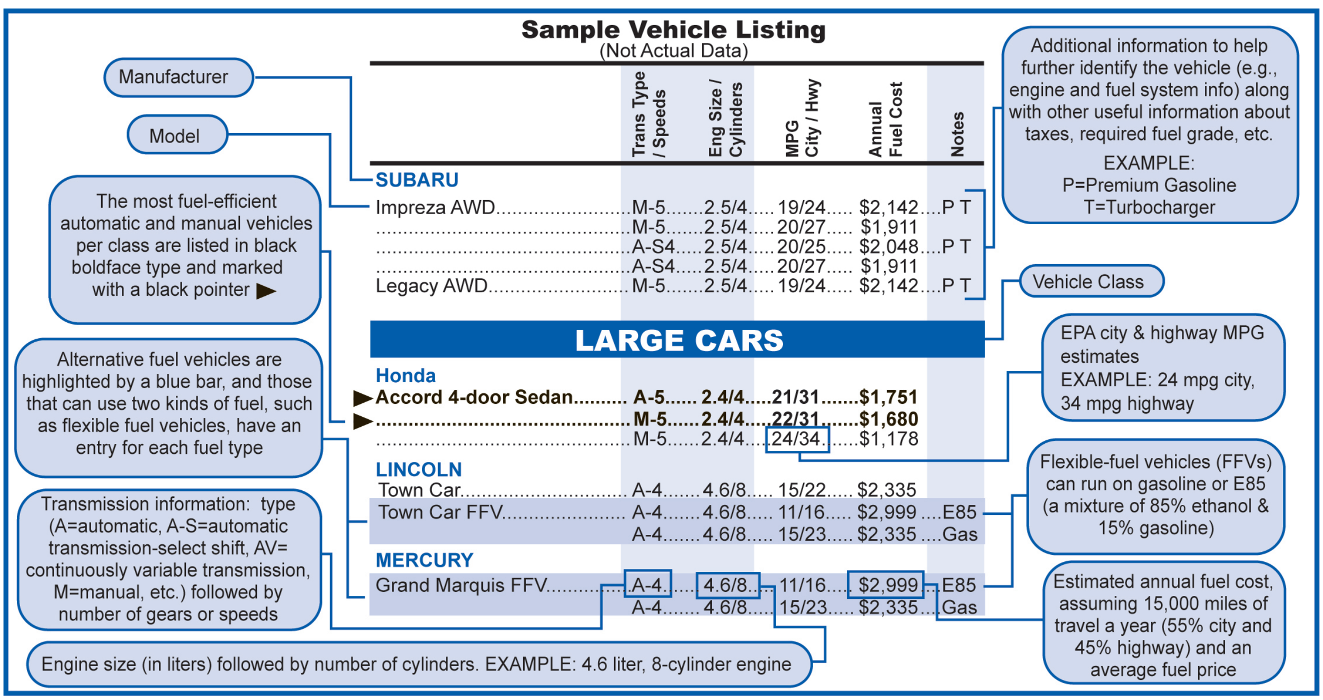
We hope you'll find the Fuel Economy Guide easy to use! Fuel economy and annual fuel cost data are organized by vehicle class (see page 2 for a list of classes). Within each class, vehicles are listed alphabetically by manufacturer and model.

Vehicle models with different features, such as engine size or transmission type, are listed as different vehicles—engine and transmission attributes are shown in columns 2 and 3. Additional attributes needed to distinguish among vehicles are listed in the "Notes" column (e.g., fuel type, suggested fuel grade). A legend for all abbreviations is provided at the bottom of of the first page of each section.

A "P" in the "Notes" column indicates that the manufacturer recommends or requires the vehicle be fueled with premiumgrade gasoline. The higher price of premium gasoline is reflected in the annual fuel cost.

The most fuel-efficient vehicles in each class and alternative fuel vehicles are indicated with special markings (see diagram below). Vehicles that can use more than one kind of fuel have an entry for each fuel type.

Interior passenger and cargo volumes are located in the index at the back of the guide.



VEHICLE CLASSES USED IN THIS GUIDE

CARS		TRUCKS	
CLASS	Passenger and Cargo Volume (cu. ft.)	CLASS	Gross Vehicle Weight Rating* (pounds)
TWO-SEATER CARS		**PICKUP TRUCKS**	
SEDANS		Small	Under 6,000
Minicompact	Under 85	Standard	6,000 to 8,500
Subcompact	85 to 99	**VANS**	Under 8,500
Compact	100 to 109	Passenger	
Midsize	110 to 119	Cargo	
Large	120 or more	**MINIVANS**	Under 8,500
STATION WAGONS		**SPORT UTILITY VEHICLES**	Under 8,500
Small	Under 130	**SPECIAL PURPOSE VEHICLES**	Under 8,500
Midsize	130 to 159		
Large	160 or more		

*Gross Vehicle Weight Rating = vehicle weight plus carrying capacity.

WHY SOME VEHICLE ARE NOT LISTED

- Fuel economy regulations currently do not apply to vehicles with a Gross Vehicle Weight Rating (vehicle weight plus carrying capacity) of more than 8,500 pounds. Therefore, some large pickup trucks, vans, and SUVs are not tested, and fuel economy labels are not posted on their windows.
- Some vehicles' fuel economy information is not available in time to be printed in the guide. However, you can find more up-to-date information at www.fueleconomy.gov.
- The availability of some vehicles is restricted.

TAX INCENTIVES AND DISINCENTIVES

Tax Credits and Deductions

If you purchase a qualifying hybrid or dedicated alternative fuel vehicle (AFV) in 2007–08, you may be eligible for a federal income tax credit of up to $3,400 for hybrids or $4,000 for AFVs—compressed natural gas (CNG) vehicles are the only AFVs commercially available as of publication of the Guide. The credit amount varies from vehicle to vehicle, and the hybrid credit will be gradually phased out based on manufacturer sales. Flexible fuel vehicles are not eligible for the alternative fuel credit.

Visit www.fueleconomy.gov for more information on qualifying models, credit amounts, and phase-out dates.

Gas Guzzler Tax

The Energy Tax Act of 1978 requires auto companies to pay agas guzzler tax on the sale of cars with exceptionally low fuel economy. Such vehicles are identifi ed in the guide by the word "Tax" in the "Notes" column. In the dealer showroom, the words "Gas Guzzler" and the tax amount are listed on the vehicle's fuel economy label. The tax does not apply to light trucks.

WHY CONSIDER FUEL ECONOMY

Save Money

You could save $200–$1,500 in fuel costs each year by choosing the most fuel-effi cient vehicle in a particular class. This can add up to thousands over a vehicle's lifetime. Fuel-efficient models come in all shapes and sizes, so you need not sacrifice utility or size.

Each vehicle listing in the Fuel Economy Guide provides an estimated annual fuel cost (see page i). The online guide at www.fueleconomy.gov features an annual fuel cost calculator that allows you to insert your local gasoline prices and typical driving conditions (% city & highway) to achieve the most accurate fuel cost information for your vehicle.

Strengthen National Energy Security

Buying a more fuel-efficient vehicle can help strengthen our national energy security by reducing our dependence on foreign oil. More than half of the oil used to produce the gasoline you put in your tank is imported. The United States uses more than 20 million barrels of oil per day, two-thirds of which is used for transportation. Petroleum imports cost us about $5.2 billion a week—that's money that could be used to fuel our own economy.

Protect the Environment

Burning fossil fuels such as gasoline and diesel adds greenhouse gases, mostly carbon dioxide (CO_2), to the Earth's atmosphere. Large-scale increases in greenhouse gases in the Earth's atmosphere can lead to global climate change.

Vehicles with lower fuel economy burn more fuel, creating more CO_2. Your vehicle creates about 20 pounds of CO_2 (170 cu. ft.) per gallon of gasoline it consumes. Therefore, you can reduce your contribution to global climate change by choosing a vehicle with higher fuel economy.

By choosing a vehicle that achieves 25 miles per gallon rather than 20, you can prevent the release of about 17 tons (260,000 cu. ft.) of greenhouse gases over the lifetime of your vehicle.

FUELING OPTIONS

Ethanol Blends – E85 & E10

Ethanol is an alcohol fuel made by fermenting and distilling starch crops, such as corn. It may also be made from "cellulosic biomass" such as trees and grasses in the near future. The use of ethanol can reduce U.S. dependence on foreign oil and reduce greenhouse gases.

E10 or "gasohol" is a blend of 10% ethanol and 90% gasoline sold in many parts of the country. All auto manufacturers approve the use of blends of 10% ethanol or less in their gasoline vehicles.

E85, a blend of 85% ethanol and 15% gasoline, can be used in flexible fuel vehicles (FFVs), which are specially designed to run on gasoline, E85, or any mixture of the two. FFVs are offered by several vehicle manufacturers. To determine if your vehicle is an FFV, check the inside of your car's fuel filler door for an identification sticker or consult your owner's manual. Several hundred filling stations in the United States currently sell E85. Visit http://afdcmap2.nrel.gov/locator/ for locations near you.

There is no noticeable difference in vehicle performance when low -level ethanol blends are used. However, FFVs operating on E85 usually experience a 20–30% drop in miles per gallon due to ethanol's lower energy content.

Biodiesel

Biodiesel is a commercially available diesel-replacement fuel manufactured from vegetable oils or animal fats. It produces fewer greenhouse gases than petroleum diesel and, since it is made domestically from renewable resources, increases national energy security.

Biodiesel can be blended at any ratio with petroleum diesel, but it is most commonly sold at ratios of 2%, 5%, or 20%, denoted as B2, B5, and B20. Most vehicle manufacturers do not yet recommend using biodiesel blends greater than B5, and some state that doing so may void the engine warranty. Check your owner's manual or with your vehicle manufacturer to determine the right blend for your vehicle.

Purchase commercial-grade biodiesel from a reputable dealer. Never refuel with clean or used grease or vegetable oil that has not been converted to biodiesel. It will damage your engine.

Use of biodiesel blends may reduce fuel economy slightly, less than 1% for B5.

Visit http://afdcmap2.nrel.gov/locator/ for locations of service stations selling biodiesel.

Premium- vs. Regular-Grade Gasoline

The recommended gasoline for most cars is regular unleaded. Using a higher-octane gasoline than recommended by the owner's manual does not improve performance or fuel efficiency; it only costs more money. Check your owner's manual to determine the lowest grade of fuel you can use.

TIPS FOR IMPROVING FUEL ECONOMY

Keep Your Car in Shape

- Fixing a car that is noticeably out of tune can improve gas mileage by about 4%. Repairing a faulty oxygen sensor can improve fuel economy by much more!
- Replacing a clogged air fi lter can signifi cantly improve gas mileage.
- Keeping tires inflated to the recommended pressure and using the recommended grade of motor oil can improve fuel economy by up to 5%. The manufacturer's recommended tire pressure can be found on the tire information placard and/or vehicle certification label located on the vehicle door edge, doorpost, glove-box door, or inside the trunk lid.

Plan and Combine Trips

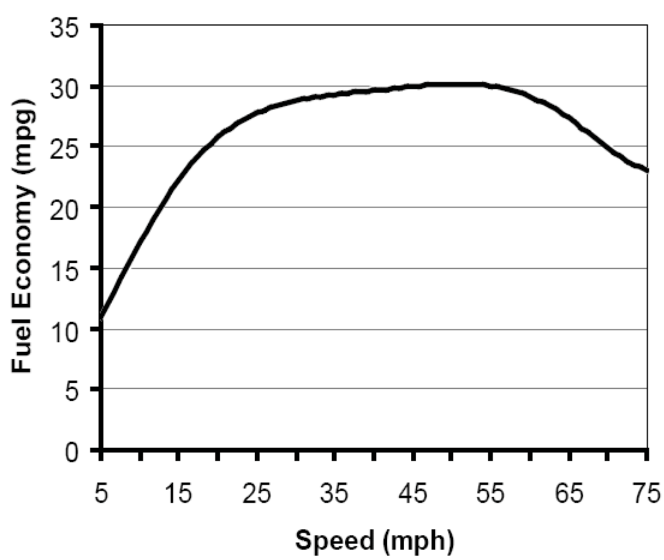
- A warmed-up engine is more fuel effi cient than a cold one. Many short trips taken from a cold start can use twice as much fuel as one multipurpose trip covering the same distance when the engine is warmed up and efficient.

  Note: Letting your car idle to warm-up doesn't help your fuel economy, it actually uses more fuel and creates more pollution.

For more tips and more information about gasoline pricing, visit www.fueleconomy.gov.

Drive More Efficiently

- Aggressive driving (speeding and rapid acceleration and braking) can lower your gas mileage by as much as 33% at highway speeds and 5% around town.
- Observe the speed limit—each 5 miles per hour (mph) you drive over 60 mph can reduce your fuel economy by 10%.
- Avoid idling—idling gets 0 miles per gallon!



MODEL YEAR 2008 FUEL ECONOMY LEADERS

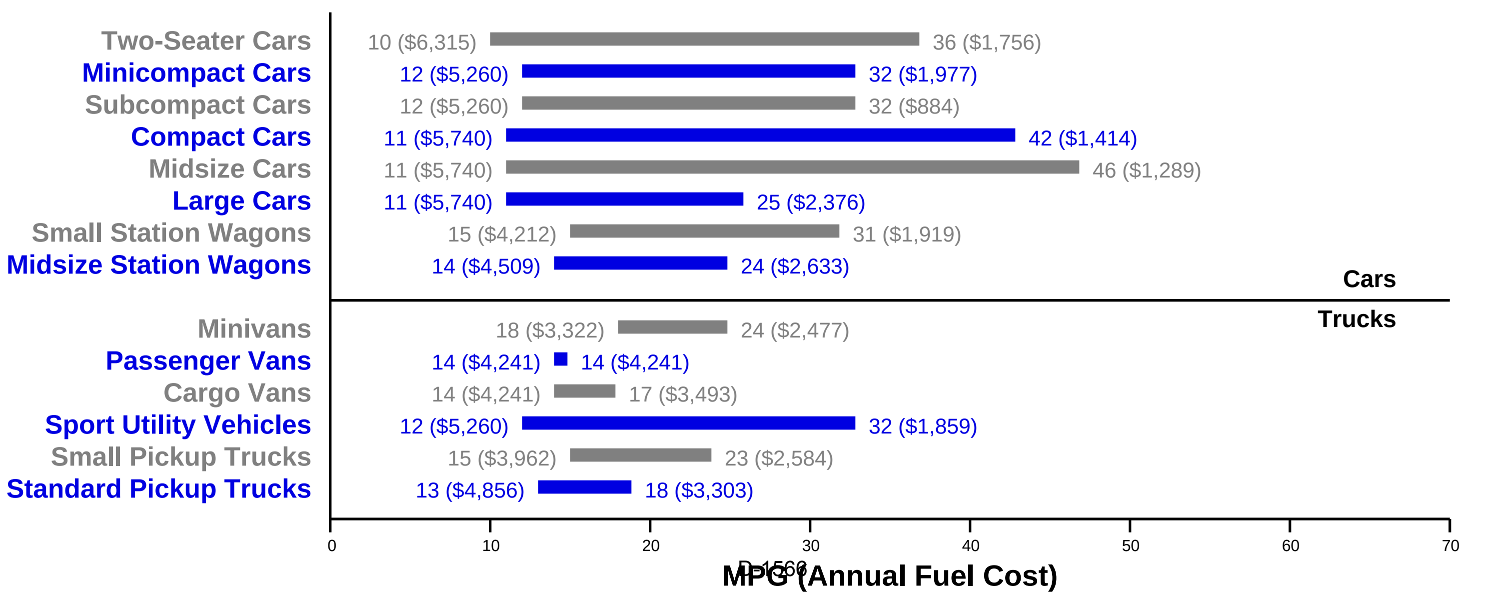
Listed below are vehicles with the highest fuel economy in the most popular classes, including vehicles with both automatic and manual transmissions. Please note that many vehicle models come in a range of engine sizes and trim lines, resulting in different fuel economy values.

	Transmission Type	MPG City/Hwy
TWO-SEATER CARS		
smart fortwo convertible	automatic	33/41
smart fortwo coupe	automatic	33/41
Mazda MX-5	manual	22/27
MINICOMPACT CARS		
MINI Cooper	automatic	26/34
MINI Cooper	manual	28/37
SUBCOMPACT CARS		
Toyota Yaris	automatic	29/35
Toyota Yaris	manual	29/36
COMPACT CARS		
Honda Civic Hybrid	automatic	40/45
Toyota Corolla	manual	28/37
MIDSIZE CARS		
Toyota Prius	automatic	48/45
Nissan Versa	manual	26/31
LARGE CARS		
Honda Accord	automatic	21/31
Honda Accord	manual	22/31
SMALL STATION WAGONS		
Honda Fit	automatic	27/34
Honda Fit	manual	28/34
MIDSIZE STATION WAGONS		
Volkswagen Passat Wagon	automatic	20/28
Volkswagen Passat Wagon	manual	20/29
SMALL PICKUP TRUCKS		
Toyota Tacoma 2WD	automatic	19/25
Ford Ranger Pickup 2WD	manual	21/26
Mazda B2300 2WD	manual	21/26
STANDARD PICKUP TRUCKS		
Chevrolet Silverado C15 2WD*	automatic	15/20
Dodge Dakota Pickup 2WD	automatic	15/20
GMC Sierra C15 2WD*	automatic	15/20
Honda Ridgeline Truck 4WD	automatic	15/20
Mitsubishi Raider Pickup 2WD	automatic	15/20
Dodge Dakota Pickup 2WD	manual	16/20
Mitsubishi Raider Pickup 2WD	manual	16/20
CARGO VANS		
Chevrolet Van 1500/2500 2WD	automatic	15/20
GMC Savana 1500/2500 2WD (cargo)	automatic	15/20
MINIVANS		
Mazda 5	automatic	21/27
Mazda 5	manual	22/28
SPORT UTILITY VEHICLES		
Ford Escape Hybrid FWD	automatic	34/30
Mazda Tribute Hybrid 2WD	automatic	34/30
Mercury Mariner Hybrid FWD	automatic	34/30
Jeep Compass 2WD	manual	23/28
Jeep Patriot 2WD	manual	23/28

* Applies to both gasoline-only and flexible fuel models.

FUEL ECONOMY AND ANNUAL FUEL COST RANGES FOR VEHICLE CLASSES

The graph below provides the fuel economy and annual fuel cost ranges for the vehicles in each class so you can see where a given vehicle's fuel economy and cost fall within its class. Combined city and highway MPG estimates are used; these assume you will drive 55% in the city and 45% on the highway. Annual fuel costs assume you travel 15,000 miles each year and fuel costs $3.96/gallon for regular unleaded gasoline and $4.21/gallon for premium. Visit www.fueleconomy.gov to calculate annual fuel cost for a specific vehicle based on your own driving conditions and per-gallon fuel costs.



2008 MODEL YEAR VEHICLES

This section contains the fuel economy values for 2008 model year vehicles. Alternative fuel vehicles are highlighted with a blue bar, and those that can use two kinds of fuel, such as flexible fuel vehicles, have an entry for each fuel type. The most fuel-efficient automatic and manual vehicles per class are listed in black boldface type and marked with a black pointer (▶).

TWO SEATERS

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
ASTON MARTIN					
V8 Vantage	A-S6	4.3/8	13/20	$4,212	P Tax
	M-6	4.3/8	12/19	$4,212	P Tax
AUDI					
R8	A-S6	4.2/8	13/19	$4,212	P Tax
	M-6	4.2/8	13/20	$4,212	P Tax
TT Roadster	A-S6	2.0/4	22/29	$2,526	P T
TT Roadster Quattro	A-S6	3.2/6	18/24	$3,158	P
	M-6	3.2/6	17/24	$3,322	P
BMW					
Z4 3.0i	A-S6	3.0/6	19/28	$2,873	P
	M-6	3.0/6	18/28	$3,006	P
Z4 3.0si	A-S6	3.0/6	19/28	$2,873	P
	M-6	3.0/6	18/28	$3,006	P
Z4 Coupe	A-S6	3.0/6	19/28	$2,873	P
	M-6	3.0/6	18/28	$3,006	P
Z4 M Coupe	M-6	3.2/6	15/23	$3,511	P Tax
Z4 M Roadster	M-6	3.2/6	15/23	$3,511	P Tax
BUGATTI					
Veyron	A-S6	8.0/16	8/14	$6,315	P T Tax
CADILLAC					
XLR	A-S6	4.4/8	14/21	$3,947	P S Tax
	A-S6	4.6/8	15/24	$3,511	P
CHEVROLET					
Corvette	A-S6	6.2/8	15/25	$3,511	P
	M-6	6.2/8	16/26	$3,322	P
	M-6	7.0/8	15/24	$3,511	P
CHRYSLER					
Crossfire Coupe	A-5	3.2/6	19/25	$3,006	P
	M-6	3.2/6	15/23	$3,511	P
Crossfire Roadster	A-5	3.2/6	19/25	$3,006	P
	M-6	3.2/6	15/23	$3,511	P

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
DODGE					
Viper Convertible	M-6	8.4/10	13/22	$3,947	P Tax
Viper Coupe	M-6	8.4/10	13/22	$3,947	P Tax
FERRARI					
599 GTB Fiorano	A-6	5.9/12	11/15	$5,260	P Tax
	M-6	5.9/12	11/15	$5,260	P Tax
F430	A-6	4.3/8	11/16	$4,856	P Tax
	M-6	4.3/8	11/16	$4,856	P Tax
HONDA					
S2000	M-6	2.2/4	18/25	$3,006	P
LAMBORGHINI					
Gallardo Coupe	A-S6	5.0/10	11/17	$4,856	P Tax
	M-6	5.0/10	10/17	$4,856	P Tax
Gallardo Spyder	A-S6	5.0/10	10/16	$5,260	P Tax
	M-6	5.0/10	10/15	$5,260	P Tax
Murcielago	A-S6	6.5/12	9/14	$5,740	P Tax
	M-6	6.5/12	8/13	$6,315	P Tax
Murcielago Reventon	A-S6	6.5/12	9/14	$5,740	P Tax
Murcielago Roadster	A-S6	6.5/12	9/14	$5,740	P Tax
	M-6	6.5/12	8/13	$6,315	P Tax
LOTUS					
Elise/Exige	M-6	1.8/4	21/27	$2,584	
	M-6	1.8/4	20/26	$2,703	S
MAZDA					
MX-5	A-S6	2.0/4	20/27	$2,747	P
▶ MX-5	**M-5**	**2.0/4**	**22/27**	**$2,633**	**P**
	M-6	2.0/4	21/28	$2,633	P
MERCEDES-BENZ					
SL55 AMG	A-S5	5.4/8	12/17	$4,509	P S Tax
SL550	A-7	5.5/8	14/21	$3,947	P Tax
SL600	A-5	5.5/12	11/18	$4,509	P T Tax
SL65 AMG	A-S5	6.0/12	11/18	$4,509	P T Tax
SLK280	A-7	3.0/6	18/24	$3,158	P
	M-6	3.0/6	17/25	$3,158	P
SLK350	A-7	3.5/6	17/23	$3,322	P

ABBREVIATIONS:

▶	Highest MPG in Class	Convsn	Conversion	HP	Horsepower
2WD	Two-Wheel Drive	D	Diesel	LRG	Low Range Gearing
4WD	Four-Wheel Drive	Di	Direct Injection	M	Manual Transmission
A	Automatic Transmission	E85	85% Ethanol/15% Gasoline	NA	Not Available at this time
A-S	Automatic Transmission-Select Shift	Eng Size	Engine Volume in Liters	P	Premium Gasoline Recommended
AV	Constantly Variable Transmission	FFV	Flexible Fuel Vehicle	S	Supercharger
AWD	All-Wheel Drive	FWD	Front-Wheel Drive	T	Turbocharger
City	MPG on City Test Procedure	Gas	Regular Gasoline	Tax	Subject to Gas Guzzler Tax
CNG	Compressed Natural Gas	HEV	Hybrid-Electric Vehicle	Trans	Transmission
		Hwy	MPG on Highway Test Procedure		

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
	M-6	3.5/6	16/23	$3,322	P
SLK55 AMG	A-S7	5.4/8	14/20	$3,947	P Tax
SLR	A-S5	5.4/8	12/16	$4,856	P S Tax
NISSAN					
350z	A-S5	3.5/6	17/24	$3,158	P
	M-6	3.5/6	18/25	$3,158	P
350z Roadster	A-S5	3.5/6	17/23	$3,322	P
	M-6	3.5/6	17/24	$3,158	P
PONTIAC					
Solstice	A-5	2.0/4	19/26	$3,006	P T
	M-5	2.0/4	19/28	$2,873	P T
	A-5	2.4/4	19/24	$3,006	P
	M-5	2.4/4	19/25	$3,006	P
PORSCHE					
911 GT2	M-6	3.6/6	16/23	$3,322	P T
911 GT3	M-6	3.6/6	15/22	$3,511	P
911 GT3 RS	M-6	3.6/6	15/22	$3,511	P
Boxster	A-5	2.7/6	19/26	$3,006	P
	M-5	2.7/6	20/29	$2,747	P
	M-6	2.7/6	19/28	$2,873	P
Boxster S	A-5	3.4/6	18/25	$3,006	P
	M-6	3.4/6	18/26	$3,006	P
Cayman	A-5	2.7/6	19/26	$3,006	P
	M-5	2.7/6	20/29	$2,747	P
	M-6	2.7/6	19/28	$2,873	P
Cayman S	A-5	3.4/6	18/25	$3,006	P
	M-6	3.4/6	18/26	$3,006	P
SATURN					
SKY	A-5	2.0/4	19/26	$3,006	P T
	M-5	2.0/4	19/28	$2,873	P T
	A-5	2.4/4	19/24	$3,006	P
	M-5	2.4/4	19/25	$3,006	P
SHELBY					
Mustang GT	M-5	4.6/8	15/22	$3,713	P Tax
SMART					
▶ **fortwo convertible**	**A-S5**	**1.0/3**	**33/41**	**$1,756**	**P**
▶ **fortwo coupe**	**A-S5**	**1.0/3**	**33/41**	**$1,756**	**P**

MINICOMPACT CARS

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
ASTON MARTIN					
DB9 Coupe	A-S6	5.9/12	11/18	$4,856	P Tax
	M-6	5.9/12	10/16	$5,260	P Tax
DB9 Volante	A-S6	5.9/12	11/17	$4,856	P Tax
	M-6	5.9/12	10/16	$5,260	P Tax
JAGUAR					
XK	A-6	4.2/8	16/25	$3,322	P
XK Convertible	A-6	4.2/8	16/25	$3,322	P
XKR	A-6	4.2/8	15/23	$3,511	P S
XKR Convertible	A-6	4.2/8	15/23	$3,511	P S
LEXUS					
SC 430	A-S6	4.3/8	16/23	$3,322	P
MINI					
▶ **Cooper**	**A-S6**	**1.6/4**	**26/34**	**$2,179**	**P**
▶ **Cooper**	**M-6**	**1.6/4**	**28/37**	**$1,977**	**P**
Cooper Convertible	AV	1.6/4	22/30	$2,526	P
	M-5	1.6/4	23/32	$2,431	P
Cooper S	A-S6	1.6/4	23/32	$2,337	P T
	M-6	1.6/4	26/34	$2,179	P T
Cooper S Convertible	A-S6	1.6/4	19/29	$2,747	P S
	M-6	1.6/4	21/29	$2,633	P S
MITSUBISHI					
Eclipse Spyder	A-S4	2.4/4	19/26	$2,703	
	M-5	2.4/4	19/26	$2,703	
	A-S5	3.8/6	16/24	$3,322	P
	M-6	3.8/6	16/25	$3,322	P
PORSCHE					
911 Turbo	A-5	3.6/6	15/23	$3,511	P T
	M-6	3.6/6	16/23	$3,511	P T
911 Turbo Cabriolet	A-5	3.6/6	15/23	$3,511	P T
	M-6	3.6/6	15/24	$3,511	P T
Carrera 2 Cabriolet	A-5	3.6/6	18/24	$3,158	P
	M-6	3.6/6	18/26	$3,006	P
Carrera 2 Coupe	A-5	3.6/6	18/24	$3,158	P
	M-6	3.6/6	18/26	$3,006	P
Carrera 2 S Cabriolet	A-5	3.8/6	17/24	$3,158	P
	M-6	3.8/6	17/25	$3,158	P
Carrera 2 S Coupe	A-5	3.8/6	17/24	$3,158	P
	M-6	3.8/6	17/25	$3,158	P
Carrera 4 Cabriolet	A-5	3.6/6	17/24	$3,322	P
	M-6	3.6/6	17/25	$3,158	P
Carrera 4 Coupe	A-5	3.6/6	17/24	$3,322	P
	M-6	3.6/6	17/25	$3,158	P
Carrera 4 S Cabriolet	A-5	3.8/6	17/23	$3,322	P
	M-6	3.8/6	16/24	$3,322	P
Carrera 4 S Coupe	A-5	3.8/6	17/23	$3,322	P
	M-6	3.8/6	16/24	$3,322	P
Carrera 4 S Targa	A-5	3.8/6	17/23	$3,322	P
	M-6	3.8/6	16/24	$3,322	P
Carrera 4 Targa	A-5	3.6/6	17/24	$3,322	P
	M-6	3.6/6	17/25	$3,158	P
VOLKSWAGEN					
New Beetle Convertible	A-S6	2.5/5	20/28	$2,584	
	M-5	2.5/5	20/28	$2,584	

SUBCOMPACT CARS

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
AUDI					
A4 Cabriolet	AV	2.0/4	21/30	$2,633	P T
A4 Cabriolet Quattro	A-S6	2.0/4	19/27	$2,873	P T
	A-S6	3.1/6	17/25	$3,158	P
A5 Quattro	A-S6	3.2/6	18/27	$3,006	P
	M-6	3.2/6	16/27	$3,158	P
RS4 Cabriolet	M-6	4.2/8	12/19	$4,509	P Tax

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
S4 Cabriolet	A-S6	4.2/8	14/21	$3,947	P Tax
	M-6	4.2/8	13/19	$4,212	P Tax
S5	A-S6	4.2/8	16/22	$3,322	P
	M-6	4.2/8	14/21	$3,947	P Tax
TT Coupe	A-S6	2.0/4	23/31	$2,431	P T
TT Coupe Quattro	A-S6	3.2/6	18/24	$3,158	P
	M-6	3.2/6	17/24	$3,322	P
BENTLEY					
Continental GTC	A-S6	6.0/12	10/17	$5,260	P T Tax
BMW					
128i	A-S6	3.0/6	19/28	$2,873	P
	M-6	3.0/6	18/28	$3,006	P
128i Convertible	A-S6	3.0/6	18/27	$3,006	P
	M-6	3.0/6	18/28	$3,006	P
135i	A-S6	3.0/6	18/26	$3,006	P T
	M-6	3.0/6	17/25	$3,158	P T
135i Convertible	A-S6	3.0/6	17/26	$3,158	P T
	M-6	3.0/6	17/26	$3,158	P T
328ci	A-S6	3.0/6	19/28	$2,873	P
	M-6	3.0/6	18/28	$3,006	P
328ci Convertible	A-S6	3.0/6	18/27	$3,006	P
	M-6	3.0/6	17/27	$3,158	P
328cxi	A-S6	3.0/6	17/25	$3,158	P
	M-6	3.0/6	17/25	$3,158	P
335ci	A-S6	3.0/6	17/26	$3,158	P T
	M-6	3.0/6	17/26	$3,158	P T
335ci Convertible	A-S6	3.0/6	17/26	$3,158	P T
	M-6	3.0/6	17/26	$3,158	P T
335cxi	A-S6	3.0/6	17/25	$3,158	P T
	M-6	3.0/6	16/25	$3,322	P T
650ci	A-S6	4.8/8	15/23	$3,511	P
	M-6	4.8/8	15/22	$3,511	P
650ci Convertible	A-S6	4.8/8	15/23	$3,511	P
	M-6	4.8/8	14/21	$3,947	P Tax
M3 Convertible	A-S7	4.0/8	14/20	$3,947	P Tax
	M-6	4.0/8	13/19	$3,947	P Tax
M3 Coupe	A-S7	4.0/8	14/20	$3,947	P Tax
	M-6	4.0/8	14/20	$3,947	P Tax
M6	A-S7	5.0/10	11/17	$4,856	P Tax
	M-6	5.0/10	11/17	$4,856	P Tax
M6 Convertible	A-S7	5.0/10	11/17	$4,856	P Tax
	M-6	5.0/10	11/17	$4,856	P Tax
CHEVROLET					
Aveo 5	A-4	1.6/4	23/32	$2,287	
	M-5	1.6/4	24/34	$2,198	
Cobalt	M-5	2.0/4	22/30	$2,526	P T
	A-4	2.2/4	22/31	$2,287	
	M-5	2.2/4	24/33	$2,198	
	A-4	2.4/4	22/31	$2,526	P
	M-5	2.4/4	22/32	$2,431	P
Cobalt XFE	M-5	2.2/4	25/36	$2,049	
CHRYSLER					
Sebring Convertible	A-4	2.4/4	20/29	$2,584	
	A-4	2.7/6	18/26	$2,827	
	A-6	3.5/6	16/26	$3,124	
Sebring Convertible FFV	A-4	2.7/6	18/26	$2,827	Gas
			13/19	$2,871	E85
FORD					
Mustang	A-5	4.0/6	16/24	$3,124	
	M-5	4.0/6	17/26	$2,970	
	A-5	4.6/8	15/22	$3,303	
	M-5	4.6/8	15/23	$3,303	
	M-6	5.4/8	14/20	$3,947	P S Tax
HONDA					
Civic	A-5	1.8/4	25/36	$2,049	
	M-5	1.8/4	26/34	$2,049	
	M-6	2.0/4	21/29	$2,633	P
Civic CNG	A-5	1.8/4	24/36	$884	CNG
HYUNDAI					
Tiburon	A-4	2.0/4	20/27	$2,703	
	M-5	2.0/4	20/28	$2,584	
	A-4	2.7/6	17/24	$2,970	
	M-5	2.7/6	17/24	$2,970	
	M-6	2.7/6	16/24	$3,124	
INFINITI					
G37 Coupe	A-S5	3.7/6	18/24	$3,158	P
	M-6	3.7/6	17/26	$3,158	P
LEXUS					
IS 250	A-S6	2.5/6	21/29	$2,633	P
	M-6	2.5/6	18/26	$3,006	P
IS 250 AWD	A-S6	2.5/6	20/26	$2,873	P
IS 350	A-S6	3.5/6	18/25	$3,158	P
IS F	A-S8	5.0/8	16/23	$3,511	P
MASERATI					
GranTurismo	A-6	4.2/8	13/19	$4,212	P Tax
MAZDA					
RX-8	A-S6	1.3/2	16/23	$3,322	P
	M-6	1.3/2	16/22	$3,511	P
MERCEDES-BENZ					
CLK350	A-7	3.5/6	17/25	$3,158	P
CLK350 (Cabriolet)	A-7	3.5/6	17/25	$3,158	P
CLK550	A-7	5.5/8	15/22	$3,713	P Tax
CLK550 (Cabriolet)	A-7	5.5/8	15/21	$3,713	P Tax
CLK63 AMG	A-S7	6.2/8	12/19	$4,509	P Tax
CLK63 AMG (Cabriolet)	A-S7	6.2/8	12/18	$4,509	P Tax
MINI					
Clubman	A-S6	1.6/4	26/34	$2,179	P
	M-6	1.6/4	28/37	$1,977	P

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
Clubman S	A-S6	1.6/4	23/32	$2,337	P T
	M-6	1.6/4	26/34	$2,179	P T
MITSUBISHI					
Eclipse	A-S4	2.4/4	20/26	$2,703	
	M-5	2.4/4	20/28	$2,584	
	A-S5	3.8/6	17/25	$3,158	P
	M-6	3.8/6	16/25	$3,322	P
NISSAN					
Altima Coupe	AV	2.5/4	23/31	$2,287	
	M-6	2.5/4	23/32	$2,287	
	AV	3.5/6	19/26	$2,873	P
	M-6	3.5/6	19/27	$2,873	P
PONTIAC					
G5 XFE	M-5	2.2/4	25/35	$2,049	
G5/Pursuit	A-4	2.2/4	22/31	$2,287	
	M-5	2.2/4	24/33	$2,198	
	A-4	2.4/4	22/31	$2,526	P
	M-5	2.4/4	22/32	$2,431	P
ROUSH PERFORMANCE					
Stage 3 Mustang	A-5	4.6/8	14/20	$3,947	P S Tax
	M-5	4.6/8	15/20	$3,713	P S Tax
SAAB					
9-3 Convertible	A-S5	2.0/4	18/24	$3,158	P T
	M-6	2.0/4	18/27	$2,873	P T
	A-S6	2.8/6	15/24	$3,511	P T
	M-6	2.8/6	16/26	$3,322	P T
SALEEN PERFORMANCE					
S281 Family	M-6	5.0/8	12/18	$4,509	P S Tax
	M-6	5.0/8	12/18	$4,509	P S Tax
SCION					
tC	A-4	2.4/4	21/29	$2,477	
	M-5	2.4/4	20/27	$2,584	
xD	A-4	1.8/4	26/32	$2,121	
	M-5	1.8/4	27/33	$2,049	
TOYOTA					
▸ **Yaris**	**A-4**	**1.5/4**	**29/35**	**$1,919**	
▸ **Yaris**	**M-5**	**1.5/4**	**29/36**	**$1,859**	
VOLKSWAGEN					
Eos	A-S6	2.0/4	21/30	$2,633	P T
	M-6	2.0/4	20/29	$2,633	P T
	A-S6	3.2/6	19/26	$2,873	P
New Beetle	A-S6	2.5/5	20/29	$2,584	
	M-5	2.5/5	20/28	$2,584	
VOLVO					
C70 Convertible	A-S5	2.5/5	18/26	$3,006	P T
	M-6	2.5/5	18/27	$3,006	P T

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
COMPACT CARS					
ACURA					
TSX	A-S5	2.4/4	20/28	$2,747	P
	M-6	2.4/4	19/28	$2,873	P
AUDI					
A4	AV	2.0/4	21/30	$2,633	P T
	M-6	2.0/4	20/31	$2,633	P T
	AV	3.1/6	18/27	$3,006	P
A4 Quattro	A-S6	2.0/4	19/27	$2,873	P T
	M-6	2.0/4	20/28	$2,747	P T
	A-S6	3.1/6	17/25	$3,158	P
	M-6	3.1/6	15/25	$3,322	P
RS4	M-6	4.2/8	13/20	$4,212	P Tax
S4	A-S6	4.2/8	14/21	$3,947	P Tax
	M-6	4.2/8	13/20	$4,212	P Tax
BENTLEY					
Azure	A-S6	6.7/8	9/15	$5,740	P T Tax
Continental GT	A-S6	6.0/12	10/17	$4,856	P T Tax
BMW					
328i	A-S6	3.0/6	19/28	$2,873	P
	M-6	3.0/6	18/28	$3,006	P
328xi	A-S6	3.0/6	17/25	$3,158	P
	M-6	3.0/6	17/25	$3,158	P
335i	A-S6	3.0/6	17/26	$3,158	P T
	M-6	3.0/6	17/26	$3,158	P T
335xi	A-S6	3.0/6	17/25	$3,158	P T
	M-6	3.0/6	16/25	$3,322	P T
M3	A-S7	4.0/8	14/20	$3,947	P Tax
	M-6	4.0/8	14/20	$3,947	P Tax
CHEVROLET					
Aveo	A-4	1.6/4	23/32	$2,287	
	M-5	1.6/4	24/34	$2,198	
CHRYSLER					
PT Cruiser Convertible	A-4	2.4/4	18/24	$3,006	P T
	A-4	2.4/4	19/24	$2,827	
	M-5	2.4/4	21/26	$2,584	
	M-5	2.4/4	20/25	$2,873	P T
FORD					
Focus	A-4	2.0/4	24/33	$2,121	
	M-5	2.0/4	24/35	$2,121	
HONDA					
Accord Coupe	A-5	2.4/4	21/30	$2,477	
	M-5	2.4/4	22/31	$2,376	
	A-5	3.5/6	19/28	$2,703	
	M-6	3.5/6	17/25	$2,970	
▸ **Civic Hybrid**	**AV**	**1.3/4**	**40/45**	**$1,414**	**HEV**

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
HYUNDAI					
Accent	A-4	1.6/4	24/33	$2,121	
	M-5	1.6/4	27/32	$2,049	
JAGUAR					
X-Type	A-5	3.0/6	16/22	$3,511	P
KIA					
Rio	A-4	1.6/4	25/35	$2,049	
	M-5	1.6/4	27/32	$2,049	
LEXUS					
GS 450h	A-S6	3.5/6	22/25	$2,747	HEV P
MAZDA					
3	A-S4	2.0/4	23/31	$2,287	
	M-5	2.0/4	24/32	$2,198	
	A-S5	2.3/4	22/29	$2,477	
	M-5	2.3/4	22/29	$2,376	
MERCEDES-BENZ					
C300	M-6	3.0/6	18/26	$3,006	P
C300 FFV	A-7	3.0/6	18/25	$3,006	Gas
			13/19	$2,871	E85
C300 4matic	A-7	3.0/6	17/25	$3,158	P
C350	A-7	3.5/6	17/25	$3,158	P
C63 AMG	A-S7	6.2/8	12/19	$4,212	P Tax
CL550	A-7	5.5/8	14/21	$3,713	P Tax
CL600	A-5	5.5/12	11/17	$4,856	P T Tax
CL63 AMG	A-S7	6.2/8	11/18	$4,509	P Tax
CL65 AMG	A-S5	5.5/12	11/17	$4,856	P T Tax
CLS550	A-7	5.5/8	14/21	$3,947	P Tax
CLS63 AMG	A-S7	6.2/8	12/18	$4,509	P Tax
MITSUBISHI					
Lancer	AV	2.0/4	22/29	$2,477	
	M-5	2.0/4	21/29	$2,477	
Lancer Evolution	A-S6	2.0/4	17/22	$3,322	P T
	M-5	2.0/4	16/22	$3,511	P T
PONTIAC					
G6	A-4	2.4/4	22/30	$2,376	
	A-S4	3.5/6	17/26	$2,970	
	A-4	3.5/6	18/29	$2,703	
	A-S6	3.6/6	17/26	$2,970	
	A-S4	3.9/6	15/22	$3,303	
ROLLS-ROYCE					
Phantom Drophead Coupe	A-S6	6.7/12	11/18	$4,509	P Tax
SAAB					
9-3 Aero Sedan AWD	A-S6	2.8/6	15/24	$3,511	P T
	M-6	2.8/6	16/24	$3,322	P T
9-3 Sport Sedan	A-S5	2.0/4	19/26	$3,006	P T
	M-6	2.0/4	19/29	$2,747	P T
	A-S6	2.8/6	15/24	$3,511	P T
	M-6	2.8/6	16/26	$3,322	P T
SATURN					
Astra 2DR Hatchback	A-4	1.8/4	24/30	$2,198	
	M-5	1.8/4	24/32	$2,198	
Astra 4DR Hatchback	A-4	1.8/4	24/30	$2,198	
	M-5	1.8/4	24/32	$2,198	
SUBARU					
Impreza AWD	A-S4	2.5/4	20/25	$2,873	P T
	A-S4	2.5/4	20/27	$2,703	
	M-5	2.5/4	19/25	$3,006	P T
	M-5	2.5/4	20/27	$2,703	
Legacy AWD	A-S4	2.5/4	20/27	$2,703	
	A-S5	2.5/4	18/24	$3,158	P T
	M-5	2.5/4	19/24	$3,006	P T
	M-5	2.5/4	20/27	$2,703	
	M-6	2.5/4	17/24	$3,158	P T
	A-S5	3.0/6	17/24	$3,158	P
SUZUKI					
Forenza	A-4	2.0/4	19/28	$2,703	
	M-5	2.0/4	20/28	$2,584	
Reno	A-4	2.0/4	19/28	$2,703	
	M-5	2.0/4	20/28	$2,584	
SX4 Sedan	A-4	2.0/4	23/31	$2,287	
	M-5	2.0/4	22/30	$2,376	
TOYOTA					
Camry Solara	A-S5	2.4/4	22/31	$2,376	
	M-5	2.4/4	21/31	$2,376	
	A-S5	3.3/6	18/27	$2,827	
Camry Solara Convertible	A-S5	3.3/6	18/26	$2,827	
Corolla	A-4	1.8/4	26/35	$2,049	
▸ **Corolla**	**M-5**	**1.8/4**	**28/37**	**$1,919**	
VOLKSWAGEN					
GTI	A-S6	2.0/4	22/29	$2,526	P T
	M-6	2.0/4	20/29	$2,633	P T
Jetta	A-S6	2.0/4	22/29	$2,526	P T
	M-6	2.0/4	20/29	$2,633	P T
	A-S6	2.5/5	21/29	$2,477	
	M-5	2.5/5	21/29	$2,477	
R32	A-S6	3.2/6	18/23	$3,158	P
Rabbit	A-S6	2.5/5	21/29	$2,477	
	M-5	2.5/5	22/29	$2,477	
VOLVO					
C30 FWD	A-S5	2.4/5	20/28	$2,747	P
	M-5	2.4/5	20/28	$2,747	P
	A-S5	2.5/5	19/27	$2,873	P T
	M-6	2.5/5	19/28	$2,747	P T
S40 AWD	A-S5	2.5/5	18/26	$3,006	P T
	M-6	2.5/5	17/25	$3,158	P T
S40 FWD	A-S5	2.4/5	20/28	$2,747	P
	M-5	2.4/5	20/28	$2,747	P

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
	A-S5	2.5/5	19/27	$2,873	P T
	M-6	2.5/5	19/28	$2,747	P T
S60 AWD	A-S5	2.5/5	18/26	$3,006	P T
	A-5	2.5/5	17/26	$3,006	P T
S60 FWD	A-S5	2.4/5	18/26	$3,006	P T
	M-6	2.4/5	18/26	$3,006	P T
	A-S5	2.5/5	19/27	$2,873	P T
	A-5	2.5/5	19/27	$2,873	P T

MIDSIZE CARS

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
ACURA					
RL	A-S5	3.5/6	16/24	$3,322	P
TL	A-S5	3.2/6	18/26	$3,006	P
	A-S5	3.5/6	17/26	$3,158	P
	M-6	3.5/6	18/27	$3,006	P
AUDI					
A6	AV	3.1/6	18/27	$3,006	P
A6 Quattro	A-S6	3.1/6	17/25	$3,158	P
	A-S6	4.2/8	16/23	$3,511	P
A8	A-S6	4.2/8	16/23	$3,511	P
S6	A-S6	5.2/10	14/19	$3,947	P Tax
S8	A-S6	5.2/10	13/19	$4,212	P Tax
BENTLEY					
Arnage	A-S6	6.7/8	10/15	$5,740	P T Tax
Continental Flying Spur	A-S6	6.0/12	10/17	$5,260	P T Tax
BMW					
528i	A-S6	3.0/6	18/27	$3,006	P
	M-6	3.0/6	18/28	$3,006	P
528xi	A-S6	3.0/6	17/25	$3,158	P
	M-6	3.0/6	17/25	$3,158	P
535i	A-S6	3.0/6	17/26	$3,158	P T
	M-6	3.0/6	17/26	$3,158	P T
535xi	A-S6	3.0/6	17/25	$3,158	P T
	M-6	3.0/6	16/25	$3,322	P T
550i	A-S6	4.8/8	15/23	$3,511	P
	M-6	4.8/8	15/22	$3,511	P
M5	A-S7	5.0/10	11/17	$4,856	P Tax
	M-6	5.0/10	11/17	$4,856	P Tax
BUICK					
Lacrosse/Allure	A-4	3.6/6	17/25	$2,970	
	A-4	3.8/6	17/28	$2,827	
	A-4	5.3/8	16/24	$3,322	P
CADILLAC					
CTS	A-S6	3.6/6	18/26	$2,827	
	A-S6	3.6/6	17/26	$2,970	Di
	M-6	3.6/6	16/25	$3,124	
	M-6	3.6/6	16/25	$3,124	Di
CTS AWD	A-S6	3.6/6	17/25	$2,970	
	A-S6	3.6/6	17/26	$2,970	Di
STS	A-S6	3.6/6	17/26	$2,970	Di
	A-S6	4.4/8	13/19	$4,212	P S Tax
	A-S6	4.6/8	15/24	$3,511	P
STS AWD	A-S6	3.6/6	17/26	$2,970	Di
	A-S6	4.6/8	14/21	$3,947	P Tax
CHEVROLET					
Classic	A-4	2.2/4	21/31	$2,376	
	A-4	3.5/6	18/28	$2,703	
Malibu	A-S6	2.4/4	22/32	$2,376	
	A-4	2.4/4	22/30	$2,376	
	A-4	3.5/6	18/29	$2,703	
	A-S6	3.6/6	17/26	$2,970	
Malibu Hybrid	A-4	2.4/4	24/32	$2,198	HEV
CHRYSLER					
Sebring	A-4	2.4/4	21/30	$2,477	
	A-4	2.7/6	19/27	$2,703	
	A-6	3.5/6	16/26	$3,124	
Sebring FFV	A-4	2.7/6	19/27	$2,703	Gas
			13/20	$2,691	E85
Sebring AWD	A-6	3.5/6	15/24	$3,303	
DODGE					
Avenger	A-4	2.4/4	21/30	$2,477	
	A-4	2.7/6	19/27	$2,703	
	A-6	3.5/6	16/26	$3,124	
Avenger FFV	A-4	2.7/6	19/27	$2,703	Gas
			13/20	$2,691	E85
Avenger AWD	A-6	3.5/6	15/24	$3,303	
Caliber	M-5	1.8/4	24/29	$2,287	
	AV	2.0/4	23/27	$2,477	
	AV	2.4/4	21/25	$2,584	
	M-5	2.4/4	23/29	$2,376	
Caliber AWD	AV	2.4/4	21/24	$2,703	
Challenger	A-5	6.1/8	13/18	$4,212	P Tax
FERRARI					
612 Scaglietti	A-6	5.7/12	9/16	$5,740	P Tax
	M-6	5.7/12	10/15	$5,260	P Tax
FORD					
Fusion	A-5	2.3/4	20/28	$2,584	
	M-5	2.3/4	20/29	$2,584	
	A-6	3.0/6	18/26	$2,827	
Fusion AWD	A-6	3.0/6	17/25	$2,970	
HYUNDAI					
Elantra	A-4	2.0/4	25/33	$2,121	
	M-5	2.0/4	24/33	$2,198	
INFINITI					
G35	A-S5	3.5/6	17/24	$3,158	P
	M-6	3.5/6	17/25	$3,158	P
G35x	A-S5	3.5/6	17/23	$3,322	P
JAGUAR					
S-Type 3.0 Litre	A-6	3.0/6	17/26	$3,158	P
S-Type 4.2 Litre	A-6	4.2/8	16/24	$3,322	P

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	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
S-Type R	A-6	4.2/8	15/22	$3,713	P S
X-Type Sport Brake	A-5	3.0/6	16/22	$3,511	P
KIA					
Optima	A-5	2.4/4	21/31	$2,376	
	M-5	2.4/4	21/31	$2,376	
	A-5	2.7/6	20/28	$2,584	
Spectra	A-4	2.0/4	24/32	$2,198	
	M-5	2.0/4	23/30	$2,287	
LEXUS					
ES 350	A-S6	3.5/6	19/27	$2,873	P
GS 350	A-S6	3.5/6	19/27	$2,873	P
GS 350 AWD	A-S6	3.5/6	18/25	$3,158	P
GS 460	A-S8	4.6/8	17/24	$3,158	P
LS 460	A-S8	4.6/8	16/24	$3,322	P
LS 460 L	A-S8	4.6/8	16/24	$3,322	P
LS 600h L	A-S8	5.0/8	20/22	$3,006	HEV P
LINCOLN					
MKZ AWD	A-6	3.5/6	17/24	$3,124	
MKZ FWD	A-6	3.5/6	18/28	$2,703	
MAZDA					
6	A-S5	2.3/4	21/28	$2,477	
	M-5	2.3/4	21/29	$2,477	
	A-S6	3.0/6	18/25	$2,970	
	M-5	3.0/6	17/25	$2,970	
Speed 3	M-6	2.3/4	18/26	$3,158	P T
MERCEDES-BENZ					
E320 Bluetec	A-7	3.0/6	23/32	$2,657	D T
E350	A-7	3.5/6	17/24	$3,322	P
E350 4matic	A-5	3.5/6	16/22	$3,511	P
E550	A-7	5.5/8	15/22	$3,713	P
E550 4matic	A-7	5.5/8	13/19	$3,947	P Tax
E63 AMG	A-S7	6.2/8	12/19	$4,212	P Tax
MERCURY					
Milan	A-5	2.3/4	20/28	$2,584	
	M-5	2.3/4	20/29	$2,584	
	A-6	3.0/6	18/26	$2,827	
Milan AWD	A-6	3.0/6	17/25	$2,970	
MITSUBISHI					
Galant	A-S4	2.4/4	20/27	$2,584	
	A-S5	3.8/6	17/25	$3,158	P
NISSAN					
Altima	AV	2.5/4	23/31	$2,287	
	M-6	2.5/4	23/32	$2,287	
	AV	3.5/6	19/26	$2,873	P
	M-6	3.5/6	19/27	$2,873	P
Altima Hybrid	AV	2.5/4	35/33	$1,746	HEV
Maxima	AV	3.5/6	19/25	$3,006	P
Sentra	AV	2.0/4	25/33	$2,121	

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
	M-6	2.0/4	24/31	$2,198	
	AV	2.5/4	24/30	$2,287	
	M-6	2.5/4	21/29	$2,633	P
Versa	AV	1.8/4	27/33	$2,049	
	A-4	1.8/4	24/32	$2,198	
▸ **Versa**	**M-6**	**1.8/4**	**26/31**	**$2,121**	
PONTIAC					
Grand Prix	A-4	3.8/6	18/28	$2,827	
	A-S4	5.3/8	16/25	$3,322	P
ROLLS-ROYCE					
Phantom	A-S6	6.7/12	11/18	$4,509	P Tax
Phantom EWB	A-S6	6.7/12	11/18	$4,509	P Tax
SAAB					
9-5 Sedan	A-S5	2.3/4	17/26	$3,158	P T
	M-5	2.3/4	18/28	$3,006	P T
SATURN					
Aura	A-4	2.4/4	22/30	$2,376	
	A-4	3.5/6	18/29	$2,703	
	A-S6	3.6/6	17/26	$2,970	
Aura Hybrid	A-4	2.4/4	24/32	$2,198	HEV
TOYOTA					
Camry	A-5	2.4/4	21/31	$2,376	
	M-5	2.4/4	21/31	$2,376	
	A-S6	3.5/6	19/28	$2,703	
Camry Hybrid	AV	2.4/4	33/34	$1,746	HEV
▸ **Prius**	**AV**	**1.5/4**	**48/45**	**$1,289**	**HEV**
VOLKSWAGEN					
Passat	A-S6	2.0/4	19/28	$2,873	P T
	M-6	2.0/4	20/29	$2,633	P T
	A-S6	3.6/6	17/26	$3,158	P
Passat 4motion	A-S6	3.6/6	16/24	$3,322	P
VOLVO					
S80 AWD	A-S6	3.0/6	15/23	$3,511	P T
	A-S6	3.2/6	16/24	$3,322	P
	A-S6	4.4/8	15/23	$3,511	P
S80 FWD	A-S6	3.2/6	16/24	$3,322	P
LARGE CARS					
AUDI					
A8 L	A-S6	4.2/8	16/23	$3,511	P
	A-S6	6.0/12	13/19	$4,212	P Tax
BENTLEY					
Arnage RL	A-S6	6.7/8	9/15	$5,740	P T Tax
BMW					
750i	A-S6	4.8/8	15/23	$3,511	P
750li	A-S6	4.8/8	15/23	$3,511	P
760li	A-S6	6.0/12	13/20	$4,212	P Tax

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
BMW ALPINA					
B7	A-S6	4.4/8	14/21	$3,947	P S Tax
BUICK					
Lucerne	A-4	3.8/6	16/25	$3,124	
	A-4	4.6/8	15/23	$3,303	275HP
	A-4	4.6/8	15/22	$3,303	300HP
CADILLAC					
DTS	A-4	4.6/8	15/23	$3,303	275HP
	A-4	4.6/8	15/22	$3,303	300HP
Funeral Coach / Hearse	A-4	4.6/8	13/18	$3,962	Tax
Limousine	A-4	4.6/8	13/18	$3,962	Tax
CHEVROLET					
Impala	A-4	3.5/6	18/29	$2,703	
	A-4	5.3/8	16/24	$3,322	P
Impala FFV	A-4	3.5/6	18/29	$2,703	Gas
			14/21	$2,691	E85
Impala FFV	A-4	3.9/6	18/28	$2,827	Gas
			13/20	$2,691	E85
CHRYSLER					
300 AWD	A-5	3.5/6	15/22	$3,303	
	A-5	5.7/8	15/22	$3,303	
300/SRT-8	A-4	2.7/6	18/26	$2,827	
	A-4	3.5/6	17/24	$2,970	
	A-5	3.5/6	17/24	$2,970	
	A-5	5.7/8	15/23	$3,303	
	A-5	6.1/8	13/18	$4,212	P Tax
DODGE					
Charger	A-4	2.7/6	18/26	$2,827	
	A-4	3.5/6	17/24	$2,970	
	A-5	3.5/6	17/24	$2,970	
	A-5	5.7/8	15/23	$3,303	
	A-5	6.1/8	13/18	$4,212	P Tax
Charger AWD	A-5	3.5/6	15/22	$3,303	
	A-5	5.7/8	15/22	$3,303	
FORD					
Crown Victoria FFV	A-4	4.6/8	15/23	$3,303	Gas
			11/16	$3,311	E85
Taurus AWD	A-6	3.5/6	17/24	$3,124	
Taurus FWD	A-6	3.5/6	18/28	$2,703	
HONDA					
▸ **Accord**	**A-5**	**2.4/4**	**21/31**	**$2,477**	
▸ **Accord**	**M-5**	**2.4/4**	**22/31**	**$2,376**	
	A-5	3.5/6	19/29	$2,703	
HYUNDAI					
Azera	A-5	3.3/6	18/26	$2,827	
	A-5	3.8/6	17/26	$2,970	
Sonata	A-4	2.4/4	21/30	$2,477	
	M-5	2.4/4	21/31	$2,376	
	A-5	3.3/6	19/28	$2,703	
INFINITI					
M35	A-S5	3.5/6	16/23	$3,322	P
M35x	A-S5	3.5/6	16/22	$3,511	P
M45	A-S5	4.5/8	16/21	$3,511	P
M45x	A-S5	4.5/8	14/20	$3,947	P Tax
JAGUAR					
Super V8	A-6	4.2/8	15/22	$3,511	P S
Vdp Lwb	A-6	4.2/8	16/25	$3,322	P
XJ8	A-6	4.2/8	16/25	$3,322	P
XJ8L	A-6	4.2/8	16/25	$3,322	P
XJR	A-6	4.2/8	15/22	$3,511	P S
KIA					
Amanti	A-5	3.8/6	17/24	$3,124	
LINCOLN					
Town Car	A-4	4.6/8	15/22	$3,303	
Town Car FFV	A-4	4.6/8	15/23	$3,303	Gas
			11/16	$3,311	E85
MASERATI					
Quattroporte	A-6	4.2/8	12/18	$4,509	P Tax
MAYBACH					
57	A-5	5.5/12	10/16	$5,260	P T Tax
57S	A-5	6.0/12	10/16	$5,260	P T Tax
62	A-5	5.5/12	10/16	$5,260	P T Tax
62S	A-5	6.0/12	10/16	$5,260	P T Tax
MERCEDES-BENZ					
S550	A-7	5.5/8	14/21	$3,947	P Tax
S550 4matic	A-7	5.5/8	14/20	$3,947	P Tax
S600	A-5	5.5/12	11/17	$4,856	P T Tax
S63 AMG	A-S7	6.2/8	11/17	$4,856	P Tax
S65 AMG	A-S5	6.0/12	11/17	$4,856	P T Tax
MERCURY					
Grand Marquis FFV	A-4	4.6/8	15/23	$3,303	Gas
			11/16	$3,311	E85
Sable AWD	A-6	3.5/6	17/24	$3,124	
Sable FWD	A-6	3.5/6	18/28	$2,703	
PONTIAC					
G8	A-S5	3.6/6	17/25	$2,970	
	A-S6	6.0/8	15/24	$3,511	P
TOYOTA					
Avalon	A-S6	3.5/6	19/28	$2,703	
SMALL STATION WAGONS					
AUDI					
A3	A-S6	2.0/4	22/29	$2,526	P T
	M-6	2.0/4	20/29	$2,633	P T
A3 Quattro	A-S6	3.2/6	18/25	$3,006	P

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
A4 Avant Quattro	A-S6	2.0/4	19/27	$2,873	P T
	M-6	2.0/4	20/28	$2,747	P T
	A-S6	3.1/6	17/25	$3,158	P
	M-6	3.1/6	15/25	$3,322	P
S4 Avant	A-S6	4.2/8	14/21	$3,947	P Tax
	M-6	4.2/8	13/20	$4,212	P Tax
BMW					
328i Sport Wagon	A-S6	3.0/6	18/27	$3,006	P
	M-6	3.0/6	17/27	$3,158	P
328xi Sport Wagon	A-S6	3.0/6	17/25	$3,158	P
	M-6	3.0/6	17/25	$3,158	P
HONDA					
Fit	A-S5	1.5/4	27/33	$2,049	
▸ **Fit**	**A-5**	**1.5/4**	**27/34**	**$1,978**	
▸ **Fit**	**M-5**	**1.5/4**	**28/34**	**$1,919**	
INFINITI					
EX35	A-S5	3.5/6	17/24	$3,322	P
	A-S5	3.5/6	16/23	$3,322	P
PONTIAC					
Vibe	A-4	1.8/4	25/31	$2,198	
	M-5	1.8/4	26/33	$2,049	
SAAB					
9-3 Aero SportCombi AWD	A-S6	2.8/6	15/24	$3,511	P T
	M-6	2.8/6	16/24	$3,322	P T
9-3 SportCombi	A-S5	2.0/4	18/24	$3,158	P T
	M-6	2.0/4	19/29	$2,747	P T
	A-S6	2.8/6	15/24	$3,511	P T
	M-6	2.8/6	16/26	$3,322	P T
SCION					
xB	A-S4	2.4/4	22/28	$2,477	
	M-5	2.4/4	22/28	$2,477	
SUBARU					
Impreza Wagon/Outback SPT AWD	A-S4	2.5/4	20/27	$2,703	
	A-S4	2.5/4	20/25	$2,873	P T
	M-5	2.5/4	19/25	$3,006	P T
	M-5	2.5/4	20/27	$2,703	
	M-6	2.5/4	17/23	$3,322	P T
SUZUKI					
Forenza Wagon	A-4	2.0/4	19/27	$2,703	
	M-5	2.0/4	19/27	$2,703	
SX4	A-4	2.0/4	22/30	$2,376	
	M-5	2.0/4	22/30	$2,376	
SX4 AWD	A-4	2.0/4	21/28	$2,477	
	M-5	2.0/4	21/28	$2,584	
TOYOTA					
Matrix	A-4	1.8/4	25/31	$2,198	
	M-5	1.8/4	26/33	$2,049	

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
VOLKSWAGEN					
Jetta SportWagon	A-S6	2.5/5	21/29	$2,477	
	M-5	2.5/5	21/29	$2,477	
VOLVO					
V50 AWD	A-S5	2.5/5	18/26	$3,006	P T
	M-6	2.5/5	17/25	$3,158	P T
V50 FWD	A-S5	2.4/5	20/28	$2,747	P
	M-5	2.4/5	20/28	$2,747	P
	A-S5	2.5/5	19/27	$2,873	P T
	M-6	2.5/5	19/28	$2,747	P T
MIDSIZE STATION WAGONS					
AUDI					
A6 Avant Quattro	A-S6	3.1/6	17/25	$3,158	P
BMW					
535xi Sport Wagon	A-S6	3.0/6	16/24	$3,322	P T
	M-6	3.0/6	16/23	$3,511	P T
KIA					
Rondo	A-4	2.4/4	19/26	$2,703	
	A-5	2.7/6	18/26	$2,827	
MERCEDES-BENZ					
E350 4matic (wagon)	A-5	3.5/6	16/21	$3,511	P
E63 AMG (wagon)	A-S7	6.2/8	12/18	$4,509	P Tax
SAAB					
9-5 SportCombi	A-S5	2.3/4	17/26	$3,158	P T
	M-5	2.3/4	18/28	$3,006	P T
VOLKSWAGEN					
▸ **Passat Wagon**	**A-S6**	**2.0/4**	**20/28**	**$2,747**	**P T**
▸ **Passat Wagon**	**M-6**	**2.0/4**	**20/29**	**$2,633**	**P T**
Passat Wagon 4Motion	A-S6	3.6/6	16/24	$3,322	P
VOLVO					
V70 FWD	A-S6	3.2/6	16/24	$3,322	P
SMALL PICKUP TRUCKS 2WD					
CHEVROLET					
Colorado 2WD	A-4	2.9/4	18/24	$2,970	
	M-5	2.9/4	18/24	$2,970	
	A-4	3.7/5	16/22	$3,303	
Colorado Cab Chassis inc 2WD	A-4	3.7/5	14/18	$3,962	
Colorado Crew Cab 2WD	A-4	2.9/4	18/24	$2,970	
	M-5	2.9/4	18/24	$2,970	
	A-4	3.7/5	16/22	$3,303	
FORD					
Ranger Pickup 2WD	A-5	2.3/4	19/24	$2,827	
▸ **Ranger Pickup 2WD**	**M-5**	**2.3/4**	**21/26**	**$2,584**	
	A-5	3.0/6	15/20	$3,493	
	M-5	3.0/6	16/22	$3,303	
	A-5	4.0/6	15/20	$3,493	
	M-5	4.0/6	15/20	$3,493	

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
GMC					
Canyon 2WD	A-4	2.9/4	18/24	$2,970	
	M-5	2.9/4	18/24	$2,970	
	A-4	3.7/5	16/22	$3,303	
Canyon Cab Chassis Inc 2WD	A-4	3.7/5	14/18	$3,962	
Canyon Crew Cab 2WD	A-4	2.9/4	18/24	$2,970	
	M-5	2.9/4	18/24	$2,970	
	A-4	3.7/5	16/22	$3,303	
ISUZU					
i-290 Extended Cab 2WD	A-4	2.9/4	18/24	$2,970	
	M-5	2.9/4	18/24	$2,970	
i-370 Crew Cab 2WD	A-4	3.7/5	16/22	$3,303	
i-370 Extended Cab 2WD	A-4	3.7/5	16/22	$3,303	
MAZDA					
B2300 2WD	A-5	2.3/4	19/24	$2,827	
▸ B2300 2WD	**M-5**	**2.3/4**	**21/26**	**$2,584**	
B3000 2WD	A-5	3.0/6	15/20	$3,493	
	M-5	3.0/6	16/21	$3,303	
B4000 2WD	A-5	4.0/6	15/20	$3,493	
NISSAN					
Frontier 2WD	A-5	2.5/4	17/22	$3,124	
	M-5	2.5/4	19/23	$2,827	
	A-5	4.0/6	15/20	$3,493	
	M-6	4.0/6	16/20	$3,493	
TOYOTA					
▸ Tacoma 2WD	**A-4**	**2.7/4**	**19/25**	**$2,827**	
	M-5	2.7/4	20/25	$2,703	
	A-5	4.0/6	16/20	$3,303	
	M-6	4.0/6	15/19	$3,493	

SMALL PICKUP TRUCKS 4WD

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
CHEVROLET					
Colorado 4WD	A-4	2.9/4	17/22	$3,124	
	M-5	2.9/4	16/22	$3,303	
	A-4	3.7/5	15/21	$3,493	
Colorado Cab Chassis inc 4WD	A-4	3.7/5	15/20	$3,493	
Colorado Crew Cab 4WD	A-4	3.7/5	15/20	$3,493	
FORD					
Ranger Pickup 4WD	A-5	3.0/6	14/19	$3,713	
	M-5	3.0/6	15/20	$3,493	
	A-5	4.0/6	14/17	$3,962	
	M-5	4.0/6	15/19	$3,713	
GMC					
Canyon 4WD	A-4	2.9/4	17/22	$3,124	
	M-5	2.9/4	16/22	$3,303	
	A-4	3.7/5	15/21	$3,493	
Canyon Cab Chassis Inc 4WD	A-4	3.7/5	15/20	$3,493	
Canyon Crew Cab 4WD	A-4	3.7/5	15/20	$3,493	
ISUZU					
i-370 Crew Cab 4WD	A-4	3.7/5	15/20	$3,493	
MAZDA					
B4000 4WD	A-5	4.0/6	14/17	$3,962	
	M-5	4.0/6	15/19	$3,713	
NISSAN					
Frontier 4WD	A-5	4.0/6	14/19	$3,713	
	M-6	4.0/6	15/19	$3,493	
TOYOTA					
Tacoma 4WD	M-5	2.7/4	17/22	$3,124	
	A-5	4.0/6	16/20	$3,303	
	M-6	4.0/6	15/18	$3,713	

STANDARD PICKUP TRUCKS 2WD

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
CHEVROLET					
▸ Silverado C15 2WD	**A-4**	**4.3/6**	**15/20**	**$3,493**	
	A-4	4.8/8	14/19	$3,713	
▸ Silverado C15 2WD	**A-4**	**5.3/8**	**15/20**	**$3,493**	
	A-4	6.0/8	13/18	$3,962	
▸ Silverado C15 2WD FFV	**A-4**	**5.3/8**	**15/20**	**$3,493**	**Gas**
			11/15	**$3,311**	**E85**
DODGE					
▸ Dakota Pickup 2WD	**A-4**	**3.7/6**	**15/20**	**$3,493**	
▸ Dakota Pickup 2WD	**M-6**	**3.7/6**	**16/20**	**$3,303**	
	A-5	4.7/8	14/19	$3,962	
Dakota Pickup 2WD FFV	A-5	4.7/8	14/19	$3,962	Gas
			9/12	$4,305	E85
Ram 1500 Pickup 2WD	A-4	3.7/6	14/19	$3,713	
	M-6	3.7/6	16/19	$3,493	
	A-5	4.7/8	13/18	$3,962	
	M-6	4.7/8	13/17	$4,241	
	A-5	5.7/8	13/19	$3,962	
Ram 1500 Pickup 2WD FFV	A-5	4.7/8	13/18	$3,962	Gas
			9/12	$4,305	E85
Ram 1500 Pickup 2WD FFV	M-6	4.7/8	13/17	$4,241	Gas
			9/12	$4,305	E85
FORD					
Explorer Sport Trac 2WD	A-5	4.0/6	14/20	$3,713	
	A-6	4.6/8	13/20	$3,713	
F150 Pickup 2WD	A-4	4.2/6	14/19	$3,713	
	M-5	4.2/6	14/20	$3,713	
	A-4	4.6/8	14/19	$3,713	
	A-4	5.4/8	13/17	$4,241	
F150 Pickup FFV 2WD	A-4	5.4/8	13/18	$3,962	Gas
			10/13	$3,913	E85
F150 STX SE 2WD	A-4	5.4/8	14/19	$3,962	
F150 STX SE FFV 2WD	A-4	5.4/8	14/19	$3,962	Gas
			10/14	$3,586	E85
GMC					
▸ Sierra C15 2WD	**A-4**	**4.3/6**	**15/20**	**$3,493**	
	A-4	4.8/8	14/19	$3,713	

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
▸ **Sierra C15 2WD**	**A-4**	**5.3/8**	**15/20**	**$3,493**	
	A-4	6.0/8	13/18	$3,962	
	A-6	6.2/8	12/19	$4,212	P
▸ **Sierra C15 2WD FFV**	**A-4**	**5.3/8**	**15/20**	**$3,493**	**Gas**
			11/15	**$3,311**	**E85**
LINCOLN					
Mark LT	A-4	5.4/8	12/16	$4,241	
MITSUBISHI					
▸ **Raider Pickup 2WD**	**A-4**	**3.7/6**	**15/20**	**$3,493**	
▸ **Raider Pickup 2WD**	**M-6**	**3.7/6**	**16/20**	**$3,303**	
	A-5	4.7/8	14/19	$3,962	
Raider Pickup 2WD FFV	A-5	4.7/8	14/19	$3,962	Gas
			9/12	$4,305	E85
NISSAN					
Titan 2WD	A-5	5.6/8	12/17	$4,241	
Titan 2WD FFV	A-5	5.6/8	12/17	$4,241	Gas
			9/13	$4,305	E85
ROUSH PERFORMANCE					
Stage 3 F150 Regular Cab 2WD	A-4	5.4/8	11/15	$4,856	P S
Stage 3 F150 Super Cab 2WD	A-4	5.4/8	11/15	$4,856	P S
Stage 3 F150 Super Crew 2WD	A-4	5.4/8	11/15	$4,856	P S
SALEEN PERFORMANCE					
F150 Supercharged	A-4	5.4/8	11/15	$4,856	P S
S331 Family	A-4	5.4/8	11/15	$4,856	P S
TECSTAR, LP					
Foose F150 Regular Cab 2WD	A-4	5.4/8	11/15	$4,856	P S
Foose F150 Super Cab 2WD	A-4	5.4/8	11/15	$4,856	P S
Foose F150 Super Crew 2WD	A-4	5.4/8	11/15	$4,856	P S
TOYOTA					
Tundra 2WD	A-S5	4.0/6	15/19	$3,493	
	A-S5	4.7/8	14/17	$3,962	
	A-S6	5.7/8	14/18	$3,713	
STANDARD PICKUP TRUCKS 4WD					
CHEVROLET					
Silverado K15 4WD	A-4	4.3/6	14/18	$3,962	
	A-4	4.8/8	14/18	$3,713	
	A-4	5.3/8	14/19	$3,713	
	A-4	6.0/8	13/17	$4,241	
Silverado K15 4WD FFV	A-4	5.3/8	14/19	$3,713	Gas
			11/14	$3,586	E85
DODGE					
Dakota Pickup 4WD	A-4	3.7/6	14/18	$3,962	
	M-6	3.7/6	15/19	$3,713	
	A-5	4.7/8	14/19	$3,962	
Dakota Pickup 4WD FFV	A-5	4.7/8	14/19	$3,962	Gas
			9/12	$4,305	E85
Ram 1500 Pickup 4WD	A-5	4.7/8	13/17	$3,962	
	M-6	4.7/8	12/16	$4,241	
	A-5	5.7/8	13/17	$4,241	
Ram 1500 Pickup 4WD FFV	A-5	4.7/8	13/17	$3,962	Gas
			9/12	$4,305	E85
Ram 1500 Pickup 4WD FFV	M-6	4.7/8	12/16	$4,241	Gas
			9/12	$4,305	E85
FORD					
Explorer Sport Trac 4WD	A-5	4.0/6	13/19	$3,962	
	A-6	4.6/8	13/19	$3,962	
F150 Pickup 4WD	A-4	4.6/8	13/17	$4,241	
	A-4	5.4/8	13/17	$4,241	
F150 Pickup FFV 4WD	A-4	5.4/8	13/17	$3,962	Gas
			9/12	$4,305	E85
GMC					
Sierra K15 4WD	A-4	4.3/6	14/18	$3,962	
	A-4	4.8/8	14/18	$3,713	
	A-4	5.3/8	14/19	$3,713	
	A-4	6.0/8	13/17	$4,241	
Sierra K15 4WD FFV	A-4	5.3/8	14/19	$3,713	Gas
			11/14	$3,586	E85
Sierra K15 AWD	A-6	6.2/8	12/18	$4,509	P
HONDA					
▸ **Ridgeline Truck 4WD**	**A-5**	**3.5/6**	**15/20**	**$3,493**	
LINCOLN					
Mark LT 4WD	A-4	5.4/8	13/17	$4,241	
MITSUBISHI					
Raider Pickup 4WD	A-4	3.7/6	14/18	$3,962	
	A-5	4.7/8	14/19	$3,962	
Raider Pickup 4WD FFV	A-5	4.7/8	14/19	$3,962	Gas
			9/12	$4,305	E85
NISSAN					
Titan 4WD	A-5	5.6/8	12/17	$4,241	
Titan 4WD FFV	A-5	5.6/8	12/17	$4,241	Gas
			9/12	$4,305	E85
ROUSH PERFORMANCE					
Stage 3 F150 Regular Cab 4WD	A-4	5.4/8	11/15	$4,856	P S
Stage 3 F150 Super Cab 4WD	A-4	5.4/8	11/15	$4,856	P S
Stage 3 F150 Super Crew 4WD	A-4	5.4/8	11/15	$4,856	P S
TECSTAR, LP					
Foose F150 Regular Cab 4WD	A-4	5.4/8	11/15	$4,856	P S
Foose F150 Super Cab 4WD	A-4	5.4/8	11/15	$4,856	P S

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
Foose F150 Super Crew 4WD	A-4	5.4/8	11/15	$4,856	P S
TOYOTA					
Tundra 4WD	A-S5	4.7/8	13/16	$3,962	
	A-S6	5.7/8	13/17	$4,241	
VANS, CARGO TYPE					
CHEVROLET					
Van 15/25 2WD Conversion	A-4	5.3/8	12/16	$4,241	
Van 15/25 2WD Conversion FFV	A-4	5.3/8	12/16	$4,241	Gas
			9/12	$4,305	E85
Van 1500 AWD Conversion	A-4	5.3/8	12/16	$4,241	
Van 1500 AWD Conversion FFV	A-4	5.3/8	12/16	$4,241	Gas
			9/12	$4,305	E85
▶ **Van 1500/2500 2WD**	**A-4**	**4.3/6**	**15/20**	**$3,493**	
	A-4	5.3/8	14/18	$3,962	
Van 1500/2500 2WD FFV	A-4	5.3/8	14/18	$3,962	Gas
			10/13	$3,913	E85
Van 1500/2500 AWD	A-4	5.3/8	13/17	$3,962	
Van 1500/2500 AWD FFV	A-4	5.3/8	13/17	$3,962	Gas
			10/12	$3,913	E85
GMC					
Savana 15/25 2WD Conversion (cargo)	A-4	5.3/8	12/16	$4,241	
Savana 15/25 2WD Conversion (cargo) FFV	A-4	5.3/8	12/16	$4,241	Gas
			9/12	$4,305	E85
Savana 1500 AWD Conversion (cargo)	A-4	5.3/8	12/16	$4,241	
Savana 1500 AWD Conversion (cargo) FFV	A-4	5.3/8	12/16	$4,241	Gas
			9/12	$4,305	E85
▶ **Savana 1500/2500 2WD (cargo)**	**A-4**	**4.3/6**	**15/20**	**$3,493**	
	A-4	5.3/8	14/18	$3,962	
Savana 1500/2500 2WD (cargo) FFV	A-4	5.3/8	14/18	$3,962	Gas
			10/13	$3,913	E85
Savana 1500/2500 AWD (cargo)	A-4	5.3/8	13/17	$3,962	
Savana 1500/2500 AWD (cargo) FFV	A-4	5.3/8	13/17	$3,962	Gas
			10/12	$3,913	E85
VANS, PASSENGER TYPE					
CHEVROLET					
Express 1500 AWD	A-4	5.3/8	12/16	$4,241	
Express 1500 AWD FFV	A-4	5.3/8	12/16	$4,241	Gas
			9/12	$4,305	E85
Express 1500/2500 2WD	A-4	5.3/8	12/16	$4,241	
Express 1500/2500 2WD FFV	A-4	5.3/8	12/16	$4,241	Gas
			9/12	$4,305	E85
GMC					
Savana 1500 AWD (Passenger)	A-4	5.3/8	12/16	$4,241	
Savana 1500 AWD (Passenger) FFV	A-4	5.3/8	12/16	$4,241	Gas

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
			9/12	$4,305	E85
Savana 1500/2500 2WD (Passenger)	A-4	5.3/8	12/16	$4,241	
Savana 1500/2500 2WD (Passenger) FFV	A-4	5.3/8	12/16	$4,241	Gas
			9/12	$4,305	E85
MINIVAN 2WD					
BUICK					
Terraza FWD	A-4	3.9/6	16/23	$3,124	
CHEVROLET					
Uplander FWD	A-4	3.9/6	16/23	$3,124	
Uplander FWD FFV	A-4	3.9/6	16/23	$3,124	Gas
			12/17	$3,074	E85
CHRYSLER					
Town and Country	A-4	3.3/6	17/24	$3,124	
	A-6	3.8/6	16/23	$3,303	
	A-6	4.0/6	16/23	$3,303	
Town and Country FFV	A-4	3.3/6	17/24	$3,124	Gas
			11/17	$3,311	E85
DODGE					
Caravan 2WD	A-4	3.3/6	17/24	$3,124	
	A-6	3.8/6	16/23	$3,303	
	A-6	4.0/6	16/23	$3,303	
Caravan 2WD FFV	A-4	3.3/6	17/24	$3,124	Gas
			11/17	$3,311	E85
HONDA					
Odyssey	A-5	3.5/6	16/23	$3,303	
	A-5	3.5/6	17/25	$2,970	
HYUNDAI					
Entourage	A-5	3.8/6	16/23	$3,303	
KIA					
Sedona	A-5	3.8/6	16/23	$3,303	
MAZDA					
▶ **5**	**A-S5**	**2.3/4**	**21/27**	**$2,584**	
▶ **5**	**M-5**	**2.3/4**	**22/28**	**$2,477**	
NISSAN					
Quest	A-5	3.5/6	16/24	$3,322	P
TOYOTA					
Sienna 2WD	A-5	3.5/6	17/23	$3,124	
SPORT UTILITY VEHICLE 2WD					
BUICK					
Enclave FWD	A-6	3.6/6	16/24	$3,124	
CADILLAC					
Escalade 2WD	A-6	6.2/8	12/19	$4,509	P
Escalade ESV 2WD	A-6	6.2/8	12/19	$4,509	P
SRX 2WD	A-S5	3.6/6	15/22	$3,493	
	A-S6	4.6/8	13/20	$3,947	P

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
CHEVROLET					
Avalanche 1500 2WD	A-4	5.3/8	14/20	$3,713	
	A-4	6.0/8	12/17	$4,241	
Avalanche 1500 2WD FFV	A-4	5.3/8	14/20	$3,713	Gas
			11/15	$3,586	E85
Equinox FWD	A-5	3.4/6	17/24	$3,124	
	A-S6	3.6/6	16/24	$3,124	
HHR FWD	A-4	2.0/4	19/28	$2,703	T
	M-5	2.0/4	21/29	$2,477	T
	A-4	2.2/4	22/30	$2,376	
	M-5	2.2/4	21/30	$2,477	
	A-4	2.4/4	22/28	$2,633	P
	M-5	2.4/4	20/28	$2,747	P
HHR Panel FWD	A-4	2.2/4	22/30	$2,376	
	M-5	2.2/4	20/30	$2,477	
	A-4	2.4/4	22/28	$2,633	P
	M-5	2.4/4	20/29	$2,747	P
Suburban 1500 2WD	A-4	5.3/8	14/20	$3,713	
	A-4	6.0/8	12/17	$4,241	
Suburban 1500 2WD FFV	A-4	5.3/8	14/20	$3,713	Gas
			11/15	$3,586	E85
Tahoe 1500 2WD	A-4	4.8/8	14/19	$3,713	
	A-4	5.3/8	14/20	$3,713	
	A-6	6.2/8	12/19	$4,509	P
Tahoe 1500 2WD FFV	A-4	5.3/8	14/20	$3,713	Gas
			11/15	$3,586	E85
Tahoe Hybrid 2WD	AV	6.0/8	21/22	$2,827	HEV
Trailblazer 2WD	A-4	4.2/6	14/20	$3,713	
	A-4	5.3/8	14/20	$3,493	
	A-4	6.0/8	12/16	$4,509	P
CHRYSLER					
Aspen 2WD	A-5	4.7/8	14/19	$3,962	
	A-5	5.7/8	13/19	$3,962	
Aspen 2WD FFV	A-5	4.7/8	14/19	$3,962	Gas
			9/12	$4,305	E85
Pacifica FWD	A-4	3.8/6	15/22	$3,303	
	A-6	4.0/6	15/23	$3,493	
PT Cruiser	A-4	2.4/4	18/24	$3,006	P T
	A-4	2.4/4	19/24	$2,827	
	M-5	2.4/4	21/26	$2,584	
	M-5	2.4/4	20/25	$2,873	P T
DODGE					
Durango 2WD	A-4	3.7/6	14/19	$3,713	
	A-5	4.7/8	14/19	$3,962	
	A-5	5.7/8	13/19	$3,962	
Durango 2WD FFV	A-5	4.7/8	14/19	$3,962	Gas
			9/12	$4,305	E85
Magnum	A-4	2.7/6	18/26	$2,827	
	A-4	3.5/6	17/24	$2,970	
	A-5	3.5/6	17/24	$2,970	
	A-5	5.7/8	15/23	$3,303	
	A-5	6.1/8	13/18	$4,212	P
Nitro 2WD	A-4	3.7/6	16/22	$3,303	
	M-6	3.7/6	16/22	$3,124	

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
	A-5	4.0/6	16/21	$3,303	
FORD					
Edge FWD	A-6	3.5/6	16/24	$3,124	
Escape FWD	A-4	2.3/4	20/26	$2,703	
	M-5	2.3/4	22/28	$2,477	
	A-4	3.0/6	18/24	$2,970	
▸ Escape Hybrid FWD	**AV**	**2.3/4**	**34/30**	**$1,859**	**HEV**
Expedition 2WD	A-6	5.4/8	12/18	$4,241	
Explorer 2WD	A-5	4.0/6	14/20	$3,713	
	A-6	4.6/8	13/20	$3,713	
Taurus X FWD	A-6	3.5/6	16/24	$3,124	
GMC					
Acadia FWD	A-6	3.6/6	16/24	$3,124	
Envoy 2WD	A-4	4.2/6	14/20	$3,713	
	A-4	5.3/8	14/20	$3,493	
Yukon 1500 2WD	A-4	4.8/8	14/19	$3,713	
	A-4	5.3/8	14/20	$3,713	
	A-6	6.2/8	12/19	$4,509	P
Yukon 1500 2WD FFV	A-4	5.3/8	14/20	$3,713	Gas
			11/15	$3,586	E85
Yukon 1500 Hybrid 2WD	AV	6.0/8	21/22	$2,827	HEV
Yukon XL 1500 2WD	A-4	5.3/8	14/20	$3,713	
	A-4	6.0/8	12/17	$4,241	
	A-6	6.2/8	12/19	$4,509	P
Yukon XL 1500 2WD FFV	A-4	5.3/8	14/20	$3,713	Gas
			11/15	$3,586	E85
HONDA					
CR-V 2WD	A-5	2.4/4	20/27	$2,584	
Element 2WD	A-5	2.4/4	20/25	$2,703	
	M-5	2.4/4	18/23	$2,970	
Pilot 2WD	A-5	3.5/6	16/22	$3,303	
HYUNDAI					
Santa Fe 2WD	A-4	2.7/6	18/24	$2,970	
	M-5	2.7/6	17/24	$2,970	
	A-5	3.3/6	17/24	$2,970	
Tucson 2WD	A-4	2.0/4	19/25	$2,703	
	M-5	2.0/4	20/25	$2,703	
	A-4	2.7/6	18/24	$2,970	
Veracruz 2WD	A-6	3.8/6	16/23	$3,303	
INFINITI					
FX35 RWD	A-S5	3.5/6	15/22	$3,511	P
QX56 2WD	A-5	5.6/8	12/18	$4,509	P
ISUZU					
Ascender 5-passenger 2WD	A-4	4.2/6	14/20	$3,713	
JEEP					
Commander 2WD	A-5	3.7/6	14/19	$3,713	
	A-5	5.7/8	13/19	$3,962	
Commander 2WD FFV	A-5	4.7/8	14/19	$3,962	Gas
			9/13	$4,305	E85

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
Compass 2WD	AV	2.0/4	23/27	$2,477	
	AV	2.4/4	21/25	$2,584	
▸Compass 2WD	**M-5**	**2.4/4**	**23/28**	**$2,376**	
Grand Cherokee 2WD	A-5	3.7/6	15/20	$3,493	
	A-5	5.7/8	13/19	$3,962	
	A-5	3.0/6	18/23	$3,450	D
Grand Cherokee 2WD FFV	A-5	4.7/8	14/19	$3,962	Gas
			9/13	$4,305	E85
Liberty 2WD	A-4	3.7/6	16/22	$3,303	
	M-6	3.7/6	16/22	$3,124	
Patriot 2WD	AV	2.0/4	23/27	$2,477	
	AV	2.4/4	21/25	$2,584	
▸Patriot 2WD	**M-5**	**2.4/4**	**23/28**	**$2,376**	
Wrangler 2WD	A-4	3.8/6	15/20	$3,493	
	M-6	3.8/6	16/21	$3,303	
KIA					
Sorento 2WD	A-5	3.3/6	16/22	$3,303	
	A-5	3.8/6	15/21	$3,493	
Sportage 2WD	A-4	2.0/4	19/25	$2,827	
	M-5	2.0/4	20/25	$2,703	
	A-4	2.7/6	17/23	$2,970	
LEXUS					
RX 350 2WD	A-S5	3.5/6	18/23	$3,158	P
	A-5	3.5/6	18/23	$3,158	P
RX 400h 2WD	AV	3.3/6	27/24	$2,526	HEV P
LINCOLN					
MKX FWD	A-6	3.5/6	16/24	$3,124	
Navigator 2WD	A-6	5.4/8	12/18	$4,241	
MAZDA					
CX-7 2WD	A-S6	2.3/4	17/23	$3,322	P T
CX-9 2WD	A-S6	3.7/6	16/22	$3,303	
Tribute FWD	A-4	2.3/4	20/26	$2,703	
	M-5	2.3/4	22/28	$2,477	
	A-4	3.0/6	18/24	$2,970	
▸Tribute Hybrid 2WD	**AV**	**2.3/4**	**34/30**	**$1,859**	**HEV**
MERCEDES-BENZ					
R350	A-7	3.5/6	15/20	$3,713	P
MERCURY					
Mariner FWD	A-4	2.3/4	20/26	$2,703	
	A-4	3.0/6	18/24	$2,970	
▸Mariner Hybrid FWD	**AV**	**2.3/4**	**34/30**	**$1,859**	**HEV**
Mountaineer 2WD	A-5	4.0/6	14/20	$3,713	
	A-6	4.6/8	13/20	$3,713	
MITSUBISHI					
Endeavor 2WD	A-S4	3.8/6	15/22	$3,511	P
Outlander 2WD	AV	2.4/4	20/25	$2,703	
	A-S6	3.0/6	17/25	$2,970	

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
NISSAN					
Armada 2WD	A-5	5.6/8	12/18	$4,241	
Armada 2WD FFV	A-5	5.6/8	12/18	$4,241	Gas
			9/13	$4,305	E85
Pathfinder 2WD	A-5	4.0/6	15/22	$3,713	P
	A-S5	5.6/8	13/18	$4,212	P
Rogue FWD	AV	2.5/4	22/27	$2,477	
Xterra 2WD	A-5	4.0/6	15/20	$3,493	
	M-6	4.0/6	16/20	$3,493	
PONTIAC					
Torrent FWD	A-5	3.4/6	17/24	$3,124	
	A-S6	3.6/6	16/24	$3,124	
SATURN					
Outlook FWD	A-6	3.6/6	16/24	$3,124	
Vue FWD	A-4	2.4/4	19/26	$2,703	
	A-S6	3.6/6	16/24	$3,124	
	A-6	3.6/6	16/23	$3,124	
Vue Hybrid	A-4	2.4/4	25/32	$2,121	HEV
SUZUKI					
Grand Vitara	A-5	2.7/6	17/22	$3,124	
	M-5	2.7/6	16/22	$3,303	
XL7 FWD	A-S5	3.6/6	16/22	$3,303	
TOYOTA					
4Runner 2WD	A-5	4.0/6	16/21	$3,303	
	A-5	4.7/8	15/19	$3,493	
FJ Cruiser 2WD	A-5	4.0/6	16/20	$3,511	P
Highlander 2WD	A-S5	3.5/6	18/24	$2,970	
RAV4 2WD	A-4	2.4/4	21/27	$2,477	
	A-5	3.5/6	19/27	$2,703	
Sequoia 2WD	A-S5	4.7/8	14/17	$3,962	
	A-S6	5.7/8	14/19	$3,962	
VOLVO					
XC 90 FWD	A-S6	3.2/6	14/20	$3,947	P
SPORT UTILITY VEHICLE 4WD					
ACURA					
MDX 4WD	A-S5	3.7/6	15/20	$3,713	P
RDX 4WD	A-S5	2.3/4	17/22	$3,322	P T
AUDI					
Q7	A-S6	3.6/6	14/20	$3,947	P
	A-S6	4.2/8	12/17	$4,509	P
BMW					
X3 3.0si	A-S6	3.0/6	17/24	$3,158	P
	M-6	3.0/6	16/23	$3,322	P
X5 3.0si	A-S6	3.0/6	15/21	$3,511	P
X5 4.8i	A-S6	4.8/8	14/19	$3,947	P
X6 xDrive35i	A-S6	3.0/6	15/20	$3,713	P
X6 xDrive50i	A-S6	4.4/8	13/18	$4,212	P T

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
BUICK					
Enclave AWD	A-6	3.6/6	16/22	$3,303	
CADILLAC					
Escalade AWD	A-6	6.2/8	12/18	$4,509	P
SRX AWD	A-S5	3.6/6	14/22	$3,493	
	A-S6	4.6/8	13/20	$4,212	P
CHEVROLET					
Avalanche 1500 4WD	A-4	6.0/8	12/17	$4,241	
Avalanche 1500 4WD FFV	A-4	5.3/8	14/19	$3,713	Gas
			11/14	$3,586	E85
Equinox AWD	A-5	3.4/6	17/24	$3,124	
	A-S6	3.6/6	16/24	$3,124	
Suburban 1500 4WD	A-4	6.0/8	12/17	$4,241	
Suburban 1500 4WD FFV	A-4	5.3/8	14/19	$3,713	Gas
			11/14	$3,586	E85
Tahoe 1500 4WD FFV	A-4	5.3/8	14/19	$3,713	Gas
			11/14	$3,586	E85
Tahoe Hybrid 4WD	AV	6.0/8	20/20	$2,970	HEV
Trailblazer 4WD	A-4	4.2/6	14/20	$3,713	
	A-4	5.3/8	13/19	$3,713	
Trailblazer AWD	A-4	6.0/8	12/16	$4,856	P
CHRYSLER					
Aspen 4WD	A-5	4.7/8	13/17	$3,962	
	A-5	5.7/8	13/18	$3,962	
Aspen 4WD FFV	A-5	4.7/8	13/17	$3,962	Gas
			9/12	$4,305	E85
Pacifica AWD	A-6	4.0/6	14/22	$3,493	
DODGE					
Durango 4WD	A-5	4.7/8	13/17	$3,962	
	A-5	5.7/8	13/18	$3,962	
Durango 4WD FFV	A-5	4.7/8	13/17	$3,962	Gas
			9/12	$4,305	E85
Magnum AWD	A-5	3.5/6	15/22	$3,303	
	A-5	5.7/8	15/22	$3,303	
Nitro 4WD	A-4	3.7/6	15/21	$3,493	
	M-6	3.7/6	16/22	$3,303	
	A-5	4.0/6	15/20	$3,493	
FORD					
Edge AWD	A-6	3.5/6	15/22	$3,303	
Escape 4WD	A-4	2.3/4	19/24	$2,827	
	A-4	3.0/6	17/22	$3,124	
Escape Hybrid 4WD	AV	2.3/4	29/27	$2,121	HEV
Explorer 4WD	A-5	4.0/6	13/19	$3,962	
	A-6	4.6/8	13/19	$3,962	
Taurus X AWD	A-6	3.5/6	15/22	$3,303	
GMC					
Acadia AWD	A-6	3.6/6	16/22	$3,303	
Envoy 4WD	A-4	4.2/6	14/20	$3,713	
	A-4	5.3/8	13/19	$3,713	
Yukon 1500 4WD FFV	A-4	5.3/8	14/19	$3,713	Gas
			11/14	$3,586	E85
Yukon 1500 Hybrid 4WD	AV	6.0/8	20/20	$2,970	HEV
Yukon Denali 1500 AWD	A-6	6.2/8	12/18	$4,509	P
Yukon XL 1500 4WD	A-4	6.0/8	12/17	$4,241	
Yukon XL 1500 4WD FFV	A-4	5.3/8	14/19	$3,713	Gas
			11/14	$3,586	E85
HONDA					
CR-V 4WD	A-5	2.4/4	20/26	$2,703	
Element 4WD	A-5	2.4/4	19/24	$2,827	
	M-5	2.4/4	18/23	$2,970	
Pilot 4WD	A-5	3.5/6	15/20	$3,493	
HUMMER					
H3 4WD	A-4	3.7/5	14/18	$3,962	
	M-5	3.7/5	13/18	$3,962	
	A-4	5.3/8	13/16	$4,241	
HYUNDAI					
Santa Fe 4WD	A-4	2.7/6	17/23	$3,124	
	M-5	2.7/6	17/23	$3,124	
	A-5	3.3/6	17/24	$3,124	
Tucson 4WD	M-5	2.0/4	19/24	$2,827	
	A-4	2.7/6	17/23	$3,124	
Veracruz 4WD	A-6	3.8/6	15/22	$3,303	
INFINITI					
FX35 AWD	A-S5	3.5/6	15/20	$3,713	P
FX45 AWD	A-S5	4.5/8	13/17	$4,509	P
QX56 4WD	A-5	5.6/8	12/17	$4,509	P
ISUZU					
Ascender 5-passenger 4WD	A-4	4.2/6	14/20	$3,713	
JEEP					
Commander 4WD	A-5	3.7/6	14/19	$3,713	
	A-5	5.7/8	13/17	$4,241	
Commander 4WD FFV	A-5	4.7/8	13/18	$4,241	Gas
			9/12	$4,305	E85
Compass 4WD	AV	2.4/4	21/24	$2,703	
	M-5	2.4/4	22/27	$2,477	
Grand Cherokee 4WD	A-5	3.7/6	15/19	$3,493	
	A-5	5.7/8	13/18	$3,962	
	A-5	6.1/8	11/14	$5,260	P
	A-5	3.0/6	17/22	$3,629	D
Grand Cherokee 4WD FFV	A-5	4.7/8	14/19	$3,962	Gas
			9/12	$4,305	E85
Liberty 4WD	A-4	3.7/6	15/21	$3,493	
	M-6	3.7/6	16/22	$3,303	
Patriot 4WD	AV	2.4/4	21/24	$2,703	
	AV	2.4/4	20/22	$2,827	
	M-5	2.4/4	22/27	$2,477	
Wrangler 4WD	A-4	3.8/6	15/19	$3,493	
	M-6	3.8/6	15/19	$3,713	

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
KIA					
Sorento 4WD	A-5	3.3/6	15/22	$3,493	
	A-5	3.8/6	15/20	$3,493	
Sportage 4WD	M-5	2.0/4	19/24	$2,827	
	A-4	2.7/6	17/21	$3,124	
LAND ROVER					
LR2	A-S6	3.2/6	15/22	$3,493	
LR3	A-S6	4.4/8	12/17	$4,241	
Range Rover	A-S6	4.2/8	12/18	$4,241	S
	A-S6	4.4/8	12/18	$4,241	
Range Rover Sport	A-S6	4.2/8	12/18	$4,241	S
	A-S6	4.4/8	12/18	$3,962	
LEXUS					
GX 470	A-5	4.7/8	14/18	$4,212	P
LX 570	A-S6	5.7/8	12/18	$4,509	P
RX 350 4WD	A-S5	3.5/6	17/22	$3,322	P
	A-5	3.5/6	17/22	$3,322	P
RX 400h 4WD	AV	3.3/6	26/24	$2,526	HEV P
LINCOLN					
MKX AWD	A-6	3.5/6	15/22	$3,303	
MAZDA					
CX-7 4WD	A-S6	2.3/4	16/22	$3,511	P T
CX-9 4WD	A-S6	3.7/6	15/21	$3,493	
Tribute 4WD	A-4	2.3/4	19/24	$2,827	
	A-4	3.0/6	17/22	$3,124	
Tribute Hybrid 4WD	AV	2.3/4	29/27	$2,121	HEV
MERCEDES-BENZ					
G 500	A-7	5.0/8	12/15	$4,856	P
G 55 AMG	A-5	5.4/8	11/13	$5,260	P S
GL320 CDI 4matic	A-7	3.0/6	18/24	$3,450	D T
GL450 4matic	A-7	4.6/8	13/18	$4,212	P
GL550 4matic	A-7	5.5/8	13/17	$4,509	P
ML320 CDI 4matic	A-7	3.0/6	18/24	$3,284	D T
ML350 4matic	A-7	3.5/6	15/20	$3,713	P
ML550 4matic	A-7	5.5/8	13/18	$4,212	P
ML63 AMG	A-S7	6.2/8	11/14	$5,260	P
R320 CDI 4matic	A-7	3.0/6	18/24	$3,284	D T
R350 4matic	A-7	3.5/6	15/19	$3,947	P
MERCURY					
Mariner 4WD	A-4	2.3/4	19/24	$2,827	
	A-4	3.0/6	17/22	$3,124	
Mariner Hybrid 4WD	AV	2.3/4	29/27	$2,121	HEV
Mountaineer 4WD	A-5	4.0/6	13/19	$3,962	
	A-6	4.6/8	13/19	$3,962	
MITSUBISHI					
Endeavor AWD	A-S4	3.8/6	15/19	$3,713	P
Outlander 4WD	AV	2.4/4	20/25	$2,703	
	A-S6	3.0/6	17/24	$2,970	

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
NISSAN					
Armada 4WD	A-5	5.6/8	12/17	$4,241	
Armada 4WD FFV	A-5	5.6/8	12/17	$4,241	Gas
			9/13	$4,305	E85
Pathfinder 4WD	A-5	4.0/6	14/20	$3,947	P
	A-S5	5.6/8	12/18	$4,509	P
Rogue AWD	AV	2.5/4	21/26	$2,584	
Xterra 4WD	A-5	4.0/6	14/20	$3,713	
	M-6	4.0/6	16/20	$3,493	
PONTIAC					
Torrent AWD	A-5	3.4/6	17/24	$3,124	
	A-S6	3.6/6	16/24	$3,124	
PORSCHE					
Cayenne	A-6	3.6/6	14/20	$3,947	P
	M-6	3.6/6	14/20	$3,947	P
Cayenne GTS	A-6	4.8/8	13/18	$4,212	P
	M-6	4.8/8	11/17	$4,856	P
Cayenne S	A-6	4.8/8	13/19	$4,212	P
Cayenne Turbo	A-6	4.8/8	12/19	$4,509	P T
SAAB					
9-7X AWD	A-4	4.2/6	14/20	$3,713	
	A-4	5.3/8	13/19	$3,713	
	A-4	6.0/8	12/16	$4,856	P
SATURN					
Outlook AWD	A-6	3.6/6	16/22	$3,303	
Vue AWD	A-6	3.5/6	15/22	$3,493	
	A-S6	3.6/6	16/22	$3,303	
	A-6	3.6/6	16/22	$3,303	
SUBARU					
Forester AWD	A-4	2.5/4	18/23	$3,158	P T
	A-4	2.5/4	20/26	$2,703	
	M-5	2.5/4	20/27	$2,703	
	M-5	2.5/4	19/25	$3,006	P T
Outback Wagon AWD	A-S4	2.5/4	20/26	$2,703	
	A-S5	2.5/4	18/24	$3,158	P T
	M-5	2.5/4	18/24	$3,158	P T
	M-5	2.5/4	19/26	$2,703	
	A-S5	3.0/6	17/24	$3,158	P
Tribeca AWD	A-S5	3.6/6	16/21	$3,303	
SUZUKI					
Grand Vitara AWD	A-5	2.7/6	17/21	$3,124	
	M-5	2.7/6	16/21	$3,303	
XL7 AWD	A-S5	3.6/6	15/22	$3,303	
TOYOTA					
4Runner 4WD	A-5	4.0/6	16/20	$3,493	
	A-5	4.7/8	14/17	$3,962	
FJ Cruiser 4WD	A-5	4.0/6	16/20	$3,713	P
	M-6	4.0/6	15/18	$3,947	P
Highlander 4WD	A-S5	3.5/6	17/23	$3,124	

	Trans Type/ Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
Highlander Hybrid 4WD	AV	3.3/6	27/25	$2,287	HEV
Land Cruiser Wagon 4WD	A-S6	5.7/8	13/18	$3,962	
RAV4 4WD	A-4	2.4/4	20/25	$2,703	
	A-5	3.5/6	19/26	$2,827	
Sequoia 4WD	A-S5	4.7/8	13/16	$4,241	
	A-S6	5.7/8	13/18	$3,962	
VOLKSWAGEN					
Touareg	A-S6	3.6/6	14/20	$3,947	P
	A-S6	4.2/8	12/17	$4,509	P
	A-S6	5.0/10	15/20	$4,057	D T
VOLVO					
XC 70 AWD	A-S6	3.2/6	15/22	$3,713	P
XC 90 AWD	A-S6	3.2/6	14/20	$3,947	P
	A-S6	4.4/8	13/19	$4,212	P
MINIVAN 4WD					
TOYOTA					
Sienna 4WD	A-5	3.5/6	16/21	$3,303	

DIESEL VEHICLES

Diesel-powered vehicles typically get 30-35% more miles per gallon than comparable vehicles by gasoline. Diesel engines are inherently more energy efficient, and diesel fuel contains 10% more energy per gallon than gasoline. In addition, new advances in diesel engine technology have improved performance, reduced engine noise and fuel odor, and decreased emissions of harmful air pollutants. New ultra-low sulfur diesel fuels now available also reduce emissions from these vehicles.

Annual fuel costs below are estimated assuming 15,000 miles of travel each year (55% city and 45% highway) and a diesel fuel cost of $4.60 per gallon.

	Transmission Type/Speeds	Engine Size/ Cylinders	MPG City/Highway	Annual Fuel cost	Notes
MIDSIZE CARS					
MERCEDES-BENZ					
E320 Bluetec	A-7	3.0/6	23/32	$2,657	D T
SPORT UTILITY VEHICLE 2WD					
JEEP					
Grand Cherokee 2WD	A-5	3.0/6	18/23	$3,450	D
SPORT UTILITY VEHICLE 4WD					
JEEP					
Grand Cherokee 4WD	A-5	3.0/6	17/22	$3,629	D
MERCEDES-BENZ					
GL320 CDI 4matic	A-7	3.0/6	18/24	$3,450	D T
ML320 CDI 4matic	A-7	3.0/6	18/24	$3,284	D T
R320 CDI 4matic	A-7	3.0/6	18/24	$3,284	D T
VOLKSWAGEN					
Touareg	A-S6	5.0/10	15/20	$4,057	D T

HYBRID-ELECTRIC VEHICLES

It's no accident the most fuel-efficient vehicles in some classes for the 2008 model year are hybrid-electric vehicles (HEVs). Hybrids combine the best features of the internal combustion engine with an electric motor and can significantly improve fuel economy without sacrificing performance or driving range. HEVs may also be configured to provide increased performance or provide electrical power to auxillary loads such as power tools.

HEVs are primarily propelled by an internal combustion engine, just like conventional vehicles. However, they also convert energy normally wasted during coasting and braking into electricity which is stored in a battery until needed by the electric motor. The electric motor assists the engine when accelerating or hill climbing and at low speeds where internal combustion engines are least efficient. Unlike all-electric vehicles, HEVs now being offered do not need to be plugged into an external source of electricity to be recharged; conventional gasoline and regenerative braking provide all the energy the vehicle needs.

Potential buyers should also be aware that the federal government is currently offering tax incentives for HEVs. Some states also offer incentives. Additional information on HEVs, including tax incentives, can be found at www.fueleconomy.gov.

Annual fuel cost is estimated assuming 15,000 miles of travel each year (55% city and 45% highway) and a gasoline fuel cost of 3.96 per gallon (regular unleaded).

	Trans Type / Speeds	Eng Size / Cylinders	MPG / City / Hwy	Annual Fuel Cost	Battery Size / Type	Notes
COMPACT CARS						
HONDA						
Civic Hybrid	AV	1.3/4	40/45	$1,414	158V Ni-MH	
LEXUS						
GS 450h	A-S6	3.5/6	22/25	$2,747	288V Ni-MH	P
MIDSIZE CARS						
CHEVROLET						
Malibu Hybrid	A-4	2.4/4	24/32	$2,198	36V Ni-MH	
LEXUS						
LS 600h L	A-S8	5.0/8	20/22	$3,006	288V Ni-MH	P
NISSAN						
Altima Hybrid	AV	2.5/4	35/33	$1,746	245V Ni-MH	
SATURN						
Aura Hybrid	A-4	2.4/4	24/32	$2,198	36V Ni-MH	
TOYOTA						
Camry Hybrid	AV	2.4/4	33/34	$1,746	245V Ni-MH	
Prius	AV	1.5/4	48/45	$1,289	202V Ni-MH	
SPORT UTILITY VEHICLE 2WD						
CHEVROLET						
Tahoe Hybrid 2WD	AV	6.0/8	21/22	$2,827	288V Ni-MH	
FORD						
Escape Hybrid FWD	AV	2.3/4	34/30	$1,859	330V Ni-MH	
GMC						
Yukon 1500 Hybrid 2WD	AV	6.0/8	21/22	$2,827	288V Ni-MH	
LEXUS						
RX 400h 2WD	AV	3.3/6	27/24	$2,526	288V Ni-MH	P
MAZDA						
Tribute Hybrid 2WD	AV	2.3/4	34/30	$1,859	330V Ni-MH	
MERCURY						
Mariner Hybrid FWD	AV	2.3/4	34/30	$1,859	330V Ni-MH	
SATURN						
Vue Hybrid	A-4	2.4/4	25/32	$2,121	36V Ni-MH	
SPORT UTILITY VEHICLE 4WD						
CHEVROLET						
Tahoe Hybrid 4WD	AV	6.0/8	20/20	$2,970	288V Ni-MH	
FORD						
Escape Hybrid 4WD	AV	2.3/4	29/27	$2,121	330V Ni-MH	
GMC						
Yukon 1500 Hybrid 4WD	AV	6.0/8	20/20	$2,970	288V Ni-MH	
LEXUS						
RX 400h 4WD	AV	3.3/6	26/24	$2,526	288V Ni-MH	P
MAZDA						
Tribute Hybrid 4WD	AV	2.3/4	29/27	$2,121	330V Ni-MH	
MERCURY						
Mariner Hybrid 4WD	AV	2.3/4	29/27	$2,121	330V Ni-MH	
TOYOTA						
Highlander Hybrid 4WD	AV	3.3/6	27/25	$2,287	288V Ni-MH	

ETHANOL FLEXIBLE-FUEL VEHICLES

This section contains the fuel economy and driving range values for ethanol flexible-fuel vehicles (FFVs). These vehicles are designed to operate on gasoline, E85 (a mixture of 85% ethanol and 15% gasoline), or any mixture of the two fuels. Annual fuel cost is estimated assuming 15,000 miles of travel each year (55% city and 45% highway) and an average fuel cost of $2.87 per gallon for E85, $3.96 per gallon for regular unleaded gasoline, and $4.21 per gallon for premium unleaded gasoline. The price of ethanol is highly variable from region to region; it is typically lower in the midwestern United States and higher in other areas. Therefore, actual consumer experience may differ significantly from the annual fuel cost estimate presented here.

Fuel economy and driving range values are shown for both gasoline and E85. When operating your FFV on mixtures of gasoline and E85, such as when alternating between using these fuels, your driving range and fuel economy values will be somewhere between those listed for the two fuels, depending on the actual percentage of gasoline and E85 in the tank.

	Trans Type / Speeds	Eng Size / Cylinders	MPG / City / Hwy	Annual Fuel Cost	Fuel	Range (miles)
SUBCOMPACT CARS						
CHRYSLER						
Sebring Convertible	A-4	2.7/6	18/26	$2,827	Gas	350
			13/19	$2,871	E85	250
COMPACT CARS						
MERCEDES-BENZ						
C300	A-7	3.0/6	18/25	$3,006	Gas	440
			13/19	$2,871	E85	320
MIDSIZE CARS						
CHRYSLER						
Sebring	A-4	2.7/6	19/27	$2,703	Gas	370
			13/20	$2,691	E85	270
DODGE						
Avenger	A-4	2.7/6	19/27	$2,703	Gas	370
			13/20	$2,691	E85	270
LARGE CARS						
CHEVROLET						
Impala	A-4	3.5/6	18/29	$2,703	Gas	320/510
			14/21	$2,691	E85	250/370
Impala	A-4	3.9/6	18/28	$2,827	Gas	320/500
			13/20	$2,691	E85	230/350
FORD						
Crown Victoria FFV	A-4	4.6/8	15/23	$3,303	Gas	340
			11/16	$3,311	E85	250
LINCOLN						
Town Car	A-4	4.6/8	15/23	$3,303	Gas	340
			11/16	$3,311	E85	250
MERCURY						
Grand Marquis FFV	A-4	4.6/8	15/23	$3,303	Gas	340
			11/16	$3,311	E85	250
STANDARD PICKUP TRUCKS 2WD						
CHEVROLET						
Silverado C15 2WD	A-4	5.3/8	15/20	$3,493	Gas	390/540
			11/15	$3,311	E85	290/410
DODGE						
Dakota Pickup 2WD	A-5	4.7/8	14/19	$3,962	Gas	330
			9/12	$4,305	E85	240
Ram 1500 Pickup 2WD	A-5	4.7/8	13/18	$3,962	Gas	330
			9/12	$4,305	E85	240
Ram 1500 Pickup 2WD	M-6	4.7/8	13/17	$4,241	Gas	360
			9/12	$4,305	E85	290
FORD						
F150 Pickup FFV 2WD	A-4	5.4/8	13/18	$3,962	Gas	390
			10/13	$3,913	E85	290
F150 STX SE FFV 2WD	A-4	5.4/8	14/19	$3,962	Gas	390/400
			10/14	$3,586	E85	310/320
GMC						
Sierra C15 2WD	A-4	5.3/8	15/20	$3,493	Gas	390/540
			11/15	$3,311	E85	290/410
MITSUBISHI						
Raider Pickup 2WD	A-5	4.7/8	14/19	$3,962	Gas	330
			9/12	$4,305	E85	240
NISSAN						
Titan 2WD	A-5	5.6/8	12/17	$4,241	Gas	390/520
			9/13	$4,305	E85	280/370
STANDARD PICKUP TRUCKS 4WD						
CHEVROLET						
Silverado K15 4WD	A-4	5.3/8	14/19	$3,713	Gas	390/540
			11/14	$3,586	E85	290/410
DODGE						
Dakota Pickup 4WD	A-5	4.7/8	14/19	$3,962	Gas	330
			9/12	$4,305	E85	240
Ram 1500 Pickup 4WD	A-5	4.7/8	13/17	$3,962	Gas	330
			9/12	$4,305	E85	240
Ram 1500 Pickup 4WD	M-6	4.7/8	12/16	$4,241	Gas	360
			9/12	$4,305	E85	290
FORD						
F150 Pickup FFV 4WD	A-4	5.4/8	13/17	$3,962	Gas	390
			9/12	$4,305	E85	260
GMC						
Sierra K15 4WD	A-4	5.3/8	14/19	$3,713	Gas	390/540
			11/14	$3,586	E85	290/410
MITSUBISHI						
Raider Pickup 4WD	A-5	4.7/8	14/19	$3,962	Gas	330
			9/12	$4,305	E85	240
NISSAN						
Titan 4WD	A-5	5.6/8	12/17	$4,241	Gas	390/520
			9/12	$4,305	E85	280/370
VANS, CARGO TYPE						
CHEVROLET						
Van 15/25 2WD Conversion	A-4	5.3/8	12/16	$4,241	Gas	430/470
			9/12	$4,305	E85	310/340

	Trans Type / Speeds	Eng Size / Cylinders	MPG / City / Hwy	Annual Fuel Cost	Fuel	Range (miles)
Van 1500 AWD Conversion	A-4	5.3/8	12/16	$4,241	Gas	440/470
			9/12	$4,305	E85	310/340
Van 1500/2500 2WD	A-4	5.3/8	14/18	$3,962	Gas	430/470
			10/13	$3,913	E85	310/340
Van 1500/2500 AWD	A-4	5.3/8	13/17	$3,962	Gas	440/470
			10/12	$3,913	E85	310/340
GMC						
Savana 15/25 2WD Conversion (cargo)	A-4	5.3/8	12/16	$4,241	Gas	430/470
			9/12	$4,305	E85	310/340
Savana 1500 AWD Conversion (cargo)	A-4	5.3/8	12/16	$4,241	Gas	440/470
			9/12	$4,305	E85	310/340
Savana 1500/2500 2WD (cargo)	A-4	5.3/8	14/18	$3,962	Gas	430/470
			10/13	$3,913	E85	310/340
Savana 1500/2500 AWD (cargo)	A-4	5.3/8	13/17	$3,962	Gas	440/470
			10/12	$3,913	E85	310/340
VANS, PASSENGER TYPE						
CHEVROLET						
Express 1500 AWD	A-4	5.3/8	12/16	$4,241	Gas	440/470
			9/12	$4,305	E85	310/340
Express 1500/2500 2WD	A-4	5.3/8	12/16	$4,241	Gas	430/470
			9/12	$4,305	E85	310/340
GMC						
Savana 1500 AWD (Passenger)	A-4	5.3/8	12/16	$4,241	Gas	440/470
			9/12	$4,305	E85	310/340
Savana 1500/2500 2WD (Passenger)	A-4	5.3/8	12/16	$4,241	Gas	430/470
			9/12	$4,305	E85	310/340
MINIVAN 2WD						
CHEVROLET						
Uplander FWD	A-4	3.9/6	16/23	$3,124	Gas	320-570
			12/17	$3,074	E85	240-420
CHRYSLER						
Town and Country	A-4	3.3/6	17/24	$3,124	Gas	380
			11/17	$3,311	E85	260
DODGE						
Caravan 2WD	A-4	3.3/6	17/24	$3,124	Gas	380
			11/17	$3,311	E85	260
SPORT UTILITY VEHICLE 2WD						
CHEVROLET						
Avalanche 1500 2WD	A-4	5.3/8	14/20	$3,713	Gas	390/540
			11/15	$3,586	E85	290/410
Suburban 1500 2WD	A-4	5.3/8	14/20	$3,713	Gas	390/540
			11/15	$3,586	E85	290/410
Tahoe 1500 2WD	A-4	5.3/8	14/20	$3,713	Gas	390/540
			11/15	$3,586	E85	290/410
CHRYSLER						
Aspen 2WD	A-5	4.7/8	14/19	$3,962	Gas	330
			9/12	$4,305	E85	240
DODGE						
Durango 2WD	A-5	4.7/8	14/19	$3,962	Gas	330

	Trans Type / Speeds	Eng Size / Cylinders	MPG / City / Hwy	Annual Fuel Cost	Fuel	Range (miles)
			9/12	$4,305	E85	240
GMC						
Yukon 1500 2WD	A-4	5.3/8	14/20	$3,713	Gas	390/540
			11/15	$3,586	E85	290/410
Yukon XL 1500 2WD	A-4	5.3/8	14/20	$3,713	Gas	390/540
			11/15	$3,586	E85	290/410
JEEP						
Commander 2WD	A-5	4.7/8	14/19	$3,962	Gas	340
			9/13	$4,305	E85	230
Grand Cherokee 2WD	A-5	4.7/8	14/19	$3,962	Gas	340
			9/13	$4,305	E85	230
NISSAN						
Armada 2WD	A-5	5.6/8	12/18	$4,241	Gas	390
			9/13	$4,305	E85	280
SPORT UTILITY VEHICLE 4WD						
CHEVROLET						
Avalanche 1500 4WD	A-4	5.3/8	14/19	$3,713	Gas	390/540
			11/14	$3,586	E85	290/410
Suburban 1500 4WD	A-4	5.3/8	14/19	$3,713	Gas	390/540
			11/14	$3,586	E85	290/410
Tahoe 1500 4WD	A-4	5.3/8	14/19	$3,713	Gas	390/540
			11/14	$3,586	E85	290/410
CHRYSLER						
Aspen 4WD	A-5	4.7/8	13/17	$3,962	Gas	330
			9/12	$4,305	E85	240
DODGE						
Durango 4WD	A-5	4.7/8	13/17	$3,962	Gas	330
			9/12	$4,305	E85	240
GMC						
Yukon 1500 4WD	A-4	5.3/8	14/19	$3,713	Gas	390/540
			11/14	$3,586	E85	290/410
Yukon XL 1500 4WD	A-4	5.3/8	14/19	$3,713	Gas	390/540
			11/14	$3,586	E85	290/410
JEEP						
Commander 4WD	A-5	4.7/8	13/18	$4,241	Gas	340
			9/12	$4,305	E85	230
Grand Cherokee 4WD	A-5	4.7/8	14/19	$3,962	Gas	340
			9/12	$4,305	E85	230
NISSAN						
Armada 4WD	A-5	5.6/8	12/17	$4,241	Gas	390
			9/13	$4,305	E85	280

COMPRESSED NATURAL GAS VEHICLES

This section supplies the driving range and fuel economy values for vehicles that operate on compressed natural gas (CNG). CNG fuel is normally dispensed in "equivalent gallons", where one equivalent gallon is equal to 121.5 cubic feet of CNG. Therefore, the fuel economy values are shown in miles per gallon-eqivalent. Annual fuel cost estimates are based on an average fuel price of $1.65 per gasoline equivalent gallon of CNG. The driving range is shown in miles and represents the distance the vehicle can travel on a full tank (or tanks) of fuel during combined city and highway driving (55% city and 45% highway).

The federal government is currently offering tax incentives for some CNG vehicles. Some states also offer incentives. For more information, visit www.fueleconomy.gov.

	Transmission Type	Engine Size/ Cylinders	MPG City/Highway	Annual Fuel cost	Fuel	Range (miles)
SUBCOMPACT CARS						
HONDA						
Civic CNG	A-5	1.8/4	24/36	$884	CNG	170

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Health Assessment Document For Diesel Engine Exhaust

EPA/600/8-90/057F
May 2002

Health Assessment Document for Diesel Engine Exhaust

National Center for Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Washington, DC

DISCLAIMER

ABSTRACT

This assessment examined information regarding the possible health hazards associated with exposure to diesel engine exhaust (DE), which is a mixture of gases and particles. The assessment concludes that long-term (i.e., chronic) inhalation exposure is likely to pose a lung cancer hazard to humans, as well as damage the lung in other ways depending on exposure. Short-term (i.e., acute) exposures can cause irritation and inflammatory symptoms of a transient nature, these being highly variable across the population. The assessment also indicates that evidence for exacerbation of existing allergies and asthma symptoms is emerging. The assessment recognizes that DE emissions, as a mixture of many constituents, also contribute to ambient concentrations of several criteria air pollutants including nitrogen oxides and fine particles, as well as other air toxics. The assessment's health hazard conclusions are based on exposure to exhaust from diesel engines built prior to the mid-1990s. The health hazard conclusions, in general, are applicable to engines currently in use, which include many older engines. As new diesel engines with cleaner exhaust emissions replace existing engines, the applicability of the conclusions in this Health Assessment Document will need to be reevaluated.

Preferred citation:

U.S. Environmental Protection Agency (EPA). (2002) Health assessment document for diesel engine exhaust. Prepared by the National Center for Environmental Assessment, Washington, DC, for the Office of Transportation and Air Quality; EPA/600/8-90/057F. Available from: National Technical Information Service, Springfield, VA; PB2002-107661, and <http://www.epa.gov/ncea>.

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FOREWORD

The diesel engine has been a vital workhorse in the United States, powering many of its large trucks, buses, and farm, railroad, marine, and construction equipment. Expectations are that diesel engine use in these areas will increase due to the superior performance characteristics of the engine. Diesel engine exhaust (DE), however, contains harmful pollutants in a complex mixture of gases and particulates. Human exposure to this exhaust comes from both highway uses (on-road) as well as nonroad uses of the diesel engine.

EPA started evaluating and regulating the gaseous emissions from the heavy-duty highway use of diesel engines in the 1970s and particle emissions in the 1980s. The reduction of harmful exhaust emissions has taken a large step forward because of standards issued in 2000 which will bring about very large reductions in exhaust emissions for model year 2007 heavy-duty engines used in trucks, buses, and other on-road uses. A draft of this assessment, along with the peer review comments of the Clean Air Scientific Advisory Committee, was part of the scientific basis for EPA's regulation of heavy-duty highway engines completed in December 2000. The information provided by this assessment was useful in developing EPA's understanding of the public health implications of exposure to DE and the public health benefits of taking regulatory action to control exhaust emissions. EPA anticipates developing similarly stringent regulations for other diesel engine uses, including those used in nonroad applications.

Until these regulations take effect, EPA is partnering with state and local agencies to retrofit older, dirtier, engines to make them run cleaner and to develop model programs to reduce emissions from idling engines. In addition, EPA and local authorities are working to ensure early introduction of effective technologies for particulate matter control and the availability of low- sulfur fuel where possible in advance of the 2007 requirements. Today, at least one engine manufacturer is producing new engines with particulate traps that, when coupled with low-sulfur fuel, meet 2007 particulate emission levels. The Agency expects significant environmental and public health benefits as the environmental performance of diesel engines and diesel fuels improves.

The health assessment concludes that long-term (i.e., chronic) exposure to DE is likely to pose a lung cancer hazard as well as damage the lung in other ways depending on exposure. The health assessment's conclusions are based on exposure to exhaust from diesel engines built prior to the mid-1990s. Short-term (i.e., acute) exposures can cause transient irritation and inflammatory symptoms, although the nature and extent of these symptoms are highly variable across the population. The assessment also states that evidence is emerging that diesel exhaust exacerbates existing allergies and asthma symptoms. The assessment recognizes that DE emissions, as a mixture of many constituents, also contribute to ambient concentrations of several criteria air pollutants including nitrogen oxides, sulfur oxides, and fine particles, as well as other hazardous air pollutants.

The particulate fraction of DE and its composition is a key element in EPA's present understanding of the health issues and formulation of the conclusions in the health assessment. The amount of exhaust particulate from on-road engines has been decreasing in recent years and is expected to decrease 90% from today's levels with the engines designed to meet the 2007 regulations. The composition of the exhaust particulates and the gases also will change. While EPA believes that the assessment's conclusions apply to the general use of diesel engines today, as cleaner diesel engines replace a substantial number of existing engines, the general applicability of the conclusions in this health assessment document will need to be reevaluated.

Paul Gilman

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Assistant Administrator
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PREFACE

This document is the U.S. Environmental Protection Agency's science-based *Health Assessment Document for Diesel Engine Exhaust*. The assessment was prepared by the National Center for Environmental Assessment which is the health risk assessment program in EPA's Office of Research and Development. The assessment broadly supports activities authorized in the 1990 Clean Air Act. This assessment was specifically prepared for EPA's Office of Transportation and Air Quality which requested information regarding the potential health hazards associated with diesel engine exhaust (DE) exposure. As DE emissions also contribute to urban air toxics and ambient particulate matter, other EPA air programs also have an interest in this assessment.

This document was preceded by five earlier drafts: a Workshop Review Draft (EPA/600/8-90/057A, July 1990), an External Review Draft (EPA/600/8-90/057B, December 1994), an SAB Review Draft (EPA/600/8-90/057C, February 1998), an SAB Review Draft (EPA/600/8-90/057D, November 1999), and an SAB Review Draft (EPA/600/8-90/057E, July 2000). There was an SAB Environmental Health Committee Review in 1990 of the July 1990 draft. The Science Advisory Board's Clean Air Scientific Advisory Committee (CASAC) reviewed the 1994 draft in public sessions in May 1995, the 1998 draft in May 1998, the 1999 draft in December 1999, and the July 2000 draft in October 2000. Public comment periods also were conducted concurrently with the CASAC reviews. In addition many reviewers, both within and outside the Agency, provided assistance at various review stages. This is the final version of the assessment which was prepared in response to CASAC advice and public comments received on the 2000 draft.

The scientific literature search for this assessment is generally current through January 2000, although a few later publications have been included.

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The National Center for Environmental Assessment (NCEA) within EPA's Office of Research and Development (ORD) was responsible for the preparation of this document.

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CHAPTER 8. DOSE-RESPONSE ASSESSMENT: CARCINOGENIC EFFECTS

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CHAPTER 9. CHARACTERIZATION OF POTENTIAL HUMAN HEALTH EFFECTS OF DIESEL EXHAUST: HAZARD AND DOSE-RESPONSE ASSESSMENTS

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The Science Advisory Board's Clean Air Scientific Advisory Committee (CASAC) reviewed the 1994 draft in public sessions in May 1995, the 1998 draft in May 1998, the 1999 draft in December 1999, and the July 2000 draft in October 2000. Public comment periods also were conducted concurrently with the CASAC reviews. In addition, many reviewers both within and outside the Agency provided assistance at various review stages. This is the final version of the assessment which was prepared in response to the latest CASAC advice and public comments.

The authors wish to thank all those who sought to improve the quality of this report with their comments and are particularly grateful to the CASAC for its advice.

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[6] CASAC Consultants are experts appointed by the Science Advisory Board Staff Director to a one-year term to serve on *ad hoc* Panels formed to address a particular issue; in this case, the CASAC Review of EPA's Health Assessment Document for Diesel Exhaust.

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ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions of several people who have made this report and the previous drafts possible.

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1. EXECUTIVE SUMMARY

1.1. INTRODUCTION

This Health Assessment Document for Diesel Engine Exhaust (DE) represents EPA's first comprehensive review of the potential health effects from ambient exposure to exhaust from diesel engines. The assessment was developed to provide information about the potential for DE to pose environmental health hazards, information that would be useful in evaluating regulatory needs under provisions of the Clean Air Act. The assessment identifies and characterizes the potential human health hazards of DE (i.e, hazard assessment) and seeks to estimate the relationship between exposure and disease response for the key health effects (i.e., dose-response assessment). A full exposure assessment and risk characterization, the other two components of a complete risk assessment, are beyond the scope of this document.

The report has nine chapters and three appendices. Chapter 2 provides a characterization of diesel emissions, atmospheric transformation, and human exposures to provide a context for the hazard evaluation of DE. Chapters 3, 4, 5, and 7 provide a review of relevant information for the evaluation of potential health hazards of DE, including dosimetry (Chapter 3), mutagenicity (Chapter 4), noncancer effects (Chapter 5), and carcinogenic effects (Chapter 7). Chapters 6 and 8 contain dose-response analyses to provide insight about the significance of the key noncancer and cancer hazards. Chapter 9 summarizes and characterizes the overall nature of the health hazard potential in the environment and the overall confidence and/or uncertainties associated with the conclusions.

1.2. COMPOSITION OF DIESEL EXHAUST

DE is a complex mixture of hundreds of constituents in either a gas or particle form. Gaseous components of DE include carbon dioxide, oxygen, nitrogen, water vapor, carbon monoxide, nitrogen compounds, sulfur compounds, and numerous low-molecular-weight hydrocarbons. Among the gaseous hydrocarbon components of DE that are individually known to be of toxicologic relevance are the aldehydes (e.g., formaldehyde, acetaldehyde, acrolein), benzene, 1,3-butadiene, and polycyclic aromatic hydrocarbons (PAHs) and nitro-PAHs.

The particles present in DE (i.e., diesel particulate matter [DPM]) are composed of a center core of elemental carbon and adsorbed organic compounds, as well as small amounts of sulfate, nitrate, metals, and other trace elements. DPM consists of fine particles (fine particles have a diameter <2.5 µm), including a subgroup with a large number of ultrafine particles (ultrafine particles have a diameter <0.1 µm). Collectively, these particles have a large surface area which makes them an excellent medium for adsorbing organics. Also, their small size makes them highly respirable and able to reach the deep lung. A number of potentially toxicologically relevant organic compounds are on the particles. The organics, in general, range from about 20% to 40 % of the particle weight, though higher and lower percentages are also reported. Many of the organic compounds present on the particle and in the gases are individually known to have mutagenic and carcinogenic properties. For example, PAHs, nitro-PAHs, and oxidized PAH derivatives are present on the diesel particles, with the PAHs and their derivatives comprising about 1% or less of the DPM mass.

DE emissions vary significantly in chemical composition and particle sizes between different engine types (heavy-duty, light-duty), engine operating conditions (idle, accelerate, decelerate), and fuel formulations (high/low sulfur fuel). Also, there are emission differences between on-road and nonroad engines simply because the nonroad engines to date are generally of older technology. The mass of particles emitted and the organic components on the particles from on-road diesel engines have been reduced over the years. Available data for on-road engines indicate that toxicologically relevant organic components of DE (e.g., PAHs, nitro-PAHs) emitted from older vehicle engines are still present in emissions from newer engines, though relative amounts have decreased. There is currently insufficient information to characterize the changes in the composition of DE from nonroad diesel engines over time.

1.3. DIESEL EXHAUST AS A COMPONENT OF AMBIENT PARTICULATE MATTER

DE is emitted from “on-road” diesel engines (vehicle engines) or “nonroad” diesel engines (e.g., locomotives, marine vessels, heavy-duty equipment, etc.). Nationwide, data in 1998 indicated that DE as measured by DPM made up about 6% of the total ambient $PM_{2.5}$ inventory (i.e., particles with aerodynamic diameter of 2.5 micrometers or less) and about 23% of the inventory, if natural and miscellaneous sources of $PM_{2.5}$ are excluded. Estimates of the DPM percentage of the total inventory in urban centers are higher. For example, estimates range from 10% to 36% in some urban areas in California, Colorado, and Arizona. Available data also indicate that over the years there have been significant reductions in DPM emissions from the exhaust of on-road diesel engines, whereas limited data suggest that exhaust emissions from nonroad engines have increased.

1.4. ATMOSPHERIC TRANSFORMATION OF DIESEL EXHAUST

After emission from the tailpipe, DE undergoes dilution and chemical and physical transformations in the atmosphere, as well as dispersion and transport in the atmosphere. The atmospheric lifetime for some compounds present in DE ranges from hours to days. DPM is directly emitted from diesel-powered engines (primary particulate matter) and can be formed from the gaseous compounds emitted by diesel engines (secondary particulate matter). Limited information is available about the physical and chemical transformation of DE in the atmosphere. It is not clear what the overall toxicological consequences of DE's transformations are because some compounds in the DE mixture are altered to more toxic forms while others are made less toxic.

1.5. EXPOSURE TO DIESEL EXHAUST

DPM mass (expressed as μg DPM/m^3) has historically been used as a surrogate measure of exposure for whole DE. Although uncertainty exists as to whether DPM is the most appropriate parameter to correlate with human health effects, it is considered a reasonable choice until more definitive information about the mechanisms of toxicity or mode(s) of action of DE becomes available. In the ambient environment, human exposure to DE comes from both on-road and nonroad engine exhaust. A large percentage of the U.S. population also is exposed to ambient $PM_{2.5}$, of which DPM is typically a significant constituent. Although this document does not provide an exposure assessment, DE exposure information is included to provide a context for the health effects information. Exposure estimates for the early to mid-1990s suggest that national annual average DE exposure from on-road engines alone was in the range of about 0.5 to 0.8 μg DPM/m^3 of inhaled air in many rural and urban areas, respectively. Exposures could be higher if there is a nonroad DE source that adds to the exposure from on-road vehicles. For example, preliminary estimates show that, on a national average basis, accounting for nonroad DE emissions adds another twofold to the on-road exposure. For localized urban areas where people spend a large portion of their time outdoors, the exposures are higher and, for example, may range up to 4.0 μg DPM/m^3 of inhaled air.

1.6. HEALTH EFFECTS OF DIESEL EXHAUST

Available evidence indicates that there are human health hazards associated with exposure to DE. The hazards include acute exposure-related symptoms, chronic exposure-related noncancer respiratory effects, and lung cancer. The health hazard conclusions are based on exhaust emissions from diesel engines built prior to the mid-1990s. With current engine use including some new and many more older engines (engines typically stay in service for a long time), the health hazard conclusions, in general, are applicable to engines currently in use. As new and cleaner diesel engines, together with different diesel fuels, replace a substantial number of existing engines, the general applicability of the health hazard conclusions will need to be re-evaluated. With new engine and fuel technology expected to produce significantly cleaner engine exhaust by 2007 (e.g., in response to new federal heavy duty engine regulations), significant reductions in public health hazards are expected for those engine uses affected by the regulations.

1.6.1. Acute (Short-Term Exposure) Effects

Information is limited for characterizing the potential health effects associated with acute or short-term exposure. However, on the basis of available human and animal evidence, it is concluded that acute or short-term (e.g., episodic) exposure to DE can cause acute irritation (e.g., eye, throat, bronchial), neurophysiological symptoms (e.g., lightheadedness, nausea), and respiratory symptoms (cough, phlegm). There also is evidence for an immunologic effect–the exacerbation of allergenic responses to known allergens and asthma-like symptoms. The lack of adequate exposure-response information in the acute health effect studies precludes the development of recommendations about levels of exposure that would be presumed safe for these effects.

1.6.2. Chronic (Long-Term Exposure) Noncancer Respiratory Effects

Information from the available human studies is inadequate for a definitive evaluation of possible noncancer health effects from chronic exposure to DE. However, on the basis of extensive animal evidence, DE is judged to pose a chronic respiratory hazard to humans. Chronic-exposure, animal inhalation studies show a spectrum of dose-dependent inflammation and histopathological changes in the lung in several animal species including rats, mice, hamsters, and monkeys.

This assessment provides an estimate of inhalation exposure of DE (as measured by DPM) to which humans may be exposed throughout their lifetime without being likely to experience adverse noncancer respiratory effects. This exposure level, known as the reference concentration (RfC) for DE of 5 $\mu g/m^3$ of DPM was derived on the basis of dose-response data on inflammatory and histopathological changes in the lung from rat inhalation studies. In recognition of the presence of DPM in ambient $PM_{2.5}$, it also is appropriate to consider the wealth of $PM_{2.5}$ human health effects data. In this regard, the 1997 National Ambient Air Quality Standard for $PM_{2.5}$ of 15 $\mu g/m^3$ (annual average concentration) also would be expected to provide a measure of protection from DPM, reflecting DPM's current approximate proportion to $PM_{2.5}$.

1.6.3. Chronic (Long-Term Exposure) Carcinogenic Effects

This assessment concludes that DE is "likely to be carcinogenic to humans by inhalation" and that this hazard applies to environmental exposures. This conclusion is based on the totality of evidence from human, animal, and other supporting studies. There is considerable evidence demonstrating an association between DE exposure and increased lung cancer risk among workers in varied occupations where diesel engines historically have been used. The human evidence from occupational studies is considered strongly supportive of a finding that DE exposure is causally associated with lung cancer, though the evidence is less than that needed to definitively conclude that DE is carcinogenic to humans. There is some uncertainty about the degree to which confounders are having an influence on the observed cancer risk in the occupational studies, and there is uncertainty evolving from the lack of actual DE exposure data for the workers. In addition to the human evidence, there is supporting evidence of DPM's carcinogenicity and associated DPM organic compound extracts in rats and mice by noninhalation routes of exposure. Other supporting evidence includes the demonstrated mutagenic and chromosomal effects of DE and its organic constituents, and the suggestive evidence for bioavailability of the DPM organics in humans and animals. Although high-exposure chronic rat inhalation studies show a significant lung cancer response, this is not thought predictive of a human hazard at lower environmental exposures. The rat response is considered to result from an overload of particles in the lung resulting from the high exposure, and such an overload is not expected to occur in humans at environmental exposures.

Although the available human evidence shows a lung cancer hazard to be present at occupational exposures that are generally higher than environmental levels, it is reasonable to presume that the hazard extends to environmental exposure levels. While there is an incomplete understanding of the mode of action for DE-induced lung cancer that may occur in humans, there is the potential for a nonthreshold mutagenic mode of action stemming from the organics in the DE mixture. A case for an environmental hazard also is shown by the simple observation that the estimated higher environmental exposure levels are close to, if not overlapping, the lower range of occupational exposures for which lung cancer increases are reported. These considerations taken together support the prudent public health choice of presuming a cancer hazard for DE at environmental levels of exposure. Overall, the evidence for a potential cancer hazard to humans resulting from chronic inhalation exposure to DE is persuasive, even though assumptions and uncertainties are involved. While the hazard evidence is persuasive, this does not lead to similar confidence in understanding the exposure/dose-response relationship.

Given a carcinogenicity hazard, EPA typically performs a dose-response assessment of the human or animal data to develop a cancer unit risk estimate that can be used with exposure information to characterize the potential cancer disease impact on an exposed population. The DE human exposure-response data are considered too uncertain to derive a confident quantitative estimate of cancer unit risk, and with the chronic rat inhalation studies not being predictive for environmental levels of exposure, EPA has not developed a quantitative estimate of cancer unit risk.

In the absence of a cancer unit risk, simple exploratory analyses were used to provide a perspective of the range of possible lung cancer risk from environmental exposure to DE. The analyses make use of reported lung cancer risk increases in occupational epidemiologic studies, and the differences between occupational and environmental exposure. The purpose of having a risk perspective is to illustrate and have a sense of the possible significance of the lung cancer hazard from environmental exposure. The risk perspective cannot be viewed as a definitive quantitative characterization of cancer risk nor is it suitable for estimation of exposure-specific population risks.

1.7. SOURCES OF UNCERTAINTY

Even though the overall evidence for potential human health effects of DE is persuasive, many uncertainties exist because of the use of assumptions to bridge data and knowledge gaps about human exposures to DE and the general lack of understanding about underlying mechanisms by which DE causes observed toxicities in humans and animals. A notable uncertainty of this assessment is whether the health hazards identified from studies using emissions from older engines can be applied to present-day environmental emissions and related exposures, as some physical and chemical characteristics of the emissions from certain sources have changed over time. Available data are not sufficient to provide definitive answers to this question because changes in DE composition over time cannot be confidently quantified, and the relationship between the DE components and the mode(s) of action for DE toxicity is/are unclear. While recognizing the uncertainty, for this assessment a judgment is made that prior-year toxicologic and epidemiologic findings can be applied to more current exposures, both of which use DPM mass in air as the measure of DE exposure.

Other uncertainties include the assumptions that health effects observed at high doses may be applicable to low doses, and that toxicologic findings in laboratory animals generally are predictive of human responses. In the absence of a more complete understanding of how DE may cause adverse health effects in humans and laboratory animals, related assumptions (i.e., the presence of a biological threshold for chronic respiratory effects based on cumulative dosage and absence of a threshold for lung cancer stemming from subtle and irreversible effects) are considered reasonable and prudent.

Although parts of this assessment, particularly the noncancer RfC estimate, have been derived with a generic consideration of sensitive subgroups within the population, the actual spectrum of the population that may have a greater susceptibility to DE is unknown and cannot be better characterized until more information is available regarding the adverse effects of DPM in humans. Increased susceptibility, for example, could result from above-average increases in DE deposition and retention in the respiratory system or intrinsic differences in respiratory system tissue sensitivity. There is no DE-specific information that provides direct insight to the question of differential human susceptibility. Given the nature of DE's noncancer effects on the respiratory system it would be reasonable, for example, to consider possible vulnerable subgroups to include infants/children, the elderly, or individuals with preexisting health conditions, particularly respiratory conditions.

In developing a perspective on the possible significance of the environmental cancer hazard of DE, this assessment uses information about the differences in the magnitude of DE exposures between the occupational and environmental settings. Although an appreciation for differences in exposure is needed only at an order-of-magnitude level for this assessment, one should recognize that individual exposure is a function of both the variable concentrations in the environment and the related breathing and particle retention patterns of the individual. Because of variations in these factors across the population, different subgroups could receive lower or higher exposure to DE than those groups mentioned in this assessment.

Lastly, this assessment considers only potential heath effects from exposures to DE alone. Effects of DE exposure could be additive to or synergistic with concurrent exposures to many other air pollutants. However, in the absence of more definitive data demonstrating interactive effects (e.g., potentiation of allergenicity effects, potentiation of DPM toxicity by ambient ozone and oxides of nitrogen) from combined exposures to DE and other pollutants, it is not possible to address this issue. Further research is needed to improve the knowledge and data on DE exposures and potential human health effects, and thereby reduce uncertainties of future assessments of the DE health effects data.

2. DIESEL EXHAUST EMISSIONS CHARACTERIZATION, ATMOSPHERIC TRANSFORMATION, AND EXPOSURES

2.1. INTRODUCTION

This chapter provides background information relating to the diesel engine, the pollutants it emits, the history of its use in highway vehicles and railroad locomotives, diesel exhaust composition and emissions trends, and air pollution regulatory standards for diesel engines in the United States. The chapter also provides specific information about the physical and chemical composition of diesel exhaust, descriptions of its atmospheric transformations, observations of measured and modeled ambient concentrations (considered alone and as a component of atmospheric particles in general), some estimates of population exposures as well as a comparison of DPM with ambient fine particulate matter ($PM_{2.5}$). In addition, this chapter gives background information that is used in conjunction with toxicology and epidemiology data to formulate conclusions about human health hazards that are discussed in later chapters of this document. The exposure information does not represent a formal or rigorous exposure assessment; it is intended only to provide a context for the health effects data and health hazard findings.

For the purposes of this document, carbonaceous matter, diesel exhaust, diesel particulate matter, elemental carbon, organic carbon, soluble organic fraction, and soot are defined below.

Carbonaceous matter: Carbon-containing compounds that are associated with particulate matter in diesel exhaust. In this document, the term carbonaceous matter includes all organic and elemental carbon-containing compounds that are found in the particle phase. In other documents, this term is sometimes used interchangeably to refer to the insoluble fraction of diesel particulate matter or the soot fraction.

Diesel engine exhaust (DE): Gaseous and particle-phase emissions resulting from the combustion of diesel fuel in an internal-combustion, compression-ignition engine. DE includes emissions from a diesel engine or diesel vehicle (inclusive of aftertreatment devices), but does not include emissions from brake and tire wear.

Diesel particulate matter (DPM): The particle-phase compounds emitted in DE. DPM can refer to both primary emissions and secondary particles that are formed by atmospheric processes. In this document, DPM refers to primary particles. Primary diesel particles are considered fresh after being emitted and aged after undergoing oxidation, nitration, or other chemical and physical changes in the atmosphere. As used in this document, DPM refers to both fresh and aged DPM unless a distinction is made.

Elemental carbon (EC): Carbon that has undergone pyrolysis (i.e., has been stripped of hydrogen). In pure form, EC contains only carbon atoms, although EC as it exists in combustion particulate matter is likely to contain some hydrogen atoms.

Organic carbon (OC): Carbon- and hydrogen-containing molecules emitted in DE largely as the result of unburned diesel fuel and, to a lesser extent, from engine lubrication oil. OC compounds also can contain oxygen, nitrogen, and sulfur, as well as other elements in small quantities.

Soluble organic fraction (SOF): The organic portion of DPM that can be extracted from the particle matrix into solution. Extraction solutions and procedures vary and are described in Section 2.2.8.1.

Soot: Agglomerations of EC and OC particles. Soot also is often characterized as the insoluble portion of DPM, and is therefore considered to be mainly EC by some investigators.

This chapter begins with a history of dieselization for on-road vehicles and locomotives, followed by an introductory discussion of the formation of primary diesel emissions to assist the reader in understanding the complex factors that influence the formation of particulate matter (PM) and other DE emissions. The next section is a summary of EPA emission standards for on-road and locomotive diesel engines and a description of the national trends in emissions from on-road and nonroad diesel engine sources based on inventory modeling. The chapter continues with a discussion of diesel fuel use and the impact of fuel properties on emissions. The chronological assessment of emissions factors is presented in summaries of chassis and engine dynamometer testing and tunnel tests. This is followed by a description of engine technologies and their effect on emissions, and a description of the chemical and physical nature of emissions. The data describing the important atmospheric transformations of DE are summarized. The chapter concludes with a summary of the available literature regarding atmospheric concentrations of DPM and exposures to DE. EPA has assessed national and urban-area annual average exposure to DPM using the Hazardous Air Pollutant Exposure Model, and this assessment is presented in Section 2.4.3. A full exposure assessment would include the distribution of ambient DE exposures in different geographic regions and among different demographic groups, the most highly exposed (90th percentile), exposures in microenvironments for short and long durations, the maximum exposure range (98th percentile), and the number of maximum-exposed individuals. However, such an assessment is not currently available. EPA is developing tools to provide a more complete exposure assessment.

2.2. PRIMARY DIESEL EXHAUST EMISSIONS

2.2.1. History of Dieselization

The diesel engine was patented in1892 by Rudolf Diesel, who conceived it as a prime mover that would provide much improved fuel efficiency compared with spark-ignition (SI) engines. To the present day, the diesel engine's excellent fuel economy remains one of its strongest selling points. In the United States, the diesel engine is used mainly in trucks, buses, agricultural and other nonroad equipment, locomotives, and ships.

The chief advantages of the diesel engine over the gasoline engine are its fuel economy and durability. Diesel engines, however, emit more PM per mile driven compared with gasoline engines of a similar weight. Over the past decade, modifications of engine components have substantially reduced particle emissions from both diesel and gasoline engines (Hammerle et al., 1994; Sawyer and Johnson, 1995).

The diesel engine compresses air to high pressure and temperature. Fuel, when injected into this compressed air, autoignites, releasing its chemical energy. The expanding combustion gases do work on the piston before being exhausted to the atmosphere. Power output is controlled by the amount of injected fuel rather than by throttling the air intake. Compared to its SI counterpart, the diesel engine's superior efficiency derives from a higher compression ratio and no part-load throttling. To ensure structural integrity for prolonged reliable operation at the higher peak pressures brought about by a higher compression ratio and autoignition, the structure of a diesel engine generally is more massive than its SI counterpart.

Diesel engines (also called compression-ignition) may be broadly identified as being either two- or four-stroke cycle, injected directly or indirectly, and naturally aspirated or supercharged. They also are classified according to service requirements such as light-duty (LD) or heavy-duty (HD) automotive/truck, small or large industrial, and rail or marine.

All diesel engines use hydraulic fuel injection in one form or another. The fuel system must meet four objectives if a diesel engine is to function properly over its entire operating range. It must: (1) meter the correct quantity of fuel, (2) distribute the fuel to the correct cylinder, (3) inject the fuel at the correct time, and (4) inject the fuel so that it is atomized and mixes well with the in-cylinder air. The first two objectives are functions of a well-designed injection pump, and the last two are mostly functions of the injection nozzle. Fuel injection systems are moving toward the use of electronic components for more flexible control than is available with purely mechanical systems to obtain lower exhaust emissions without diminishing fuel efficiency.

Both the fuel and the lubricants that service diesel engines are highly finished petroleum-based products combined with chemical additives. Diesel fuel is a mixture of many different hydrocarbon molecules from about C_7 to about C_{35}, with a boiling range from roughly 350 °F to 650 °F. Many of the fuel and oil properties, such as specific energy content (which is higher than gasoline), ignition quality, and specific gravity, are related to hydrocarbon composition. Therefore, fuel and lubricant composition affect many aspects of engine performance, including fuel economy and exhaust emissions.

Complete and incomplete combustion of fuel in the diesel engine results in the formation of a complex mixture of gaseous (gas-phase hydrocarbons, CO, CO_2, NO, NO_2, SO_2) and particulate exhaust (carbonaceous matter, sulfate, and trace elements). Because of concerns over health effects associated with DE, EPA began regulating emissions from diesel engines in 1970 (for smoke) and then added regulations for gaseous emissions. EPA first regulated particulate emissions from HD diesels in 1988.

2.2.1.1. *Dieselization of the On-Road Fleet*

Because of their durability and fuel economy, the use of diesel engines, particularly in long-distance applications, has increased over the years. The Census of Transportation, Truck Inventory and Use Survey (TIUS) indicates that among Class 3-8 trucks, diesel engine use has increased more rapidly than gasoline engine use in the past 20 years. Truck classes are defined by gross vehicle weight as described in Table 2-1. Dieselization first occurred among Class 7 and 8 trucks. The TIUS indicates that 81.5% of diesel trucks on the road in 1963 were Class 7 or 8 trucks (Table 2-2). Class 7 sales became predominantly (>50%) diesel in the 1970s and Class 8 sales became predominantly diesel in the 1960s. Diesels did not make up a majority of class 5 and 6 sales until the 1990s (Figures 2-1 and 2-2). HD trucks have historically constituted the majority of diesel sales and mileage. However, an increasing number of LD diesel trucks have been sold domestically in recent years. In the 1990s, approximately one in three diesel trucks sold was a Class 1 or Class 2 vehicle. Diesel trucks have historically been driven more miles per truck than gasoline trucks. For example, the TIUS indicates that 59% of diesel trucks were driven more than 50,000 miles in 1963, compared with 3% of gasoline trucks.

Table 2-1. Vehicle classification and weights for on-road trucks

Class	Gross vehicle weight (lb)
1	<6,000
2	6,001–10,000
3	10,001–14,000
4	14,001–16,000
5	16,001–19,500
6	19,501–26,000
7	26,001–33,000
8A[a]	33,001–60,000
8B[a]	>60,000
Medium duty (MD)	10,001–19,500 (same as Classes 3–5)
Light-heavy duty (LHD)	19,501–26,000 (same as Class 6)
Heavy-heavy duty (HHD)	>26,001 (same as Class 7–8)

[a]Class 8A and Class 8B are often considered together.

Table 2-2. Total (gas and diesel) diesel trucks in the fleet in 1992

Truck class	1992 gas and diesel trucks	1992 diesel trucks	% Diesels
Class 1 and 2 (Light duty)	55,193,300	1,387,600	3
Class 3, 4, and 5 (Medium duty)	1,258,500	326,300	26
Class 6 (Light heavy-duty)	732,300	273,800	37
Class 7 and 8 (Heavy heavy-duty)	2,016,600	1,725,300	86

Source: Census of Transportation, 1995.

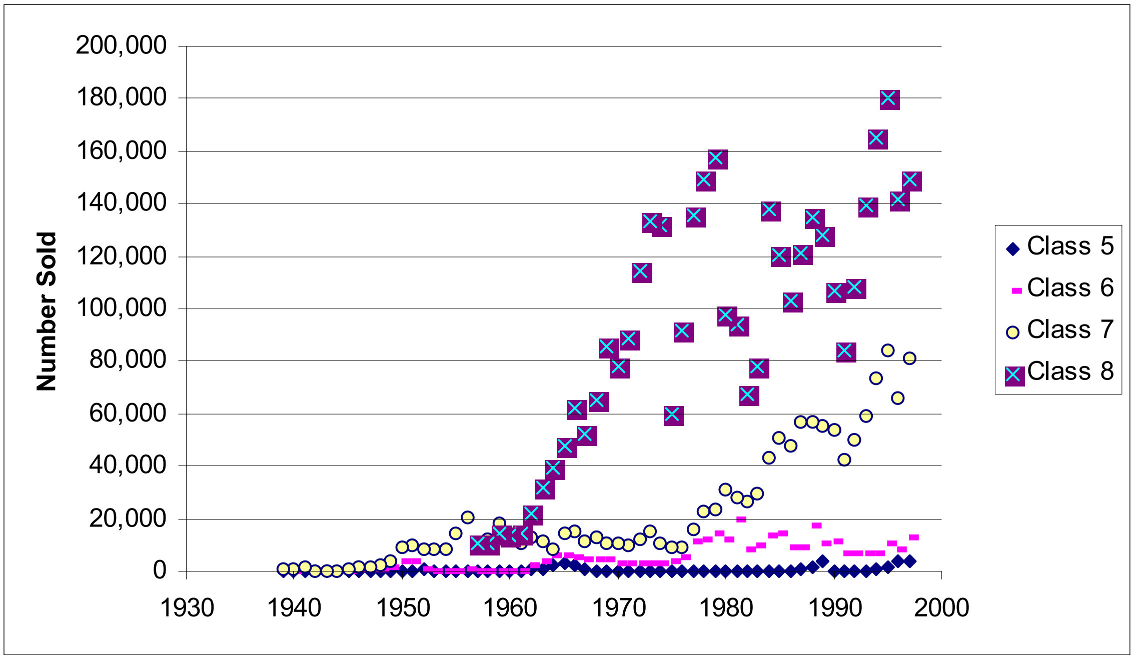


Figure 2-1. Diesel truck sales (domestic) for the years 1939-1997.
Source: AAMA, 1927-1974 and 1975-1998.

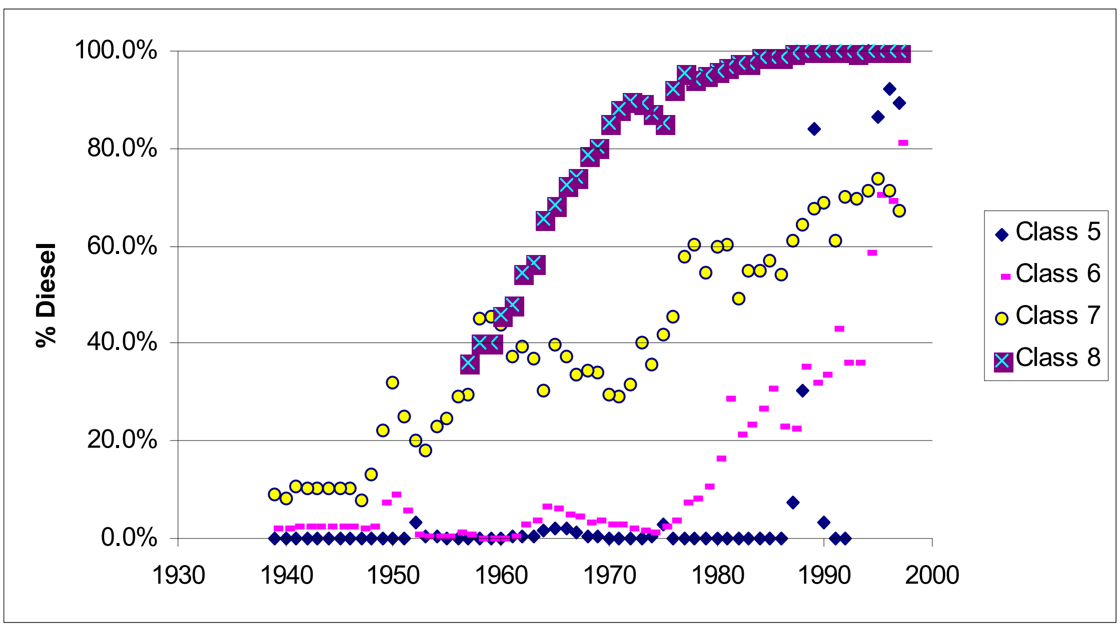
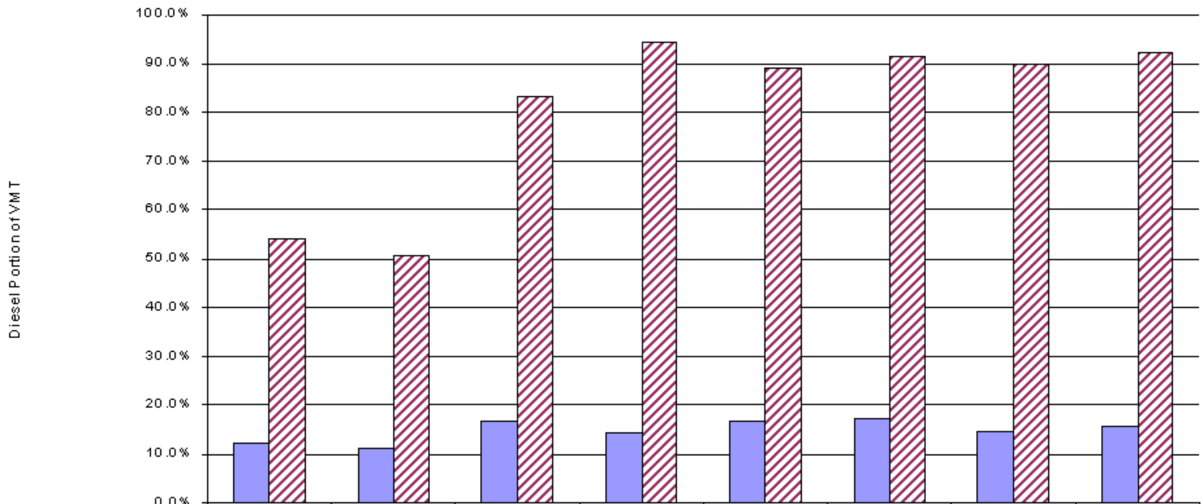


Figure 2-2. Diesel truck sales as a percentage of total truck sales for the years 1939-1997.
Source: AAMA, 1927-1974 and 1975-1998.

Among combination trucks, consisting of tractor-trailers and single-unit trucks with trailers, diesel vehicles have driven a majority of the miles since at least 1963, the first year in which TIUS was conducted (Figure 2-3).



	1963	1967	1972	1977	1982	1987	1992	1997
Total Trucks	12.1%	10.9%	16.7%	14.1%	16.8%	17.2%	14.4%	15.6%
Combination Trucks	53.9%	50.5%	83.2%	94.2%	89.1%	91.5%	89.8%	92.4%

Calendar Year

Figure 2-3. Percentage of truck miles attributable to diesel trucks. VMT= vehicle miles traveled.
Source: U.S. Bureau of the Census, 1999b.

The longevity of diesel trucks is an important factor to understand past, current, and projected exposures to DE because older vehicles are subject to less stringent regulations and may remain in use for several decades after their manufacture. American Automobile Manufacturers Association publications (AAMA, 1927-1997) indicate that 53% of trucks from model years 1947-1956 were still on the road after 14 years. The proportion of trucks in use after 14 years was 63% for model years 1974-1983, suggesting that the lifespan of trucks built in later years is longer. According to the 1997 TIUS, vehicles older than 10 years made up 40% of Class 7 and 8 trucks and 16% of Class 7-8 vehicle miles traveled (VMT) (Figures 2-4 and 2-5). Almost all Class 7 and 8 trucks were diesel vehicles in the period 1982-1997 (93% in 1982 and 99% in 1997).

2.2.1.2. *Dieselization of Railroad Locomotive Engines*

Early in the 20th century the political and economic pressure on the railroads to replace steam locomotives was substantial. Railroads were losing business to other forms of transport. The diesel-electric locomotive provided 90% in-service time, compared with only 50% for steam locomotives, and had three times the thermal efficiency (Klein, 1991; Kirkland, 1983).

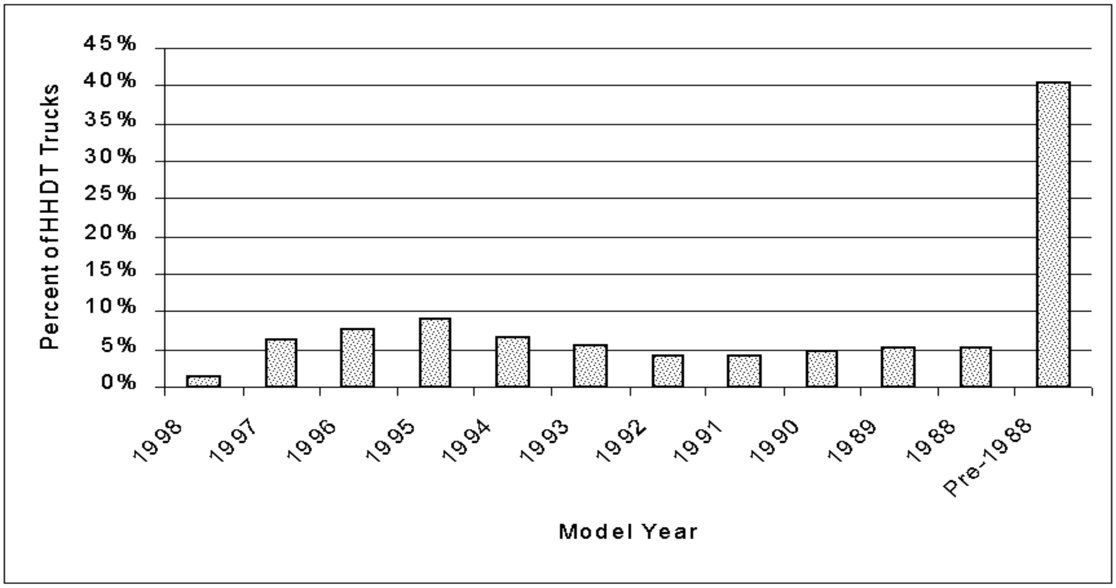


Figure 2-4. Model year distribution of in-use HD truck fleet in 1997.
Source: U.S. Bureau of the Census, 1999b.

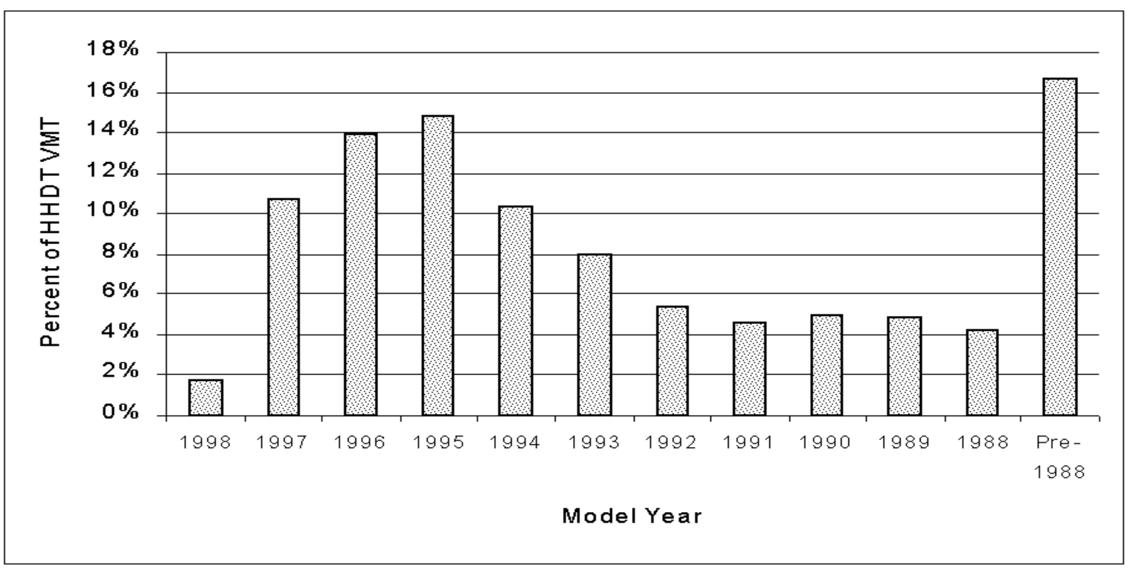


Figure 2-5. Model year distribution of vehicle miles traveled by the in-use HD truck fleet in 1997.
Source: U.S. Bureau of Census, 1999b.

Additionally, several cities had passed laws barring steam locomotives within the city limits because the large quantities of smoke obscured visibility, creating a safety hazard. The first prototype diesel locomotive was completed in 1917. By 1924 General Electric (GE) was producing a standard line of switching locomotives on a production basis. Electro-Motive Corporation was founded the same year to produce diesel locomotives in competition with GE. This company was purchased in 1929 by General Motors (GM) and became the Electro-Motive Division. After this acquisition, GM began to develop the two-stroke engine for this application. Up to this time, all locomotive diesel engines were four-stroke. Two-strokes offered a much higher power-to-weight ratio, and GM's strategy was to get a large increase in power by moving to the two-stroke cycle. The first true high-speed, two-stroke, diesel-electric locomotives were produced by GM in 1935. However, because of the economic climate of the Great Depression, few of these were sold until after the Second World War. At the end of the war, most locomotives were still steam-driven but were more than 15 years old, and the railroads were ready to replace the entire locomotive fleet. Few, if any, steam locomotives were sold after 1945 because the entire fleet was converted to diesel (Coifman, 1994).

The locomotive fleet has included significant percentages of both two- and four-stroke engines. The four-stroke diesel engines were naturally aspirated in the 1940s and 1950s. It is unlikely that any of the two-stroke engines used in locomotive applications were strictly naturally aspirated. Nearly all two-stroke diesel locomotive engines are uniflow scavenged, with a positive-displacement blower for scavenging assistance. In 1975, it was estimated that 75% of the locomotives in service were two-stroke, of which about one-half used one or more turbochargers in addition to the existing positive-displacement blower for additional intake boost pressure.

Almost all of the four-stroke locomotive engines were naturally aspirated in 1975. Electronic fuel injection for locomotive engines was first offered in the 1994 model year (U.S. EPA, 1998b). All locomotive engines manufactured in recent years are turbocharged, aftercooled or intercooled four-stroke engines. In part, this is because of the somewhat greater durability of four-strokes, although impending emissions regulations may have also been a factor in this shift. The typical lifespan of a locomotive has been estimated to be more than 40 years (U.S. EPA, 1998b). Many of the smaller railroads are still using engines built in the 1940s, although the engines may have been rebuilt several times since their original manufacture.

2.2.2. Diesel Combustion and Formation of Primary Emissions

A basic understanding of diesel combustion processes can assist in understanding the complex factors that influence the formation of DPM and other DE emissions. Unlike SI combustion, diesel combustion is a fairly nonhomogenous process. Fuel is sprayed at high pressure into the compressed cylinder contents (primarily air with some residual combustion products) as the piston nears the top of the compression stroke. The turbulent mixing of fuel and air that takes place is enhanced by injection pressure, the orientation of the intake ports (inducement of intake-swirl tangential to the cylinder wall), piston motion, and piston bowl shape. In some cases, fuel and air mixing is induced via injection of the fuel into a turbulence-generating pre-chamber or swirl chamber located adjacent to the main chamber (primarily in older, higher speed engines and some LD diesels). Examples of typical direct injection and indirect injection combustion systems are compared in Figure 2-6. Diesel combustion can be considered to consist of the following phases (Heywood, 1988; Watson and Janota, 1982):

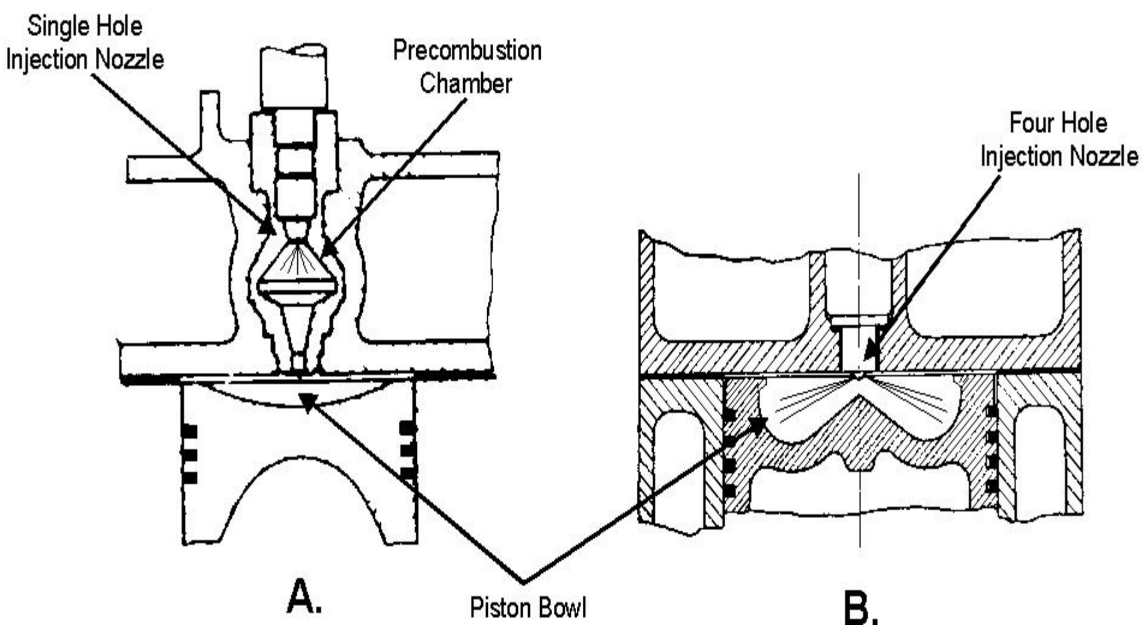


Figure 2-6. A comparison of IDI (A) and DI (B) combustion systems of high-speed HD diesel truck engines. DI engines almost completely replaced IDI engines for these applications by the early 1980s. (IDI = indirect injection, DI=direct injection)

- An ignition delay period, which starts after the initial injection of fuel and continues until the initiation of combustion. The delay period is governed by the rate of fuel and air mixing, diffusion, turbulence, heat transfer, chemical kinetics, fuel vaporization, and fuel composition. Fuel cetane rating is an indication of ignition delay.
- Rapid, premixed burning of the fuel and air mixture from the ignition delay period.
- Diffusion-controlled burning, where the fuel burns as it is injected and diffuses into the cylinder.
- A very small amount of rate-controlled burning during the expansion stroke, after the end of injection.

Engine speed and load are controlled by the quantity of fuel injected. Thus, the overall fuel-to-air ratio varies greatly as engine speed and load vary. On a macro scale, the cylinder contents are always fuel-lean. Depending on the time available for combustion and the proximity of oxygen, the fuel droplets are either completely or partially oxidized. At temperatures above 1,300 K, much of the unburned fuel that is not oxidized is pyrolized (stripped of hydrogen) to form EC (Dec and Espey, 1995). In addition to EC, other carbonaceous matter is present, largely from unburned fuel. The agglomeration of elemental and OC forms particles that are frequently referred to as "soot" particles. In this document, the terms "EC" and "OC" are used to refer to the carbon-containing components of DPM, and collectively, they are referred to as the carbonaceous fraction of a diesel particle.

Carbonaceous particle formation occurs primarily during the diffusion-burn phase of combustion, and is highest during high load and other conditions consistent with high fuel-air ratios. Most of the carbonaceous matter formed (80% to 98%) is oxidized during combustion, most likely by hydroxyl radicals (Kittelson et al., 1986; Foster and Tree, 1994).

DPM is defined by the measurement procedures summarized in the Code of Federal Regulations, Title 40 CFR, Part 86, Subpart N (CFR 40:86.N). These procedures define DPM emissions as the mass of material collected on a filter at a temperature of 52 °C or less after dilution of the exhaust with air. DPM is formed by a number of physical processes acting in concert as the exhaust is cooled and diluted. These are nucleation, coagulation, condensation, and adsorption. The core DE particles are formed by nucleation and coagulation from primary spherical particles consisting of solid carbonaceous (EC) material and ash (trace metals and other elements). To these, through coagulation, adsorption, and condensation, are added organic and sulfur compounds (sulfate) combined with other condensed material (Figure 2-7). Because of

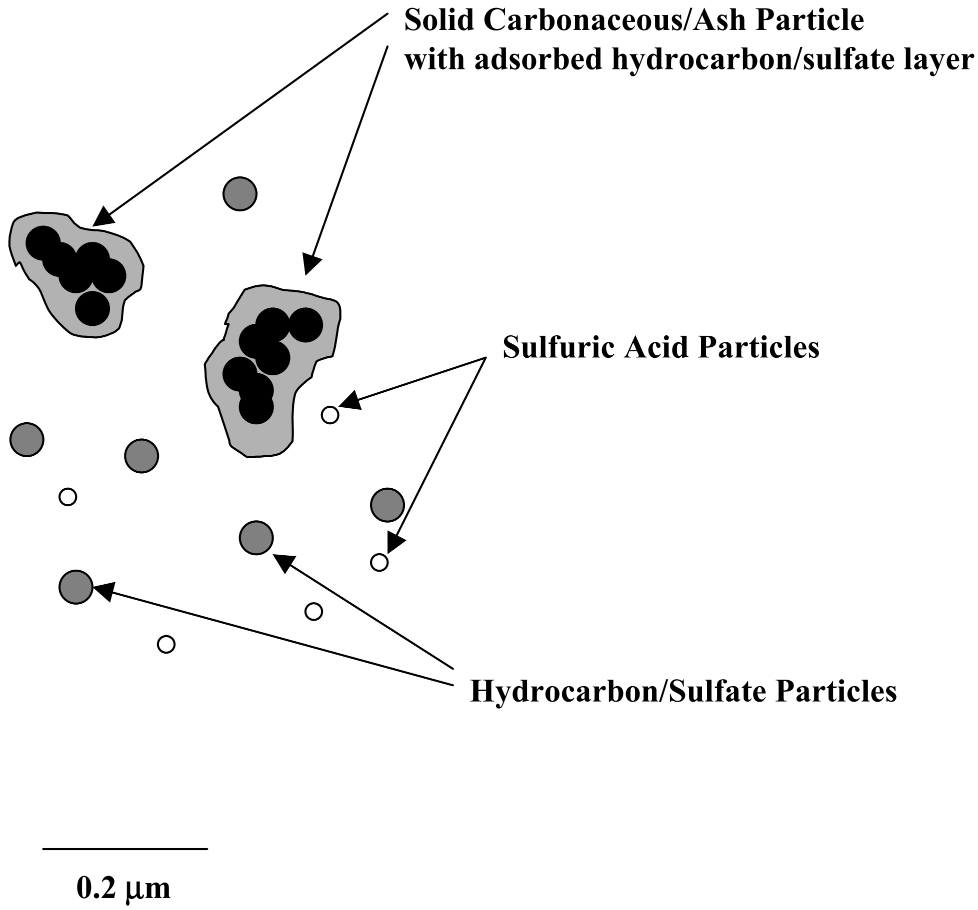


Figure 2-7. Schematic diagram of diesel engine exhaust particles.

Source: Modified from Kittelson, 1998.

their size, <0.5 mm, these particles have a very large surface area per gram of mass, which makes them able to adsorb large quantities of ash, organic compounds, and sulfate. The specific surface area of the EC core has been measured to be approximately 30–50 m^2/g (Frey and Corn, 1967). Pierson and Brachaczek (1976) report that after the extraction of adsorbed organic material, the surface area of the diesel particle core is approximately 90 m^2/g.

The organic material associated with diesel particles originates from unburned fuel, engine lubrication oil, and small quantities of partial combustion and pyrolysis products. This is frequently quantified as the SOF, which is discussed in much more detail in Section 2.2.7. The formation of sulfate in DE depends primarily on fuel sulfur content. During combustion, sulfur compounds present in the fuel are oxidized to sulfur dioxide (SO_2). Approximately 1% to 4% of fuel sulfur is oxidized to form sulfuric acid (H_2SO_4) (Wall et al., 1987; Khatri et al., 1978; Baranescu, 1988; Barry et al., 1985). Upon cooling, sulfuric acid and water condense into an aerosol that is nonvolatile under ambient conditions. The mass of sulfuric acid DPM is more than doubled by the mass of water associated with the sulfuric acid under typical DPM measurement conditions (50% relative humidity, 20–25 °C) (Wall et al., 1987).

Emissions from combustion engines produce oxide of nitrogen (NO_x) primarily (at least initially) as of NO. High combustion temperatures cause reactions between oxygen and nitrogen to form NO and some NO_2. Most NO_2 formed during combustion is rapidly decomposed. NO can also decompose to N_2 and O_2, but the rate of decomposition is very slow (Heywood, 1988; Watson and Janota, 1982). Thus, almost all of the NO_x emitted is NO.

Some organic compounds from unburned fuel and from lubricating oil consumed by the engine can be trapped in crevices or cool spots within the cylinder and thus are not sufficiently available to conditions that would lead to their oxidation or pyrolysis. These compounds are emitted from the engine and either contribute to gas-phase organic emissions or to DPM emissions, depending on their volatility. Within the exhaust system, temperatures are sufficiently high that these compounds are entirely present within the gas phase (Johnson and Kittelson, 1996). Upon cooling and mixing with ambient air in the exhaust plume, some of the less volatile organic compounds can adsorb to the surfaces of the EC agglomerate particles. Lacking sufficient EC adsorption sites, the organic compounds may condense on sulfuric acid nuclei to form a heterogeneously nucleated organic aerosol (Abdul-Khalek et al., 1999).

Although not unique to DE, the high content of EC associated with typical DPM emissions has long been used by some investigators to distinguish diesel engine sources of this particle from other combustion aerosols. Diesel particles from newer HD engines are typically composed of ~75% EC (EC can range from 33% to 90%), ~20% OC (OC can range from 7% to 49%), and small amounts of sulfate, nitrate, trace elements, water, and unidentified components (Figure 2-8). Metallic compounds from engine component wear, and from compounds in the fuel and lubricant, contribute to DPM mass. Ash from oil combustion also contributes trace amounts.

Ambient $PM_{2.5}$ measured in the eastern United States is dominated by sulfate (34%), whereas ambient $PM_{2.5}$ in the western United States is dominated by OC (39%) (Table 2-3) (U.S. EPA, 1999a). Many sources contribute to ambient $PM_{2.5}$, and these sources and their relative contribution to ambient $PM_{2.5}$ can be identified on the basis of the chemical species present. The OC fraction of DPM is increasingly being used to assist investigators in identifying the contribution of diesel engine emissions to ambient $PM_{2.5}$. In particular, hopane and sterane compounds (aromatic compounds, $>C_{30}$) have been used in addition to other polycyclic aromatic hydrocarbons (PAHs) and long-chain alkanes to distinguish DPM from other mobile source PM and from ambient PM (Schauer et al., 1996; Fujita et al., 1998). Although PAH compounds make up 1% or less of DPM mass, diesel emissions have been observed to have elevated concentrations of methylated naphthalenes and methylated phenanthrene isomers compared to other combustion aerosols (Benner et al., 1989; Lowenthal et al., 1994; Rogge et al., 1993). Enrichment of benzo[*a*]anthracene and benzo[*a*]pyrene (B[*a*]P) in DPM has also been

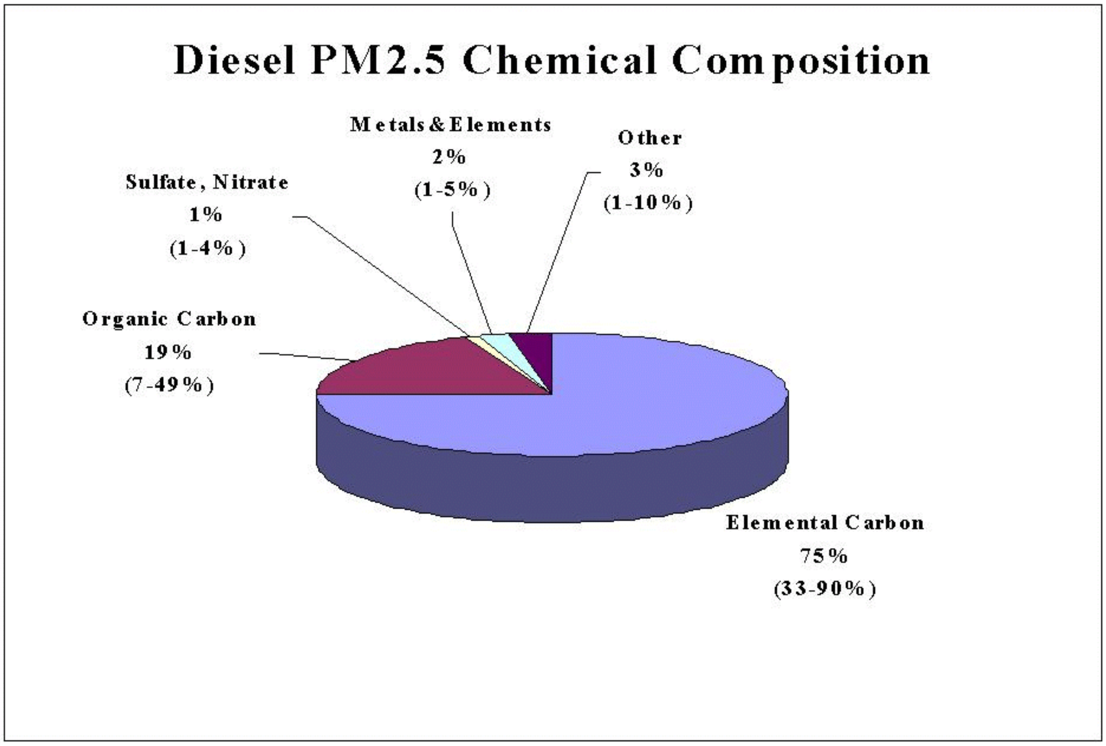


Figure 2-8. Typical chemical composition for diesel particulate matter ($PM_{2.5}$) from new (post-1990) HD diesel vehicle exhaust.

Table 2-3. Typical chemical composition of fine particulate matter

	Eastern U.S.	Western U.S.	Diesel $PM_{2.5}$
Elemental carbon	4%	15%	75%
OC	21%	39%	19%
Sulfate, nitrate, ammonium	48%	35%	1%
Minerals	4%	15%	2%
Unknown	23%	–	3%

Source: U.S. EPA, 1999a.

observed under some conditions and has been used to assess the relative contribution of DE to ambient PM.

Although specific OC species are being used to help distinguish DPM aerosols from other combustion aerosols, up to 90% of the organic fraction associated with DPM is currently classified as unresolvable complex material. Ultrafine DPM (5–50 nm) accounts for the majority (50% to 90%) of the number of particles but only 1% to 20% of the mass of DPM. A study conducted by Gertler (1999) in the Tuscarora Mountain tunnel demonstrated an increase in 20 nm diameter particles as the fraction of diesel vehicles in the tunnel increased from 13% to 78%. The contribution of nuclei-mode particles from a freeway on an ambient aerosol size distribution was reported by Whitby and Sverdrup (1980).

In summary, four main characteristics of DPM are (1) the high proportion of EC, (2) the large surface area associated with the carbonaceous particles in the 0.2 μm size range, (3) enrichment of certain polycyclic organic compounds, and (4) 50%–90% of the number of DPM particles in diesel engine exhaust are in the nuclei-mode size range, with a mode of 20 nm.

2.2.3. Diesel Emission Standards and Emission Trends Inventory

EPA set a smoke standard for on-road HD diesel engines beginning with the 1970 model year and added a carbon monoxide (CO) standard and a combined hydrocarbon (HC) and NO_x standard for the 1974 model year (Table 2-4). Beginning in the 1979 model year, EPA added a HC standard while retaining the combined HC and NO_x standard. All of the testing for HC, CO, and NO_x was completed using a steady-state test procedure. Beginning in the 1985 model year,EPA added a NO_x standard (10.7 g/bhp-hr), dropped the combined HC and NO_x standard, and converted from steady-state to transient testing for HC, CO, and NO_x emissions. EPA introduced a particulate standard for 1988 model year diesel engines using the transient test (0.6 g/bhp-hr). Transient testing involves running an engine on a dynamometer over a range of load and speed set points.

Since the 1985 model year, only the NO_x and particulate standards have been tightened for on-road diesel engines. For truck and bus engines, the particulate standard was reduced to 0.25 g/bhp-hr in 1991, and it was reduced again in 1994 for truck engines to 0.1 g/bhp-hr. For urban bus engines, the particulate standard was reduced in 1994 to 0.07 g/bhp-hr and again in 1996 to 0.05 g/bhp-hr. The NO_x standard was reduced to 4.0 g/bhp-hr in 1998 for all on-road diesel engines (bus and truck engines). The standards for nonmethane hydrocarbon (NMHC) and NO_x combined were further lowered in a 1997 rulemaking, to take effect in 2004. EPA has recently finalized a regulation that will further reduce $NO_{x,}$ NMHC, and PM emissions from diesel engines starting in 2007.

Table 2-4. U.S. emission standards: HD highway diesel engines

Model year	Pollutant (g/bhp-hr)					Smoke[a]
	HC	CO	NO_x	HC + NO_x	Particulate (PM) t=truck, b=bus, ub=urban bus	
1970	—	—	—	—	—	A:40%; L:20%
1974	—	40	—	16[b]	—	A:20%; L:15%; P:50%
1979	1.5	25	—	10[b]	—	A:20%; L:15%; P:50%
1985[c]	1.3	15.5	10.7	—	—	A:20%; L:15%; P:50%
1988	1.3	15.5	10.7	—	0.60	A:20%; L:15%; P:50%
1990	1.3	15.5	6.0	—	0.60	A:20%; L:15%; P:50%
1991	1.3	15.5	5.0	—	0.25	A:20%; L:15%; P:50%
1993	1.3	15.5	5.0	—	0.25 t, 0.10 b	A:20%; L:15%; P:50%
1994	1.3	15.5	5.0	—	0.10 t, 0.07 ub	A:20%; L:15%; P:50%
1996	1.3	15.5	5.0	—	0.10 t, 0.05 ub	A:20%; L:15%; P:50%
1998	1.3	15.5	4.0	—	0.10 t, 0.05 ub	A:20%; L:15%; P:50%
2004	1.3	15.5	—	2.4 NMHC[d]	0.10 t, 0.05 ub	A:20%; L:15%; P:50%
2007		15.5	0.2	0.14 NMHC	0.01	A:20%; L:15%; P:50%

[a]Emissions measured in percent opacity during different operating modes: A=acceleration; L=lug; P=peaks during either mode.

[b]Total HC.

[c]In 1985, test cycle changed from steady-state to transient operation for HC, CO, and NO_x measurement and in 1988 for PM.

[d]Or 2.5 plus a limit of 0.5 nonmethane hydrocarbon (NMHC).

In December 1997, EPA adopted emission standards for NO_x, HC, CO, PM, and smoke for newly manufactured and remanufactured railroad locomotives and locomotive engines. The rulemaking, which took effect in the year 2000, applies to locomotives originally manufactured in 1973 or after, and any time they are manufactured or remanufactured (locomotives originally manufactured before 1973 are not regulated). Three sets of emission standards have been adopted (Tier 0, 1, and 2); they apply to locomotives and locomotive engines originally manufactured from 1973 through 2001 (Tier 0), from 2002 through 2004 (Tier 1), and in 2005 and later (Tier 2) (Table 2-5; see EPA web page at http://www.epa.gov/omswww/ or http://www.dieselnet.com/standards/ for current information on mobile source emission standards). The emissions are measured over two steady-state test cycles that represent two

Table 2-5. U.S. emission standards: locomotives (g/bhp-hr)

	Year[a]	CO	HC	NO_x	PM
Line-haul	1973-2001 (Tier 0)	5.0	1.0	9.5	0.6
Switch	1973-2001 (Tier 0)	8.0	2.1	14.0	0.72
Line-haul	2002-2004 (Tier 1)	2.2	0.55	7.4	0.45
Switch	2002-2004 (Tier 1)	2.5	1.2	11.0	0.54
Line-haul	2005 + (Tier 2)	1.5	0.3	5.5	0.20
Switch	2005 + (Tier 2)	2.4	0.6	8.1	0.24

[a]Date of engine manufacture.

different types of service, including line-haul (long-distance transport) and switch (involved in all transfer and switching operations in switchyards) locomotives.

Emission standards for nonroad equipment are not as stringent as current standards for on-road equipment and are being phased in within the next decade. Currently, Federal PM standards exist for nonroad equipment of several horsepower ratings. For equipment between 175 and 750 horsepower, the PM standard was set at 0.4 g/bhp-hr in 1996 and will decrease to 0.15 g/bhp-hr between 2001 and 2003 depending on the power rating (Table 2-6). This equipment includes construction, agricultural, and industrial such as bulldozers, graders, cranes, and tractors. The current PM standard for this equipment is only slightly lower than the 0.6 g/bhp-hr PM standard in place for on-road HD diesel engines in the late 1980s.

The EPA emission trends report (U.S. EPA, 2000a) provides emission inventories for criteria pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_x, volatile organic compounds [VOC], CO, Pb, and NH_3) from point, area, and mobile sources, which indicate how emissions have changed from 1970 to 1998. The emission trends are based on the EPA mobile source inventory models MOBILE, PART5, and the draft NONROAD model. PART5 derives particulate emission rates for HD diesel vehicles using data generated for new engine certification purposes. PART5 is currently being modified to account for deterioration, in-use emissions, poor maintenance, and tampering effects, all of which would increase emission factors. PM, SO_2, NO_x, and VOC emissions trends from the report are discussed below. Ambient urban/suburban PM samples rarely reflect the large fraction of natural and miscellaneous sources suggested by the national inventory, owing to removal of a large portion of these emissions close to their sources as well as dispersion from these sources to urban/suburban sites. The removal of natural and miscellaneous PM_{10} (largely fugitive dust) near their source is a result of the lack of inherent thermal buoyancy, low release height, and interaction with their surroundings (impaction and filtration by vegetation).

Table 2-6. U.S. emission standards for nonroad diesel equipment (g/bhp-hr)

Power rating	Model year	Pollutant (g/bhp-hr)					Smoke %[a]
		HC	CO	NO_x	NMHC + NO_x	PM	
11 < hp	2000	—	6.0	—	7.8 (ABT)	0.74 (ABT)	
	2005+	—	6.0	—	5.6 (ABT)	0.60 (ABT)	
11≤ hp < 25	2000	—	4.9	—	7.0 (ABT)	0.60 (ABT)	
	2005+	—	4.9	—	5.6 (ABT)	0.60 (ABT)	
25≤ hp < 50	2000	—	4.1	—	7.0 (ABT)	0.60 (ABT)	
	2005+	—	4.1	—	5.6 (ABT)	0.44 (ABT)	
50≤ hp <100	1998+	—	—	6.9 (ABT)	—	—	20/15/50
	2004	—	3.7		5.6 (ABT)	0.30 (ABT)	
	2008+	—	3.7		3.5 (ABT)	—	
100≤ hp <175	1997+	—	—	6.9 (ABT)	—	—	20/15/50
	2003	—	3.7	—	4.9 (ABT)	0.22 (ABT)	
	2007+	—	3.7	—	3.0 (ABT)	—	
175≤ hp < 750	1996+	1.0	8.5	6.9 (ABT)	—	0.4	20/15/50
175≤ hp < 300	2003	—	2.6	—	4.9 (ABT)	0.15 (ABT)	
	2006+	—	2.6	—	3.0 (ABT)	—	
300≤ hp < 600	2001	—	2.6	—	4.8 (ABT)	0.15 (ABT)	
	2006+	—	2.6	—	3.0 (ABT)	—	
600≤ hp < 750	2002	—	2.6	—	4.8 (ABT)	0.15 (ABT)	
	2006+	—	2.6	—	3.0 (ABT)	—	
≥750 hp	2000+	1.0	8.5	6.9 (ABT)	—	0.4	20/15/50
	2006+	—	2.6	—	4.8 (ABT)	0.15 (ABT)	

[a]Emissions measured in percent opacity during different operating modes: acceleration/lug/peaks during either mode.
ABT=average banking and trading.

Note: The standards for engines less than 50 hp also apply to diesel marine engines.

For the summaries presented here, natural and miscellaneous sources are excluded from the national PM and NO_x inventories.

From 1970 to 1998, PM_{10} emissions decreased from slightly over 12,200,000 tons to just over 2,800,000 tons (Figure 2-9). PM_{10} emissions from on-road and nonroad diesel engines increased from 320,000 tons to more than 521,000 tons during this same period, so that in 1970 diesel engine emissions were 3% of the PM_{10} inventory whereas in 1998, diesel engine emissions were 18% of the PM_{10} inventory. Diesel engines also contribute to secondary PM formation from NO_x and SO_2 emissions that are converted to nitrate and sulfate. VOCs from diesel engines also contribute to secondary organic particle formation. The contribution of secondary PM is not included in the national trends inventories cited here.

Mobile sources of PM include both gasoline- and diesel-powered on-road vehicles and a variety of nonroad equipment. Nonroad diesel engine sources include construction equipment, agricultural equipment, marine vessels, locomotives, and other sources. The EPA emission trends report (U.S. EPA, 2000a) indicates that, excluding natural and miscellaneous sources, mobile sources were responsible for 25% of PM_{10} emissions in 1998. Diesel engines (on-road and nonroad combined) were estimated to contribute 72% of mobile-source PM_{10} emissions.

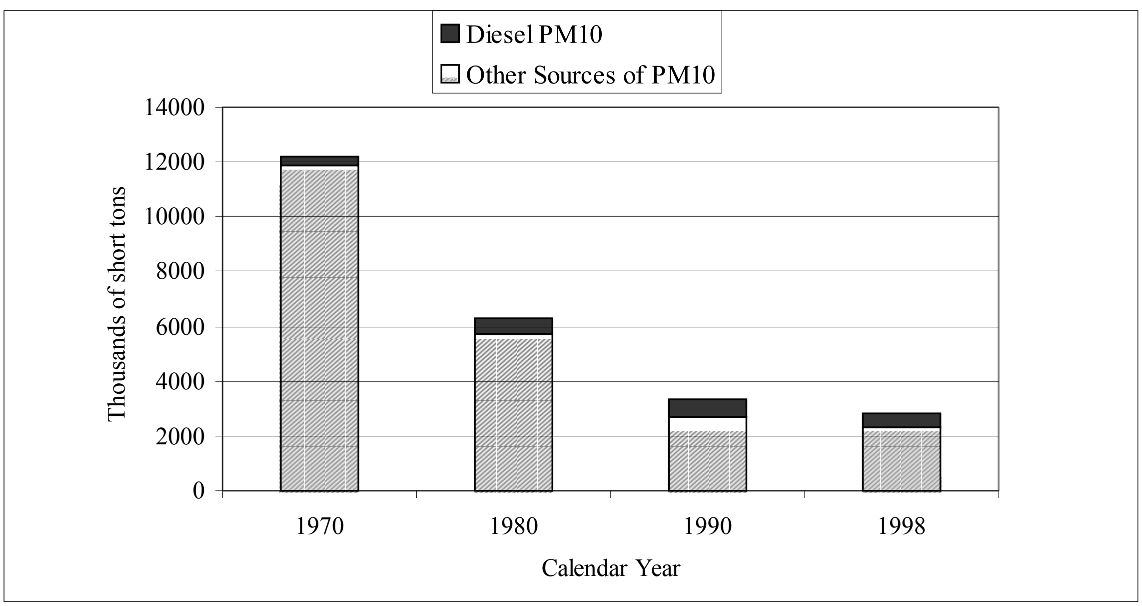


Figure 2-9. Trends in PM_{10} emissions from on-road and nonroad engines combined and other anthropogenic sources of PM_{10} from 1970 to 1998 (excludes miscellaneous and natural sources).

Source: U.S. EPA, 2000a, National Air Pollutant Emission Trends, 1900-1998.

Because of the high concentration of fine particles in engine emissions, diesel engines (on-road and nonroad combined) were estimated to contribute 77% of mobile-source $PM_{2.5}$ emissions and 23% of total $PM_{2.5}$ in 1998 (excluding natural and miscellaneous emissions). If natural and miscellaneous $PM_{2.5}$ sources are included in the inventory, diesel $PM_{2.5}$ contributes 6% to the national inventory.

Gram per mile particulate emissions from diesel vehicles are much greater than those from gasoline-fueled vehicles, accounting for the large contribution of diesel engine emissions to the national inventory in spite of the smaller number of diesel engines in use. Particulate emissions (PM_{10}) from gasoline-fueled engines decreased dramatically in 1975 with the widespread introduction of unleaded gasoline. Particulate emissions from diesel highway vehicles have decreased recently because of EPA emission standards for new model year HD diesel trucks that were first implemented in 1988 and became increasingly stringent in 1991, 1994, and 2000, as presented in Table 2-4. A decrease in on-road HD DPM emissions since the mid-1980s is confirmed by in-use vehicle testing, as described in Section 2.2.5. Because of the implementation of existing regulations, DPM emissions from on-road sources are expected to decrease 37% from 1998 to 2007; however, nonroad DPM emissions are expected to increase 15% in the same period (Figure 2-10).

The EPA emission trends report (U.S. EPA, 2000a) indicates that annual on-road vehicle PM_{10} emissions decreased from 397,200 tons to 257,080 tons from 1980 to 1998.[1] Passenger car particulate emissions decreased 53% (from 119,000 to 56,000 tons) in this timeframe, while on-road diesel vehicle PM_{10} emissions decreased 27% (from 208,000 to 152,000 tons) (Figure 2-10). Nonroad diesel engine PM_{10} emissions increased 17% (from 314,000 tons in 1980 to 69,000 tons in 1998). Emissions data for $PM_{2.5}$ are available only for the period from 1990 to 1998. Between 1990 and 1998, $PM_{2.5}$ emissions from mobile sources decreased by 14%, largely as the result of decreased on-road emissions.

From 1970 to 1998, NO_x emissions increased from 20,598,000 tons to 24,126,000 tons (Figure 2-11). NO_x emissions from on-road and nonroad diesel engines increased from 1,748,000 tons to 4,753,000 tons during this same period, so that in 1970 diesel engine emissions were 8% of the NO_x inventory while in 1998, diesel engine emissions were 20% of the NO_x

[1]Exhaust emissions constitute the majority of PM emissions from mobile sources, with tire and brake wear contributing the remainder. To compare trends estimates from past years with future projections (which are provided for exhaust emissions only), the fraction of brake and tire wear would need to be omitted from these estimates as reported in the emission trends report (U.S. EPA, 2000a). On average in the late 1990s 39% and 64% of gasoline vehicle particulate emissions originated from exhaust and 95% and 98% of on-road diesel emissions originated from exhaust for PM_{10} and $PM_{2.5}$, respectively.

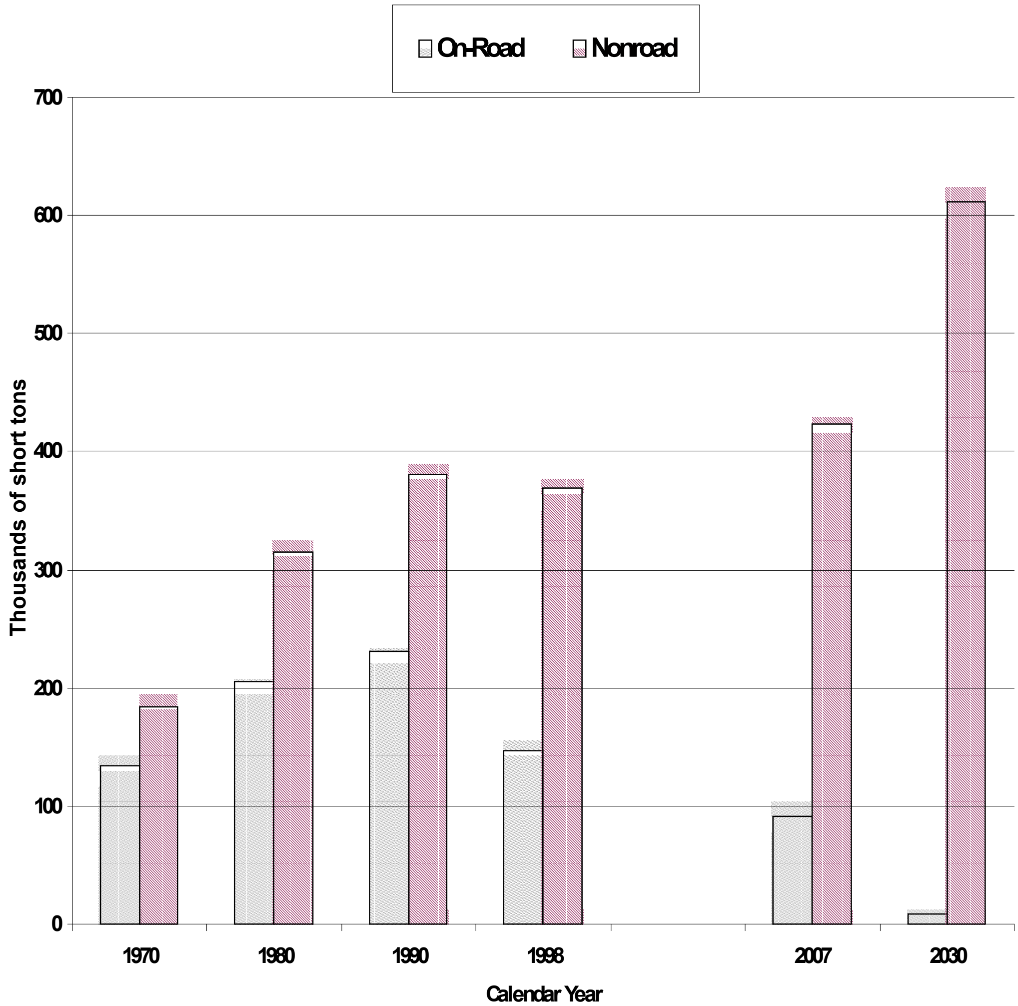


Figure 2-10. Trends in PM_{10} emissions from on-road and nonroad diesel engines from 1970 to 1998 and projections of emissions to 2007 and 2030*.

Source: U.S. EPA, 2000a, National Air Pollutant Emission Trends, 1900-1998.
*Projection to 2030 includes implementation of the recently finalized regulation "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements" U.S. EPA, 2000b.

inventory. As mentioned above, some of this NO_x will be converted to particulate nitrate in the atmosphere, and this contribution to ambient PM is not quantified in national inventories.

In 1998, 53% of total emitted NO_x came from mobile sources, with diesels responsible for 57% of the mobile-source contribution. Overall, NO_x emissions from mobile sources have remained relatively constant over time, increasing an estimated 7% from 1980 to 1998. Whereas

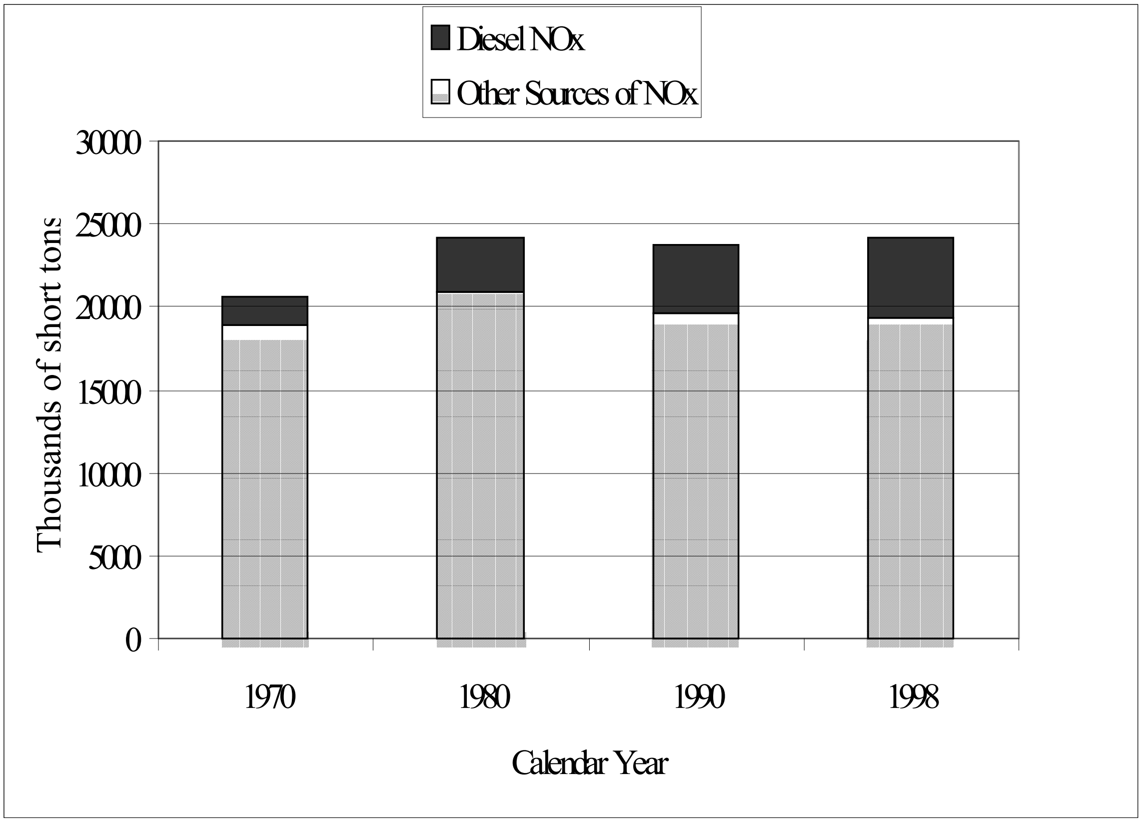


Figure 2-11. Trends in NO_x emissions from on-road and nonroad diesel engines combined and other anthropogenic sources of NO_x from 1970 to 1998 (excludes miscellaneous and natural sources).

Source: U.S. EPA, 2000a, National Air Pollutant Emission Trends, 1900-1998.

NO_x from LD gasoline vehicles decreased from 1980 to 1998, resulting in an overall decrease in on-road NO_x emissions of 9%, NO_x from diesel trucks and buses increased 7% (from 2,463,390 tons in 1980 to 2,630,120 tons in 1998), owing to the illegal use of electronic control devices that bypassed the trucks' emission control systems, as discussed in Section 2.2.5. NO_x emissions from nonroad diesel engines (including commercial marine and locomotives) have increased 46% (from 3,251,600 tons in 1980 to 4,752,800 tons in 1998) (Figure 2-12).

About 7% of SO_2 came from mobile sources in 1998, with diesels responsible for 74% of that total. EPA regulations for on-road diesel fuel sulfur content (which started in 1993) have significantly reduced SO_2 emissions from highway diesels. SO_2 emissions from highway diesel

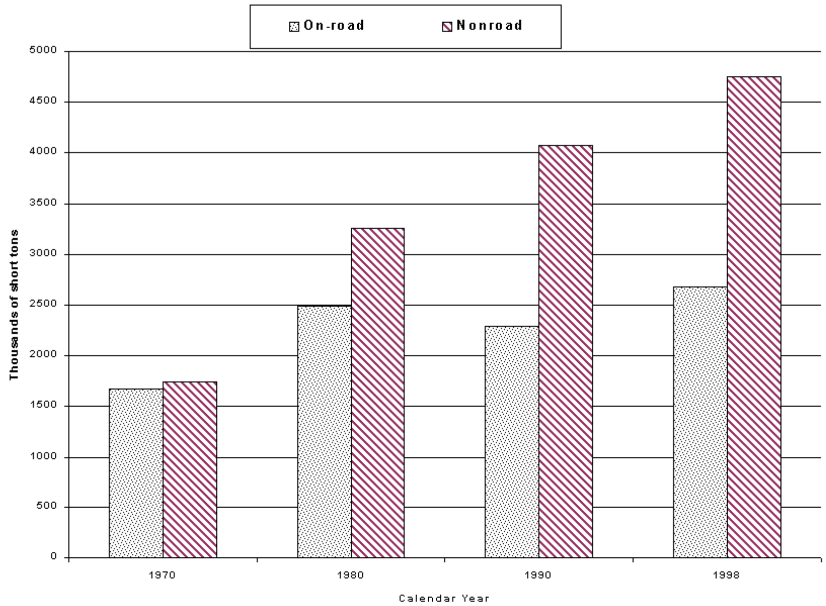


Figure 2-12. Trends in NO_x emissions from on-road and nonroad diesel engines from 1970 to 1998.

Source: U.S. EPA, 2000a, National Air Pollutant Emission Trends, 1900-1998.

engines have decreased 72% (from 303,000 tons in 1980 to 85,000 tons in 1998) (Figure 2-13). Similar trends are not apparent for nonroad diesels, although in 1998 nonroad diesel engines, excluding commercial marine vessels, emitted 785,000 tons of SO_2, accounting for 56% of mobile-source SO_2 emissions in 1998.

Diesel engines are not a large source of VOC emissions compared with gasoline engines. VOC emissions from diesel engines in 1998 were estimated at 2% of the total emissions from all sources. VOC emissions from diesel mobile sources decreased 9% (from 779,000 tons in 1980 to 721,000 tons in 1998) (Figure 2-14).

Diesel engines are also not a large source of CO emissions compared with gasoline engines. In 1998, mobile sources emitted 79% of all CO, and diesel engines accounted for 4% of the mobile-source CO. CO emissions from on-road diesel vehicles increased 34% between 1980 and 1998, during which time nonroad diesel emissions of CO increased 45% (Figure 2-15).

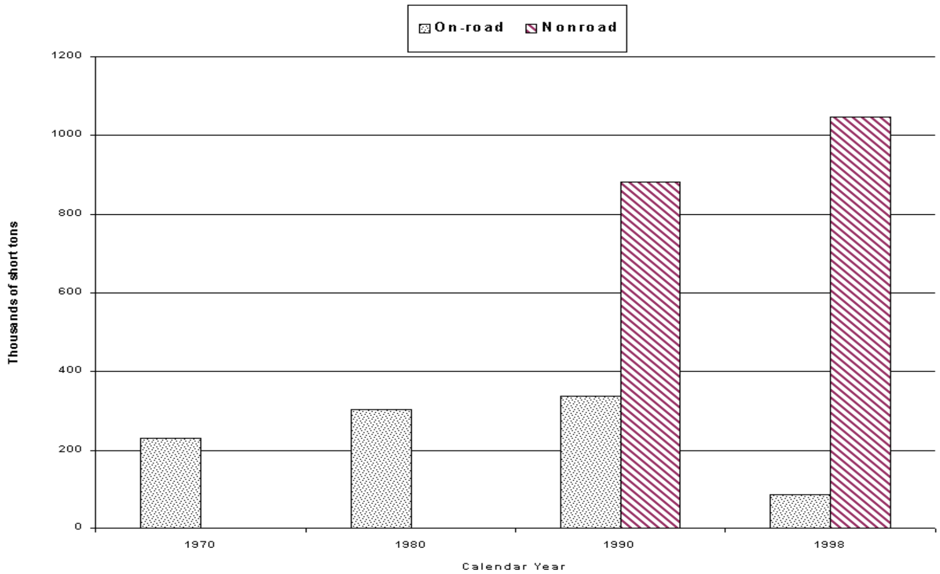


Figure 2-13. Trends in SO_2 emissions from on-road diesel engines from 1970 to 1998 and nonroad diesel engines from 1990 to 1998.

Source: U.S. EPA, 2000a, National air pollutant emission trends, 1900-1998.

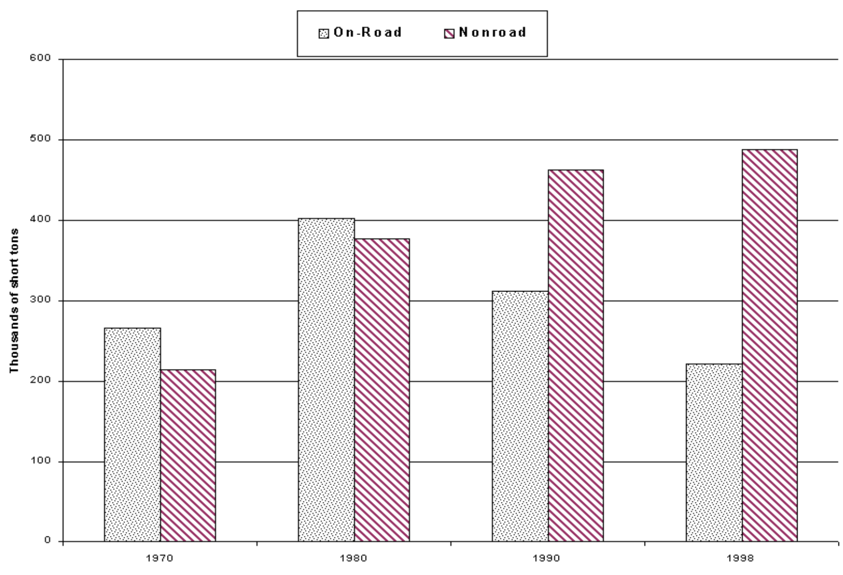


Figure 2-14. Trends in VOC emissions from on-road and nonroad diesel engines from 1970 to 1998.

Source: U.S. EPA, 2000a, National air pollutant emission trends, 1900-1998.

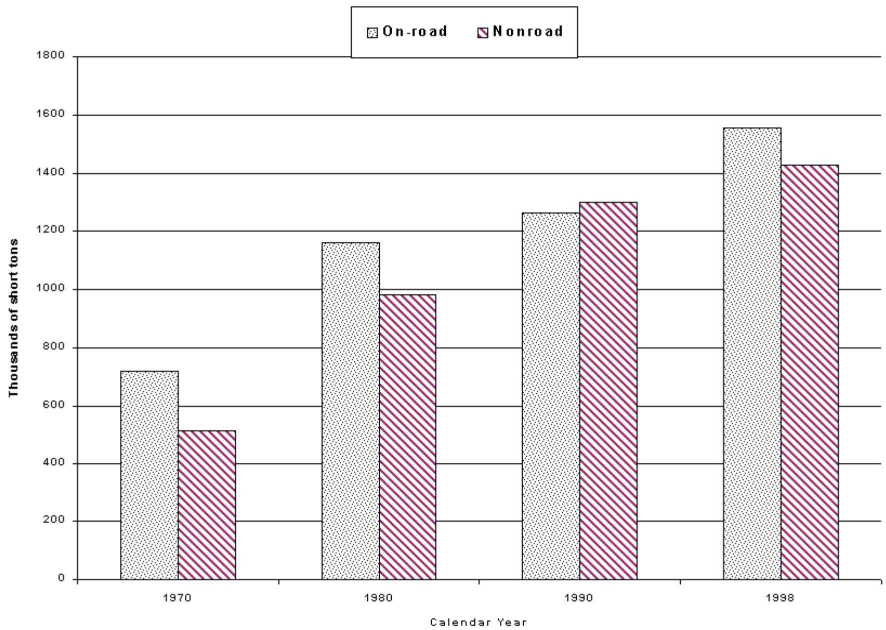


Figure 2-15. Trends in CO emissions from on-road and nonroad diesel engines from 1970 to 1998.

Source: U.S. EPA, 2000a, National Air Pollutant Emission Trends, 1900-1998.

2.2.4. Historical Trends in Diesel Fuel Use and Impact of Fuel Properties on Emissions

Use of diesel fuel increased steadily in the second half of the 20th century. According to statistics from the Federal Highway Administration (1995, 1997), in 1949 diesel fuel was approximately 1% of the total motor fuel used, and in 1995 it was about 18%. Over the same time, diesel fuel consumption in the United States increased from about 400 million gallons to 26 billion gallons per year, an increase by a factor of more than 60 (Figures 2-16 and 2-17).

The chemistry and properties of diesel fuel have a direct effect on emissions of regulated pollutants from diesel engines. Researchers have studied the NOx and DPM effect of sulfur content, total aromatic content, polyaromatic content, fuel density, oxygenate content, cetane number, and T90 on emissions of regulated pollutants. T90 is the 90% distillation point temperature. An increase in T90 has been observed to cause an increase in DPM emissions (Cunningham et al., 1990; Sienicki et al., 1990). Cetane number is a measure of the ignition quality, or ignition delay time, of a diesel fuel. The percent of cetane (less commonly referred to as hexadecane, $C_{16}H_{34}$) by volume in a blend with alpha-methylnaphthalene ($C_{10}H_7CH_3$) defines the cetane number that provides the same ignition delay time as the fuel in use.

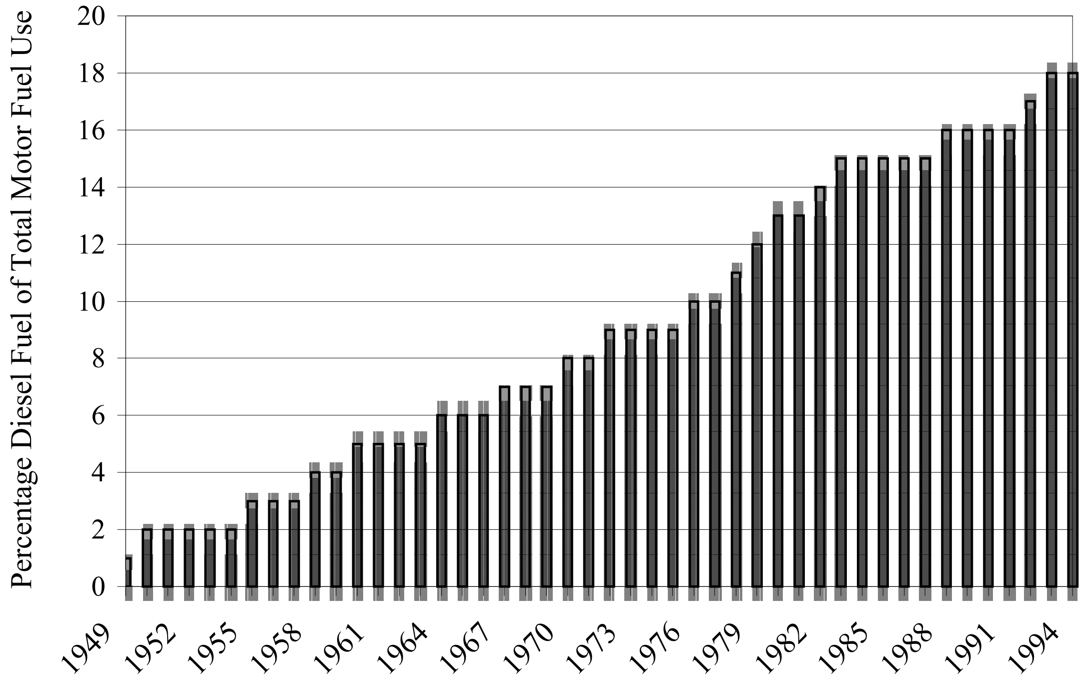


Figure 2-16. Percentage of total motor fuel use that is on-road diesel fuel since 1949.

Source: Federal Highway Administration, 1995.

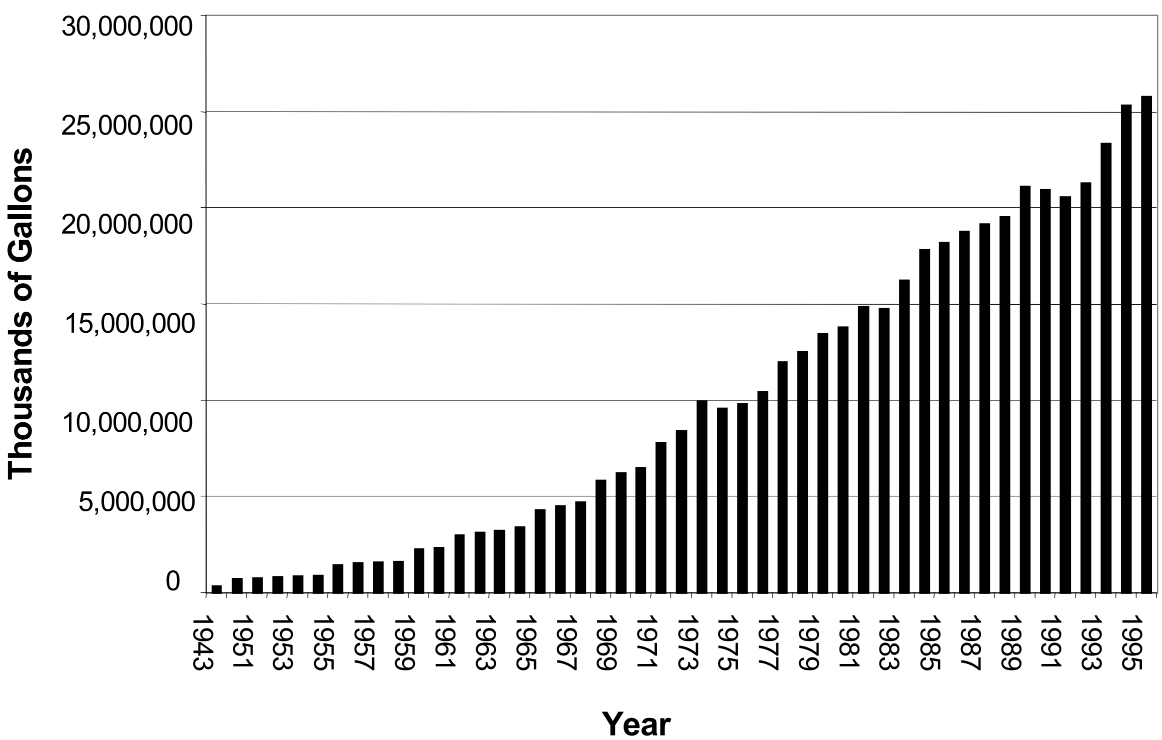


Figure 2-17. On-highway diesel fuel consumption since 1943, values in thousands of gallons.

Source: Federal Highway Administration, 1995.

Before 1993, diesel fuel sulfur levels were not federally regulated in the United States, although the State of California had such regulations. Industry practices that were in place (e.g., the ASTMD 975 specification for No. 2 oils) limited sulfur to 0.5%. During the years 1960 to 1986, fuel sulfur content showed no chronological increasing or decreasing trends and ranged from 0.23 to 0.28 wt% (NIPER, 1986). A maximum allowable on-road diesel fuel sulfur content in the United States was established at 0.05 mass % in 1993, in advance of the 1994 0.10 g/bhp-hr PM standard for HD on-highway trucks. Nationally, on-road fuels averaged 0.032% sulfur in 1994 while nonroad fuels averaged 10-fold the sulfur level of on-road fuel, or 0.32% (Dickson and Sturm, 1994). The reduction in diesel fuel sulfur reduced total DPM mass emissions through reduction of sulfate PM (primarily present as sulfuric acid).

Considerably higher sulfuric acid PM emissions are possible with DE aftertreatment systems containing precious metals (oxidation catalysts, lean NO_x catalysts, catalyzed DPM traps). At temperatures over 350 °C to 500 °C (depending on device), SO_2 in the exhaust can be oxidized to sulfuric acid (McClure et al., 1992; McDonald et al., 1995; Wall, 1998). Sulfur content remains at unregulated levels for off-highway diesel fuels and fuels used in railroad locomotives.

The chemical makeup of diesel fuel has changed over time, in part because of new regulations and in part because of technological developments in refinery processes. EPA currently regulates on-road diesel fuel and requires the cetane index (a surrogate for actual measurements of cetane number) to be greater than or equal to 40, or the maximum aromatic content to be 35% or less (CFR 40:80.29). EPA recently finalized a regulation that will limit the sulfur content of on-road diesel fuel to 15 ppm starting in 2006 (U.S. EPA, 2000b). California has placed additional restrictions on the aromatic content of diesel fuel (California Code of Regulations, Title 13, Sections 2281-2282) and requires a minimum cetane number of 50 and an aromatics cap of 10% by volume, with some exceptions for small refiners and alternative formulations as long as equivalent emissions are demonstrated. Diesel fuel from larger refiners is limited to 10% aromatic content, and for three small refiners (a small fraction of diesel sales) to 20% aromatic content. The refiners can also certify a fuel with higher aromatic content as being emissions-equivalent to the 10% (or 20%) aromatic content fuels by performing a 7-day engine dynamometer emissions test. This method is chosen by most, if not all, California refiners, and so a typical California diesel fuel has an aromatic content above 20%. Emissions equivalence has been obtained through use of cetane enhancers, oxygenates, and other proprietary additives. Nonroad diesel fuel is not regulated, and consequently, cetane index, aromatic content, and sulfur content vary widely with nominal values for cetane number around 43, 31% aromatics, and sulfur approximately 3,000 ppm.

The average cetane number of U.S. diesel fuel declined steadily from 50.0 to 45.1, or about 0.2% per year, from 1960 to 1986 (NIPER, 1986). The decline in cetane number was likely accompanied by an increase in aromatic content and density (Lee et al., 1998). A number of EPA-sponsored studies refer to fuels with nominally 22% aromatics content as "national average fuel" during the 1970s (Hare, 1977; Springer, 1979), whereas by the 1980s a so-called national average fuel contained 30% aromatics (Martin, 1981a,b). Shelton (1979, 1977) has reported a trend of increasing T90 from 1960 through the late 1970s, which is consistent with increasing density, aromatic content, and polyaromatic content. Unfortunately, aromatic content was not commonly measured before the 1980s.

Studies measuring the emissions impact of changes in cetane number and aromatic content for roughly 1990 model year engine technology find that increasing the aromatic content from 20% to 30%, with an accompanying decrease in the cetane number from 50 to 44, results in a 2% to 5% increase in NO_x and a 5% to 10% increase in total DPM (McCarthy et al., 1992; Ullman et al., 1990; Sienicki et al., 1990; Graboski and McCormick, 1996). These ranges may be reasonable upper bounds for the effect of changes in fuel quality on NO_x and DPM emissions during the years 1960–1990.

In the northern United States during wintertime, on-road No. 2 diesel may contain some percentage of No. 1 diesel to improve cold-flow properties. Discussions with refiners indicate that a typical wintertime No. 1 diesel blending level is 15 volume %; however, this number must be taken as a rough estimate. Blending of No. 1 may lower the aromatic content, resulting in improved emissions performance. Nationally, on-highway No. 1 fuels averaged 17% aromatic content in 1994 (Dickson and Sturm, 1994). Thus, there may also be some small but perceptible seasonal changes in emissions from diesel engines.

Railroad-grade diesel fuel is currently unregulated. Typically, railroad-grade diesel fuel is a blend of approximately 10% on-road fuel and 90% nonroad diesel fuel. There are no recent data on the composition of railroad-grade diesel fuel. Somewhat dated diesel fuel oil surveys (Shelton, 1979) reported that railroad-grade diesels had lower cetane number, higher density, and higher T90. Also, the cetane index for these fuels can be as much as 9 cetane units higher than the cetane number, an indication of a high aromatic content in railroad-grade diesels.

Fuel chemistry is also important for emission of particle-associated PAHs. In studies performed over more than a decade, Williams and Andrews of the University of Leeds have shown that the solvent-extractable PAHs from diesel particulate originate almost entirely in the fuel (Williams et al., 1987; Andrews et al., 1998; Hsiao-Hsuan et al., 2000). The PAH molecules are relatively refractory, so a significant fraction survive the combustion process and condense onto the DPM. These studies have been confirmed by other research groups (Crebelli et al., 1995; Tancell et al., 1995). There is a consensus among these researchers that pyrosynthesis of PAHs occurs only at the highest temperature operating conditions in a diesel engine. Under these conditions, most of the DPM and other pyrolysis products are ultimately burned before exiting the cylinder. These results indicate that emissions of PAHs are more a function of the PAH content of the fuel than of engine technology. For a given refinery and crude oil, diesel fuel PAH correlates with total aromatic content and T90. Representative data on aromatic content for diesel fuels in the United States do not appear to be available before the mid-1980s. However, the decreasing trend in cetane number, increasing trend in T90, and the increasing use of light cycle oil from catalytic cracking beginning in the late 1950s suggest that diesel PAH content has increased over the past 40 years. Because PAHs have been implicated as one potential contributing component to the observed toxicity of DE, changes in PAH content of diesel fuel over time, as well as differences between diesel fuels used in different applications (on-road, nonroad, locomotive), may influence the hazard observed in exposed populations from different occupations. However, such a relationship would be difficult to differentiate in an epidemiologic study because there are several other properties of DE that may be contributing to the observed toxicity. Historical trends in PAH-measured emissions are discussed in Section 2.2.8.2.

2.2.5. Chronological Assessment of Emission Factors

2.2.5.1. *On-Road Vehicles*

Numerous studies have been conducted on emissions from in-use on-road HD diesel vehicles. HD vehicles are defined as having a rated gross vehicle weight (GVWR) of greater than 8,500 lb, and most over-the-road trucks have a GVWR of 80,000 lb. Emissions of regulated pollutants from these studies have been reviewed (Yanowitz et al., 2000); the review findings, which encompass vehicles from model years 1976 to 1998, are summarized below. In addition, a large amount of engine dynamometer data on HD diesel engines have been published since the mid-1970s. These data are used below to confirm and expand upon the findings from in-use vehicle testing.

Figure 2-18 shows chassis dynamometer data for more than 200 different vehicles (approximately one-half of which are transit buses), reported in 20 different published studies, as well as a large amount of additional data collected by West Virginia University (Yanowitz et al., 1999; Warner-Selph and Dietzmann, 1984; Dietzmann et al., 1980; Graboski et al., 1998a,b; McCormick et al., 1999; Clark et al., 1995, 1997; Bata et al., 1992; Brown and Rideout, 1996, Brown et al., 1997; Dunlap et al., 1993; Ferguson et al., 1992; Gautam et al., 1992; Katragadda

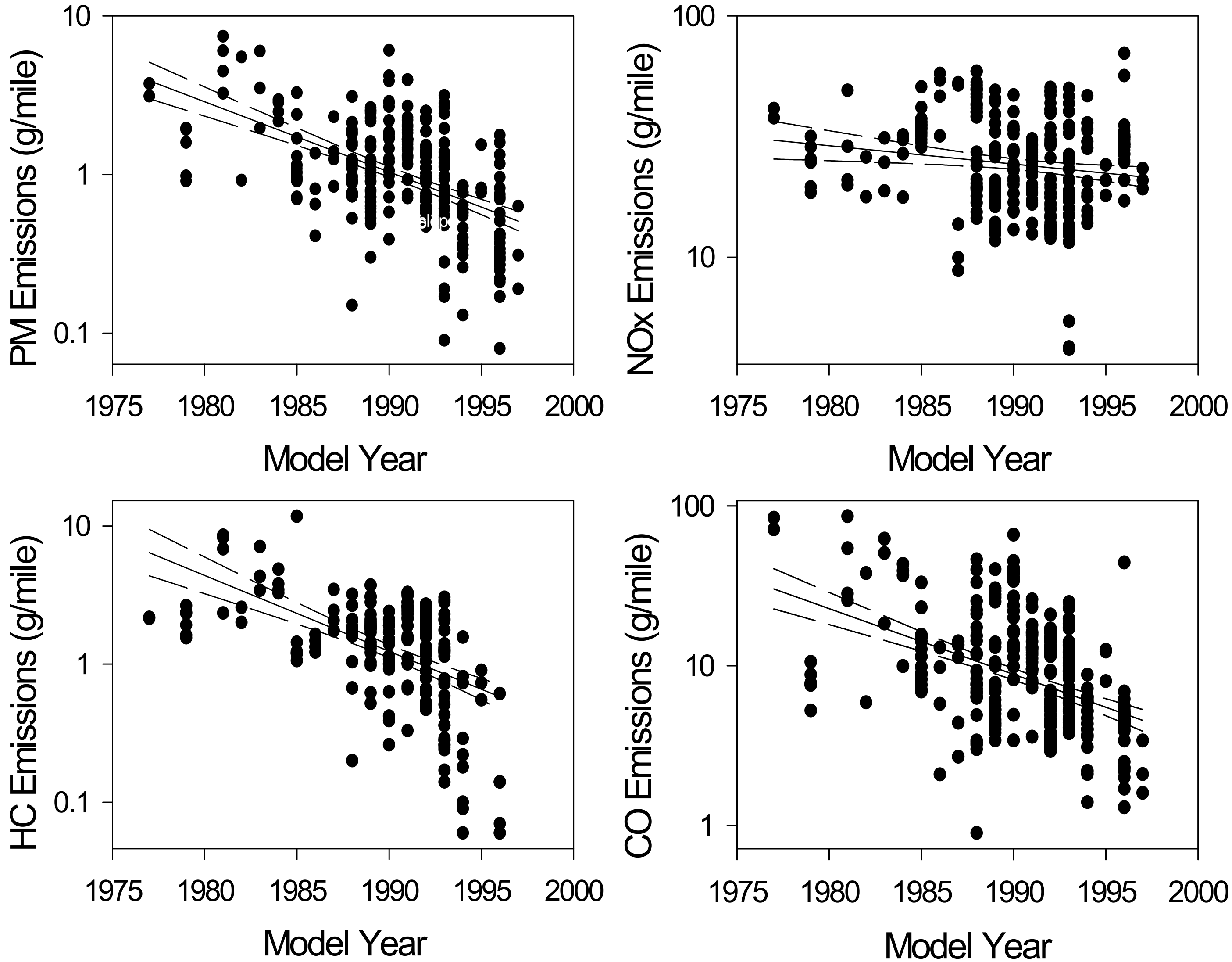


Figure 2-18. Model year trends in PM, NO_x, HC, and CO emissions from HD diesel vehicles (g/mile).

Source: Yanowitz et al., 2000.

et al., 1993; Rideout et al., 1994; Wang et al., 1993, 1994; Williams et al., 1989; Whitfield and Harris, 1998; West Virginia University data available on the World Wide Web at www.afdc.nrel.gov). The results from vehicles tested more than once using the same test cycle, and without any additional mileage accumulated between tests, are averaged and reported as one data point. Buses were tested using the Central Business District (CBD) cycle, while most trucks were tested using the Urban Dynamometer Driving Schedule (UDDS), also known as the Schedule 1d cycle. Some of the trucks were tested using the West Virginia 5-peak cycle, which generates considerably lower g/mi emissions than the CBD or UDDS (Yanowitz et al., 1999). Emissions results from vehicles tested under different test cycles or at different points in the engine's life cycle have been reported as separate data points. Note that all NO_x mass emissions data are reported as equivalent NO_2. Table 2-7 compares the make-up of the fleet of trucks that was tested with the in-use truck fleet according to the 1997 Vehicle Inventory and Use Survey (U.S. Bureau of the Census, 1999a). The tested fleet is mostly vehicles in the 33,000-60,000 lb range. Analysis of the tested fleet also shows that the model year distribution is skewed toward newer vehicles. The 1997 Vehicle Inventory and Use Survey indicates a flat distribution with roughly the same number of in-use vehicles for each of the model years in the decade preceding 1997. The 1992 Truck Inventory and Use Survey (U.S. Bureau of the Census, 1995) shows the same trend, as shown in Figure 2-1. Analysis of odometer mileage for the tested fleet shows that 45% of the vehicles had less than 50,000 miles at the time of testing. Only 10% of the vehicles had more than 250,000 miles. Although the mileage distribution of the in-use fleet is unknown, it seems unlikely to be as heavily weighted to low-mileage vehicles. Because of the relatively low mileage of most of the vehicles tested, deterioration of emissions may not be reflected in the

Table 2-7. Comparison of in-use truck fleet with truck fleet tested on chassis dynamometer, percent of total vehicles

Class	In-use trucks, 1995 census	Tested trucks
3	17.7	1
4 & 5	13.3	0
6 & 7	25.0	17
8A	20.9	52
8B	23.1	30

results. Yanowitz and co-workers (2000) report that average emissions of regulated pollutants for vehicles of the different classes listed in Table 2-7 are approximately the same. This is clearly a reflection of the small number of vehicles in the lighter weight classes for this dataset, but it also indicates no real difference in emissions for vehicles in Classes 6–8. The data are mainly for vehicles of 19,500 lb and greater GVWR (Classes 6 and 7 and heavier), and predominantly for vehicles of 33,000 lb and greater GVWR (Class 8 trucks and buses).

Figure 2-18 shows emissions trends in g/mi. Least-squares linear regressions and 95% confidence intervals are plotted on each graph and yield the following equations for predicting emissions trends (applicable to the years 1976–98):

$$\text{Log } NO_x \text{ (g/mile)} = (\text{Model year} * -0.008) + 16.519 \quad R^2 = 0.024 \tag{2-1}$$

$$\text{Log PM (g/mile)} = (\text{Model year} * -0.044) + 88.183 \quad R^2 = 0.28 \tag{2-2}$$

$$\text{Log HC (g/mile)} = (\text{Model year} * -0.055) + 109.39 \quad R^2 = 0.27 \tag{2-3}$$

$$\text{Log CO (g/mile)} = (\text{Model Year} * -0.041) + 82.876 \quad R^2 = 0.22 \tag{2-4}$$

As shown in Figure 2-18, changes in NO_x emissions have been relatively small, with an emission rate averaging about 26 g/mi. The data reported in Figure 2-18 are real-world, in-use emissions measurements and therefore more accurately reflect emission factors than engine test data during this period. There are two potential causes for the relative constancy of NO_x emissions as described by Figure 2-18. The first is emissions deterioration due to engine wear. Weaver and Klausmeier (1988) have shown that diesel engine deterioration results in lower NO_x emissions and higher DPM emissions, and this finding has recently been confirmed by McCormick and co-workers (2000). Wear of mechanical devices that limit smoke, fuel pumps, and fuel injectors alters the effective injection timing to decrease NO_x. Because deterioration is more a function of maintenance than vehicle age or mileage, deterioration introduces a wide range in NO_x emission factors measured in the chassis dynamometer studies. The lack of a decreasing trend in NO_x emissions can also be attributed to the use of illegal emissions control devices that bypassed the trucks' emission control systems under some driving conditions such as steady-state cruise. EPA has reached a settlement with the diesel engine manufacturers to discontinue use of these devices. The illegal devices produced low NO_x emissions on the transient test (HD FTP) but operated in a high-NO_x/high-fuel-economy mode in use under highway cruise conditions.

Figure 2-19 shows engine certification data for NO_x emissions reported in the many studies that have employed the transient test over the past 25 years. The engine testing data are also listed in Table 2-8. The data compiled in Figure 2-19 show a significant decline in NO_x

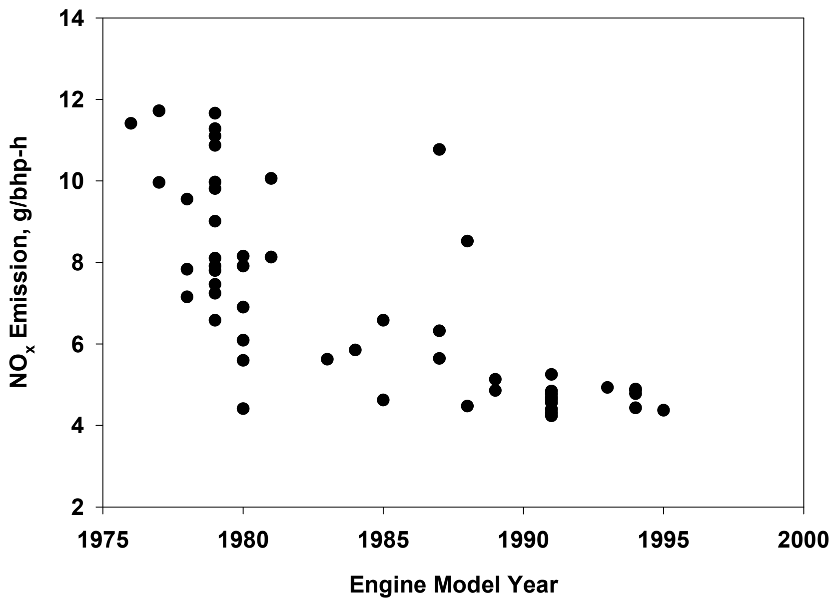


Figure 2-19. Diesel engine certification data for NO_x emissions as a function of model year.

Source: Data are from the transient test results provided in Table 2-8.

emissions, and all engines would appear to meet the regulatory standards for their year of manufacture because of the illegal emissions devices. From 1980 to 1997, the EPA emissions trends report (U.S. EPA, 1998a) predicted a decline in NO_x emissions from HD diesel vehicles because these data are based on engine test data. The emissions trend includes the growth in vehicle miles traveled over time as well as changes in emission factors. The more recent trends inventory (U.S. EPA, 2000a, discussed earlier) includes emission from the illegal emissions devices and accordingly demonstrates a slight increase in NO_x emissions from on-road HD diesel vehicles from 1990 to 1998.

DPM, CO, and THC emissions, although widely variable within any model year, have shown a pronounced declining trend (Figure 2-18). DPM emissions from chassis dynamometer tests decreased from an average of 3-4 g/mi in 1977 to an average of about 0.5 g/mi in 1997, suggesting a decrease in DPM emissions of a factor of about 6. Note that these data are for vehicles or engines tested on in-use or industry-average fuel at the time they were tested. Indications are that the observed decline in DPM is caused primarily by changes in engine

Table 2-8. Diesel engine emissions data from engine dynamometer tests

Reference	Engine[a]	Year	Test[b]	NO_x g/bhp-hr	PM g/bhp-hr	CO g/bhp-hr	THC g/bhp-hr	SOF g/bhp-hr	SOF Meth[c]	Total aldehyde, mg/bhp-hr	B[*a*]P (PAH) ug/bhp-hr[d]	1-NP (NPAH) ug/bhp-hr[e]
Hare, 1977	Cat 3208 (NA)	1976	SS	7.98	0.871	4.04	1.11	0.103	c-hexane		0.76	
	DDC 6V71 (blower)	1976	SS	10.24	1.92	6.55	0.71	0.937	c-hexane		0.24	
Springer, 1979	Mack ETAY(B)673A (DI, TC,AC)	1977	SS	6.613	0.61	1.588	0.476	0.098	Benz/cyc	65	2.23	
	Cat 3208 (EGR, NA)	1977	SS	3.747	2.21	6.200	1.163		Benz/cyc	161	1.72	
	Cat 3406 (DI, TC, AC)	1977	SS	9.79	0.35	2.34	0.35	0.063	Benz/cyc	73	0.15	
	Cat 3406 (DI, TC, AC, EGR)	1977	SS	5.49	0.93	4.81	0.17	0.181		80	0.08	
	Cat 3406 (IDI, TC, AC)	1977	SS	5.14	0.28	1.26	0.12	0.031	Benz/cyc	80	0.11	
	DB OM-352A (DI, TC, AC)	1977	SS	8.93	0.56			0.190	Benz/cyc	280	0.87	
	DB OM-352A (DI, NA)	1977	SS	7.46	0.99			0.287	Benz/cyc	280	1.07	
Perez, 1980	Cat (DI, NA)	1978	SS	8.12	0.77	5.92	0.77	0.19	DCM		1.08	
	Cat (DI, EGR)	1978	SS	5.16	1.21	5.37	0.57	0.079	DCM		4.34	
	Cat (DI, TC, AC)	1978	SS	7.66	0.33	2.20	0.27	0.037	DCM		0.34	
Martin, 1981a	Cat 3208	1978	T	7.83	1.06							
	Cummins NTC350	1976	T	11.41	0.81							
	DDC 6V92T (2S)	1978	T	9.55	0.72							
	Cummins NTCC350	1979	T	6.58	0.52							
	DDC 8V71N (2S)	1978	T	7.15	0.92							
	DDC 6V92TA (2S)	1979	T	7.80	0.65							
	IH DTI466B	1979	T	7.46	0.48							
	Mack ETAY(B)673A	1979	T	9.01	0.77							
	Mack ETSX676-01	1980	T	6.90	0.85							
	Cummins VTB-903	1979	T	8.10	0.53							
	Cat 3406	1979	T	11.28	0.69							
	Cat 3406PCTA	1979	T	7.24	0.49							
	Cummins BigCam NTC350	1979	T	9.97	0.54							
	IH DT466	1979	T	7.91	0.71							
	DDC 6V92TA (2S)	1979	T	11.66	0.73							
	DDC 8V71TA (2S)	1979	T	9.81	0.51							
	Cummins NTC290	1979	T	11.10	0.78							
	Cummins NH-250	1979	T	10.87	0.97							
Martin, 1981b	Cummins VTB-903	1980	T	5.59	0.67	2.0	2.23	0.228	DCM			
	DDC 8V71TA (2S)	1980	T	7.91	0.44	2.28	0.73	0.176	DCM			
	IH DTI466B	1980	T	4.41	0.62	2.35	0.87	0.186	DCM			
Ullman et al., 1984	DDAD 6V-71 (2S)	1980	T	6.09	0.56	3.86	1.42	0.298	DCM	23	--	
Martin, 1984	Cummins NTC300	1981	T	8.13	0.45	2.70	1.36	--				
Barry et al., 1985	Cat 3406B	1985	T	6.58	0.48	2.1	0.5	0.061	DCM	70	1	
	DDC 8V-92 TA (2S)	1980	T	8.15	0.45	2.61	0.53	--				

2-34

Table 2-8. Diesel engine emissions data from engine dynamometer tests (continued)

Reference	Engine[a]	Year	Test[b]	NO_x g/bhp-hr	PM g/bhp-hr	CO g/bhp-hr	THC g/bhp-hr	SOF g/bhp-hr	SOF Meth[c]	Total aldehyde, mg/bhp-hr	B[*a*]P (PAH) ug/bhp-hr[d]	1-NP (NPAH) ug/bhp-hr[e]
			SS	6.64	0.36	1.83	0.38	0.0255				
Enga et al., 1985	DDC 8V-71 TAC (2S)	1984	T	5.85	1.26	2.99	1.48	--		--	--	
Baines, 1986	Cummins NTCC-400	1985	T	4.62	0.55	3.21	0.53					
Wachter, 1990	Iveco 8460	1991	T		0.22			0.0957	?			
McCarthy et al., 1992	Navistar DTA466 ES210	1993	T	4.93	0.082	1.3	0.28	0.0237	SFE			
Perez and Williams, 1989	Engine 1	1982	T		0.93			0.179	DCM		26	0.83
	Engine 2	1982	T		0.86			0.145	DCM		5.8	--
	Engine 3	1982	T		0.59			0.185	DCM		4.9	0.89
	Engine 4	1982	T		0.96			0.325	DCM		26	1.2
	Engine 5	1982	T		1.06			0.076	DCM		5.3	--
	Engine 6	1982	T		0.88			0.344	DCM			
Needham et al., 1989	Average of 16 engines	1988	T		0.37			0.12	DCM			
	Average of 3 engines	1991	T		0.24			0.10	DCM			
Kreso et al., 1998	Cummins L10-300	1988	SS	5.15	0.103		0.26	0.030	DCM			
	Cummins L10-310	1991	SS	4.70	0.035		0.067	0.022	DCM			
	Cummins M11-330E	1995	SS	3.82	0.037		0.16	0.016	DCM			
Bagley et al., 1998	Cat 3304 (IDI, NA) non-road	1983	SS		0.56			0.319	Benz/cyc		1.5(133)	2.2
Graboski, 1998b (and references therein)	DDC 6V-71N-77 (MUI, 2S)	1977	T	9.96	0.83	3.59	2.01	0.729	DCM			
	DDC 6V-92TA-91 (DDECII)	1991	T	4.23	0.197	1.51	0.72	0.0788	?			
	DDC-6V-92TA-87 (2S)	1987	T	10.77	0.59	0.71	--	--				
	DDC-6V92TA-83 (MUI, 2S)	1983	T	5.62	0.265	1.19	0.435	0.133	DCM			
	DDC 6V-92TA -88 (DDECII, 2S)	1988	T	8.52	0.2	1.6	0.6	0.116	Tol/EtOH			
	DDC 6V-92TA-91 (DDECII, 2S)	1991	T	4.4	0.276	1.65	0.42	0.07	Tol/EtOH			
	DDC 6V-71N-77 (MUI, 2S)	1977	T	11.72	0.282	3.18	0.86	0.212	DCM			
	DDC 6V-92TA-81/89 (MUI, 2S)	1981	T	10.06	0.268	2.16	0.42	0.144	DCM	--	--	
	DDC 6V-92TA-91 (DDECII, 2S)	1991	T	4.84	0.227	1.51	0.44	--		--	--	
	DDC 6V-92TA-89 (DDECII, 2S)	1989	T	4.855	0.338	2.499	0.526	--		--	--	
	DDC Series 60-91 DDECII	1991	T	4.635	0.300	4.458	0.164	--				
	Cummins L-10-87 (MUI)	1987	T	5.64	0.309	2.33	0.89	--				
	DDC Series 60-91 (DDECII)	1991	T	4.68	0.220	2.26	0.08	0.066	DCM			
	Cummins N-14-87 (MUI)	1987	T	6.32	0.369	2.20	0.58	0.100	?			
	DDC Series 60-89 (DDECII)	1989	T	5.128	0.252	4.008	0.154	--				--
	DDC Series 60-91 (DDECII)	1991	T	4.303	0.182	2.004	0.392	0.061	Tol/EtOH	--	--	
	Cummins B5.9	1995	T	4.37	0.106	1.47	0.30	0.05	DCM		0.24((18.5)	
Spreen et al., 1995	Navistar DTA466	1994	T	4.779	0.090	0.989	0.181	0.035	DCM	26		
Norbeck et al., 1998b	Cummins L10	1991	T	4.77	0.224	2.26	0.53	--		80	20(1725)	1.95(4.92)
	DDC Series 60	1994	T	4.89	0.112	1.402	0.065	0.043	DCM	17		
Sienicki et al., 1990	Navistar DTA466	1991	T	5.25	0.22	--	0.23	0.05	DCM			

Table 2-8. Diesel engine emissions data from engine dynamometer tests (continued)

Reference	Engine[a]	Year	Test[b]	NO_x g/bhp-hr	PM g/bhp-hr	CO g/bhp-hr	THC g/bhp-hr	SOF g/bhp-hr	SOF Meth[c]	Total aldehyde, mg/bhp-hr	B[*a*]P (PAH) ug/bhp-hr[d]	1-NP (NPAH) ug/bhp-hr[e]
Ullman et al., 1990	DDC Series 60	1991	T	4.552	0.188	2.102	0.508	--				
Kado et al., 1998	Cat 3406E	1997	T						DCM		0.07(30)	0.34
Ullman, 1988	Cummins NTCC400	1988	T	4.47	0.42	2.22	0.53					
Mitchell et al., 1994	DDC Series 60	1994	T	4.43	0.111	2.17	0.22	0.021	DCM	34	(141)	0.04(0.12)
	Navistar DTA466	1994	T	4.86	0.099	1.10	0.34	0.046	DCM	56	0.11(242)	0.3(0.6)
Tanaka et al., 1998	Unknown	1994	SS	4.934	0.143	0.807	0.352	0.036	DCM		.076	
Rantanen et al., 1993	Scania	1990	SS	9.30	0.157			0.031	DCM			
	Valmet	1990	SS	8.67	0.157							
	Volvo	1990	SS	9.87	0.262							
	Volvo	1995	SS	4.56	0.135							

[a]NA=naturally aspirated. TC=turbocharged (engines not designated as NA or TC are turbocharged). AC=aftercooled. DI=direct injection. IDI=indirect injection. EGR=exhaust gas recirculation. 2S=two-stroke (engines not designated as 2S are four-stroke). MUI=mechanical unit injector (not electronically controlled). DDEC=Detroit Diesel Corporation's engine control module (electronic control).
[b]SS=various single or multimode steady-state tests. T=heavy-duty FTP (transient test).
[c]SOF extraction method. SFE=Supercritical fluid extraction. All others by Soxhlet extraction using the indicated solvents (? for unreported). DCM=dichloromethane. Tol/EtOH=toluene/ethanol mixture. Benz/cyc=benzene/cyclohexane mixture. C-hexane=cyclohexane.
[d]Number in parentheses is the total PAH emission obtained by summing emissions of all PAHs reported.
[e]Number in parentheses is the total NPAH emission obtained by summing emissions of all NPAHs reported.

technology that often result from emission standards, as well as by the lowering of on-road diesel fuel sulfur content in 1993.

As the discussion above indicates, there is a reasonable amount of data upon which to base emission factor estimates for late 1970s and later HD vehicles. However, very little transient test data are available on engines earlier than the mid-1970s. The limited data available from six pre-1976 vehicles tested using the transient cycle suggests that PM emission rates ranged from 1.6 g/mi to 9.0 g/mi, which is a substantially greater range than in post-1976 engines (Fritz et al., 2001).

Although a substantial decreasing trend in DPM emissions from in-use chassis dynomometer testing and engine testing (Figure 2-20) is evident, these data reflect a wide range in emission factors within any given model year. For example, emission factors for model year 1996 range from less than 0.1 g/mi to more than 1 g/mi (Yanowitz et al., 2000; Graboski et al., 1998b). The high variability in DPM emissions measured in the chassis dynamometer tests is observed because of several factors, including differences in measurement methods and test conditions at the various testing facilities, deterioration, and engine-to-engine variation. Although there can be excellent agreement between chassis dynamometer testing facilities (Graboski et al., 1998a), there is no standard HD chassis dynamometer Federal test procedure, and no detailed procedures for such testing are described in any authoritative source such as the Code of Federal Regulations, which does contain such procedures for engine dynamometer

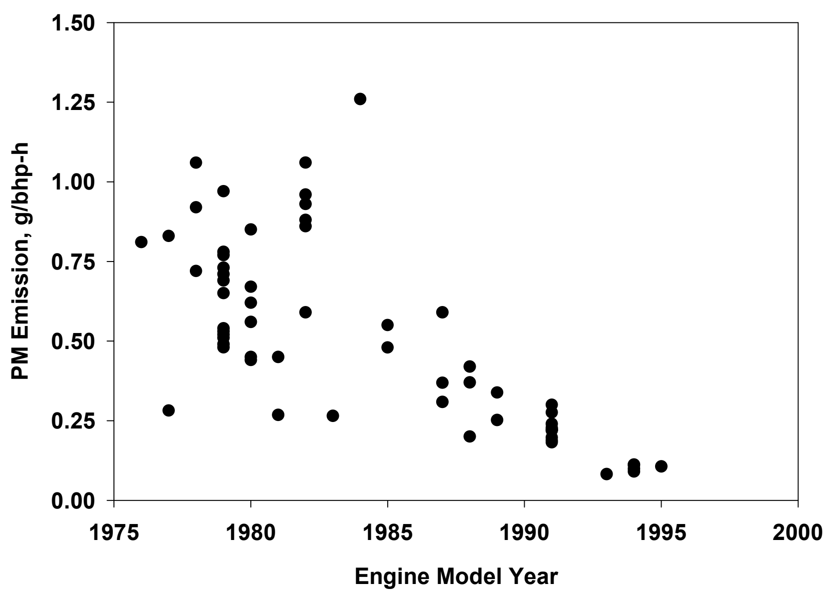


Figure 2-20. Diesel engine certification data for PM emissions as a function of model year.

Source: Data are from the transient test results provided in Table 2-8.

testing used for EPA emission regulations. Therefore, each facility has developed its own approach to HD testing. Clark et al. (1999) report that the test cycle can have a substantial effect on DPM emissions, with higher DPM emissions reported from test cycles that incorporate full-power accelerations. Test cycles incorporating full-power accelerations reflect urban HD vehicle driving for several types of vehicles (garbage trucks, buses) operating in urban areas. Clark et al. (1999) also report that aggressive acceleration produces higher DPM emission rates than does conservative acceleration, and Clark and co-workers suggest that real in-use driving is more likely to mimic aggressive acceleration. Although figures are currently unquantified, it is generally believed that the majority of DPM is generated under transient conditions such as heavy acceleration.

Weaver and Klausmeier (1988) have examined potential causes and frequency of DPM emissions deterioration for in-use HD diesel vehicles. Potential causes include manufacturing defects and malfunctions such as retarded timing, fuel injector malfunction, smoke-limiting mechanism problems, clogged air filter, wrong or worn turbocharger, clogged intercooler, engine mechanical failure, excess oil consumption, and electronics that have been tampered with or have failed. The recent report by McCormick and co-workers (2000) indicates that many of these malfunctions can have very large effects on DPM emissions, resulting in DPM increases of typically 50% to 100%. Although Yanowitz and co-workers (1999) found that DPM emissions were positively correlated with odometer mileage for a fleet of 21 vehicles, it is more likely that the vehicle state of maintenance will be more important than mileage for determining the degree of emissions deterioration. In fact, in a similar analysis performed on the chassis dynamometer results included in the review of Yanowitz et al. (2000), DPM emissions could not be correlated with odometer mileage. Differences in testing methods between various facilities as well as varying states of maintenance for vehicles of the same mileage and model year probably account for this lack of correlation.

It is difficult, given current information, to quantitatively assess the contribution of high-emitting or smoking diesel vehicles to ambient DPM. Emission models used to prepare diesel particulate emission inventories do not account for deterioration. The relative contribution of high-emitting diesel vehicles to the total mass and overall chemical composition of diesel particulates is being quantified. Some studies report numerous smoking diesel trucks. A study of the smoke opacity-based inspection and maintenance program in California found failure rates of 20% and higher, suggesting that high-emitting vehicles are not uncommon (CARB/EEAI, 1997). In the Northeast, smoke opacity testing conducted on 781 HD trucks found that 15% of the vehicles failed the smoke standard (40% opacity for 1991 and newer HD diesel vehicles and 50% opacity for pre-1991 HD diesel vehicles) (Cooper, 1999). Although the correlation between smoke and particulate emissions tends to be qualitative or semiquantitative (discussed below), there is a good correlation between opacity and EC concentrations, and it is expected that high-emitting diesel vehicles may be an important part of the DPM emission inventory.

Others have attempted to determine if the effects of deterioration could be detected for in-use vehicles. In a study of 21 vehicles (Yanowitz et al., 1999), a linear multivariate regression analysis found that DPM emissions were positively correlated with odometer mileage (several other correlation factors were also identified, including model year). A similar analysis performed on the chassis dynamometer results included in the review of Yanowitz et al. (2000) found that DPM emissions could not be correlated with odometer mileage, probably because of differences in testing methods between the various facilities.

Other approaches for measuring emissions from in-use on-road diesel vehicles include tunnel tests and remote sensing, the latter of which measures gaseous, but not DPM, emissions. The literature reports of those studies are summarized in Tables 2-9 and 2-10. Several tunnel test studies have reported DPM emission factors (Pierson and Brachaczek, 1976; Japar et al., 1984; Pierson et al., 1983; Kirchstetter et al., 1999; Gertler et al., 1996, 1999).

The method for determining emission rates for vehicles traveling through a tunnel is explained in detail by Pierson et al. (1996). Briefly, the emissions of a species are determined by measuring the concentration of a pollutant entering and leaving a tunnel along with knowledge of the cross-section of the tunnel and measurements of the wind flux at the inlet and outlet of the tunnel. The emission rate is calculated by dividing the mass of the pollutant by the number of vehicles that passed through the tunnel and the length of the tunnel. The diesel and gasoline vehicle contributions to the total emission of the pollutant are separated by a simple regression analysis where the intercepts (100% HD and 100% LD) are the diesel and gasoline emission rates, respectively.

Emission factors from tunnel studies provide a snapshot of real-world emissions under driving conditions experienced in the tunnel and reflect emission factors representative of the mix of in-use vehicles and the atmospheric dilution and short-term transformation processes of DE. Emission factors derived from tunnel studies are often used as one source of information to study the impact of improved technology and fleet turnover on emissions because they allow random sampling of large numbers of vehicles, including a range of ages and maintenance conditions. However, tunnel studies are limited in that they represent driving conditions on a single roadway passing through a tunnel and represent mostly steady-state driving conditions, whereas most DPM is generated during transient modes of operation; also, tunnel studies do not include cold-start operations. Both of these factors need to be assessed to understand emission rates for DPM to which people are exposed (U.S. EPA, 1992, 1995). DPM emission factors from in-use fleets derived from tunnel studies in the 1970s and 1980s compared with the 1990s

Table 2-9. HD diesel emissions results from tunnel tests (adapted from Yanowitz et al., 1999)

Test	Tunnel location, year of study	Fuel efficiency (mi/gal)	NO_x[a] (g/mi)	NMHC (g/mi)	CO (g/mi)	DPM (g/mi)	CO_2 (g/mi)	NO_x[a] (g/gal)	NMHC (g/gal)	CO (g/gal)	DPM (g/gal)
Pierson and	Allegheny, 1974	5.42[b]				.90-1.80					4.9-9.8
Brachaczeck, 1983	Allegheny, 1975					1.75 ± 0.19					9.49±1.03
	Allegheny, 1976					1.5 ± 0.10					8.1 ± 0.54
	Allegheny, 1976					1.4 ± 0.07					7.6 ± 0.4
	Tuscarora, 1976					1.3 ± 0.19					7.0 ± 1.0
	Tuscarora, 1976					1.39 ± 26					7.5 ± 1.40
	Allegheny, 1977					1.3 ± 0.08					7.0 ± 0.43
	Allegheny, 1979					1.2 ± 0.03					6.5 ± 0.16
	Allegheny, 1979					1.4 ± 0.04					7.6 ± 0.19
Rogak et al., 1998	Cassiar Tunnel, 1995, Vancouver	8.03[b]	19.50 ± 4.22	-0.16 ± 0.88	6.79 ± 11.78		1,280 ± 40	157 ± 34	-1 ± 7	55 ± 95	
Miguel et al., 1998	Caldecott Tunnel, 1996, San Francisco	5.42[c]	23.82 ± 4.17			1.67 ± 0.24[d]		129 ± 23			9.0 ± 1.3[d]
Weingartner et al., 1997b	Gubrist Tunnel, 1993, Zurich	5.60[e]				0.62 ± 0.02[f]					3.5 ± 0.1[f]
Pierson et al., 1996	Fort McHenry Tunnel, downhill, 1992, Baltimore	11.46[b]	9.66 ± 0.32	0.92 ± 0.21	6.8 ± 1.5		897 ± 48	111 ± 4	11 ± 2	78 ± 17	
Pierson et al., 1996	Fort McHenry Tunnel, uphill, 1992, Baltimore	5.42[b]	22.50 ± 1.00	2.55 ± 1.05	14.3 ± 5.5		1,897 ± 168	122 ± 5	14 ± 6	78 ± 30	
Pierson et al., 1996	Tuscarora Tunnel 1992, Pennsylvania	6.44[b]	19.46 ± 0.85	0.68 ± 0.20	6.03 ± 1.61		1,596 ± 78	125 ± 5	4 ± 1	39 ± 10	
Kirchstetter et al., 1999	Caldecott Tunnel, 1997, San Francisco	5.42[c]	23.82 ± 2.98			1.43 ± 0.12[g]		129 ± 16			7.7 ± 0.6[g]
Gertler,1999	Tuscarora Tunnel, 1999, Pennsylvania					0.29					

[a] NO_x reported as NO_2.
[b] Calculated from observed CO_2 emissions assuming fuel density 7.1 lb/gal and C is 87% of diesel fuel by weight.
[c] Since CO_2 emissions not available, fuel efficiency assumed to be the same as in slightly uphill tunnel (Fort McHenry).
[d] Reported as black carbon, assumed that 50% of total PM emissions are BC.
[e] Slope of tunnel unknown, so used average fuel efficiency for the United States.
[f] PM_3.
[g] $PM_{2.5}$.
[h] Uncertainty reported as ±1.0 standard deviation, except where literature report did not specify standard deviation; in those cases uncertainty listed as reported.

Table 2-10. Remote sensing results for HD vehicles

	Reference	Year study conducted	Emissions (g/gal)
NO_x	Jimenez et al., 1998	1997	150 [a,b,c]
	Cohen et al., 1997	1997	108 [a,b,c]
	Countess et al., 1999	1998	187 [a,b,c]
CO	Bishop et al., 1996	1992	59 [b]
	Cohen et al., 1997	1997	54 [b]
	Countess et al., 1999	1998	85 [b]
THC	Bishop et al., 1996	1992	0.002 HC/CO_2 mole ratio [d]
	Cohen et al., 1997	1997	0.00073 HC/CO_2 mole ratio [d]

[a]Remote sensing measures NO. The reported value was corrected to a NO_x (as NO_2) value by assuming 90% (mole fraction) of NO_x is NO.
[b]Emissions in g/gal calculated by assuming that fuel density is 7.1 lb/gal and C is 87% by weight of fuel.
[c]No humidity correction factor is included.
[d]In order to calculate emissions in g/gal, an average molecular weight is needed.

Source: Yanowitz et al., 1999.

suggest approximately a fivefold decrease in DPM mass emission factors over that time, with the most recent data from 1999 reporting an emission factor of 0.29 g/mi for the on-highway HD diesel fleet (Figure 2-21).

Emission factors vary substantially for the various tunnels, with NO_x emissions ranging from 9.7 to 23.8 g/mi in the 1990s, CO emissions ranging from 6 to 14 g/mi, and THC emissions ranging from 0.16 to 2.55 g/mi.

Remote sensing reports emission factors in terms of pollutant emissions per unit of fuel, not on a per-mile basis. Agreement between remote sensing and tunnel studies for NO_x emissions is reasonably good for the fleet as a whole, suggesting an average level for the fleet of about 130 g/gal, comparable to the average emissions factor measured in chassis dynamometer studies (remote sensing can measure emissions from an individual vehicle, whereas tunnel studies measure emissions from the fleet as a whole). Generally, chassis dynamometer tests and engine dynamometer test results are corrected for ambient humidity, in accordance with the Federal Test Procedure (CFR 40, Subpart N). Tunnel tests and remote sensing tests have typically not included corrections for humidity. Appropriate humidity corrections for NO_x and DPM can be greater than 20% and 10%, respectively (or a total difference of more than 45% and 20%, respectively, between low- and high-humidity areas), under normally occurring climatic conditions. Additionally, the remote sensing literature has not addressed how to determine the

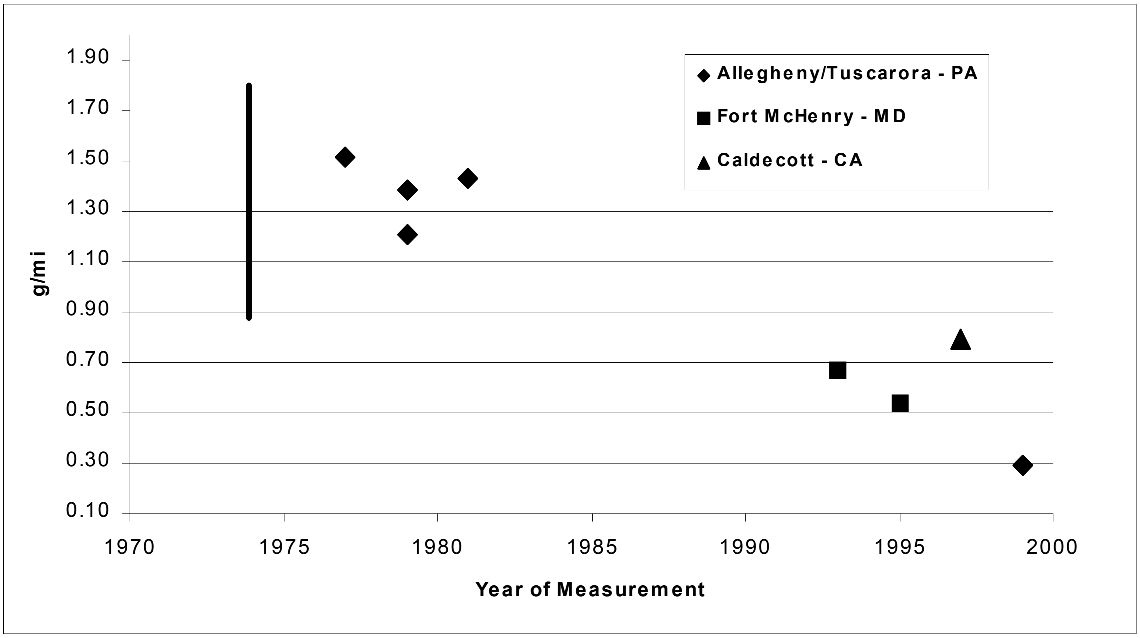


Figure 2-21. Emission factors from HD diesel vehicles from tunnel studies.

Source: Data from Pierson and Brachaczek, 1976; Japar et al., 1984; Pierson et al., 1996; Kirchstetter et al., 1999; Gertler et al., 1995, 1996; Gertler, 1999.

correct value for the NO/NO_x ratio, and there is reason to believe that this value may differ systematically from site to site, although almost all of the NO_x is NO as it leaves the vehicle.

In addition to the humidity correction discussed above, several factors must be taken into account when comparing DPM measurements from tunnel tests to chassis dynamometer measurements (Yanowitz et al., 2000): (1) Chassis testing measures only tailpipe emissions; tunnel tests can include emissions from other sources (tire wear, etc.), and (2) tunnel tests typically measure emissions under steady-speed freeway conditions, whereas most chassis dynamometer tests are measured on cycles that are more representative of stop-and-go urban driving conditions. This latter limitation also applies to remote sensing readings, which measure instantaneous emissions versus emissions over a representative driving cycle.

Because THC emissions for diesel vehicles are very low in total mass in comparison with gasoline vehicles, tunnel test results for THC have a high degree of uncertainty. A regression analysis to determine the contribution of the limited number of HD vehicles to THC emissions is unstable; small errors in the total measurements can change estimates substantially. Similarly, CO emissions are comparable to automobile emissions on a per-vehicle-mile basis, but because there are generally many more automobiles than HD diesels in tunnel tests, CO measurements from diesels may also have a high degree of uncertainty.

2.2.5.2. *Locomotives*

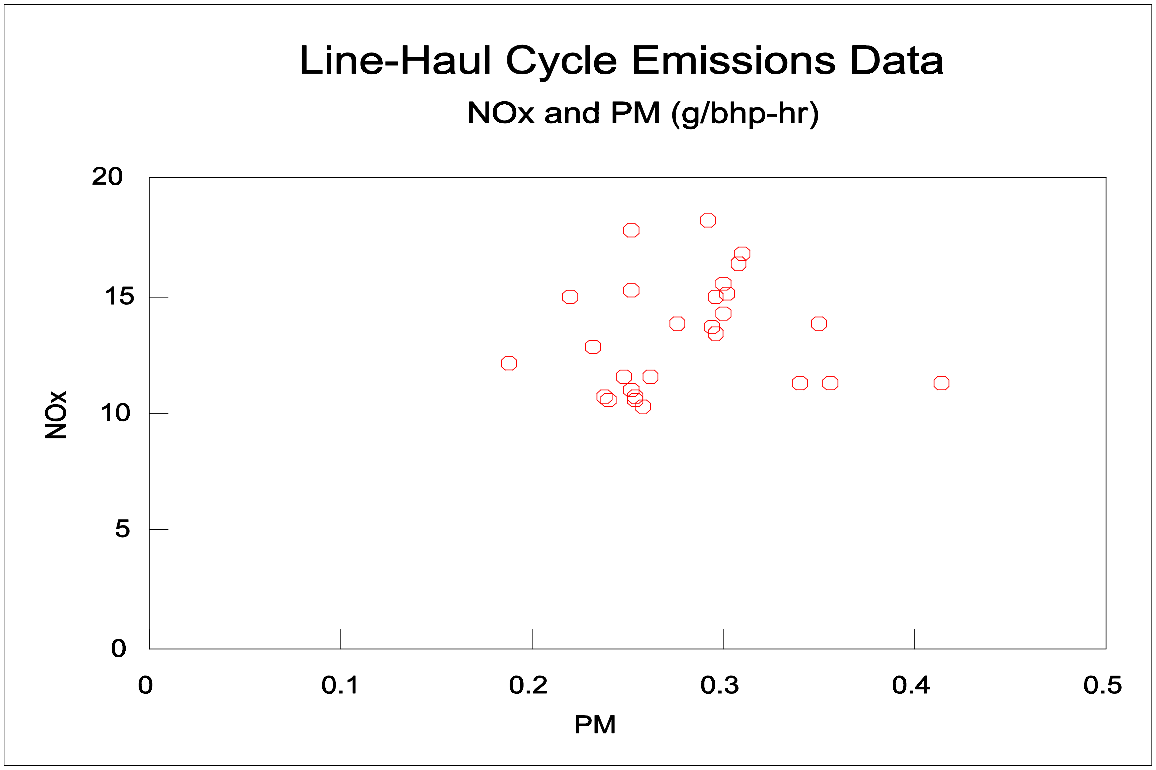
Locomotive engines generally range from 1,000 horsepower up to 6,000 horsepower. Similar to the much smaller truck diesel engines, the primary pollutants of concern are NO_x, DPM, CO, and HC. Unlike truck engines, most locomotive engines are not mechanically coupled to the drive wheels. Because of this decoupling, locomotive engines operate in specific steady-state modes rather than the continuous transient operation normal for trucks. Because the locomotive engines operate only at certain speeds and torques, the measurement of emissions is considerably more straightforward for locomotive engines than for truck engines. Emissions measurements made during the relatively brief transition periods from one throttle position to another indicate that transient effects are very short and thus could be neglected for the purposes of overall emissions estimates.

Emissions measurements are made at the various possible operating modes with the engine in the locomotive, and then weighting factors for typical time of operation at each throttle position are applied to estimate total emissions under one or more reasonable operating scenarios. In the studies included in this analysis, two scenarios were considered: line-haul (movement between cities or other widely separated points) and switching (the process of assembling and disassembling trains in a switchyard).

The Southwest Research Institute made emissions measurements for three different engines in locomotives in 1972 (Hare and Springer, 1972) and five more engines in locomotives using both low- and high-sulfur fuel in 1995 (Fritz, 1995). Two engine manufacturers (the Electro-Motive Division of GM, and GE Transportation Systems) tested eight different engine models and reported the results to EPA (U.S. EPA, 1998b). All available data on locomotives are summarized in the regulatory impact assessment and shown in Figure 2-22.

2.2.6. Engine Technology Description and Chronology

NO_x emissions, DPM emissions, and brake-specific fuel consumption (BSFC) are among the parameters that are typically considered during the development of a diesel engine. Many engine variables that decrease NO_x can also increase DPM and BSFC. One manifestation of the interplay among NO_x, DPM, and BSFC is that an increase in combustion temperatures will tend to increase NO formation. Higher temperatures will also often improve thermal efficiency, can improve BSFC, and can increase the rate of DPM oxidation, thus lowering DPM emissions. One example of this is the tradeoff of DPM emissions and BSFC versus NO_x emissions with fuel



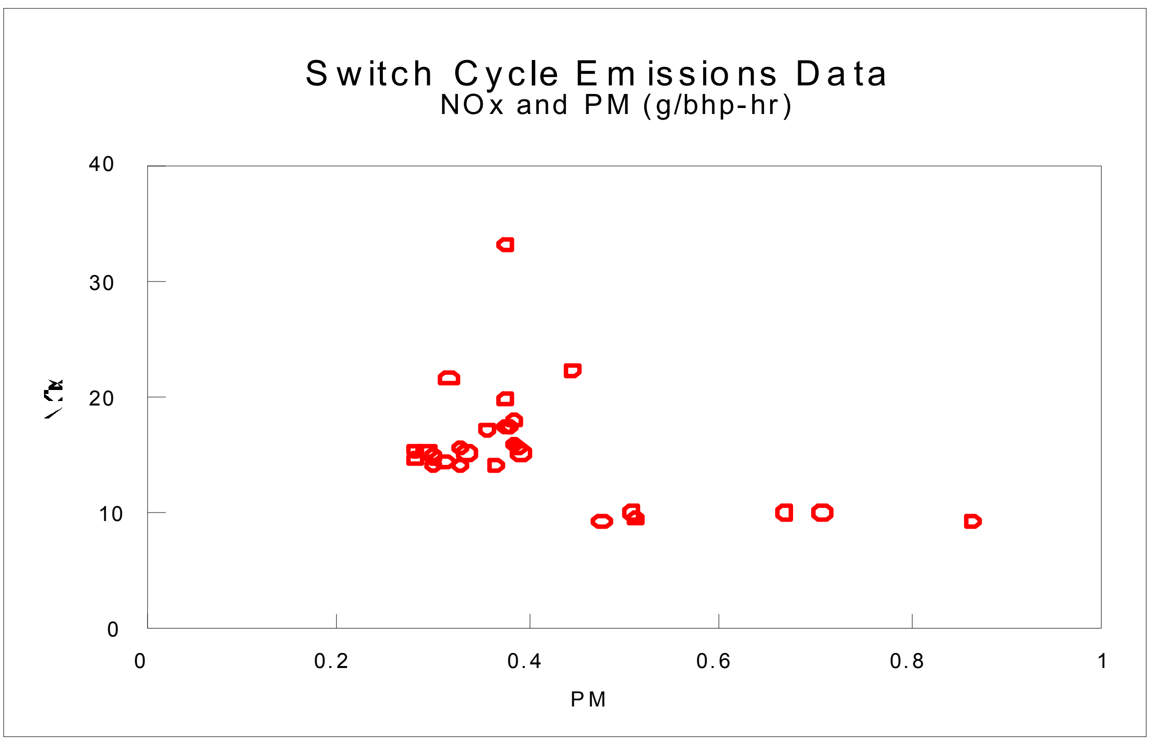


Figure 2-22. Line-haul and switch emissions data.

Source: U.S. EPA, 1998a.

injection timing. Many recent advances in reducing the emissions of diesel engines without aftertreatment are combinations of technologies that provide incremental improvements in the tradeoffs among these emissions and fuel consumption. The sum total, however, can be considerable reductions in regulated emissions within acceptable levels of fuel consumption.

The majority of current HD diesel truck engines certified for use in the United States utilize:

- A four-stroke cycle
- Direct-injection, high-pressure (1,200 bar to >2,000 bar) fuel injection systems with electronic control of injection timing and, in some cases, injection rate
- Centrally located multihole injection nozzles
- Three or four valves per cylinder
- Turbochargers
- In many cases, air-to-air aftercooling
- In some cases, the use of an oxidation catalyst.

These features have phased into use with HD truck engines because they offer a relatively good combination of fuel consumption, torque-rise, emissions, durability, and the ability to better "tune" the engines for specific types of applications. Fuel consumption, torque-rise, and drivability have been maintained or improved while emissions regulations have become more stringent. Many Class 8a and 8b diesel truck engines are now capable of 700,000 to 1,000,000 miles of driving before their first rebuild and can be rebuilt several times because of their heavy construction and the use of removable cylinder liners. These engines are expected to last longer and therefore have a useful life longer than the regulatory estimate of full useful life for HD engines (~1,000,000 miles) previously used by EPA (for 1980 engines that were driven less than 300,000 miles between rebuilds and were rebuilt up to three times). Current four-stroke locomotive engines use engine technology similar to on-highway diesel engines, except that electronic controls have only recently been introduced.

It is difficult to separate the components of current high-speed diesel engines for discussion of their individual effects on emissions. Most of the components interact in numerous ways that affect emissions, performance, and fuel consumption.

2.2.6.1. ***Indirect and Direct Injection High-Speed Diesel Engines***

Prior to the 1930s, diesel engine design was limited to relatively low-speed applications because sufficiently high-pressure fuel injection equipment was not available. With the advent of high-speed and higher pressure pump-line-nozzle systems, introduced by Robert Bosch in the

1930s, it became possible to inject the fuel directly into the cylinder for the first time, although indirect injection (IDI) diesel engines continued in use for many years. As diesels were introduced into the heavy truck fleet in the 1930s through the 1950s, both IDI and direct injection (DI) naturally aspirated variants were evident. A very low-cost rotary injection pump technology was introduced by Roosa-Master in the 1950s, reducing the cost of DI systems and allowing their introduction on smaller displacement, higher speed truck engines. After this time, only a small fraction of truck engines used an IDI system.

DI diesel engines have now all but replaced IDI diesel engines for HD on-highway applications.[2] IDI engines typically required much more complicated cylinder head designs but generally were capable of using less sophisticated, lower pressure injection systems with less expensive single-hole injection nozzles. IDI combustion systems are also more tolerant of lower grades of diesel fuel. Fuel injection systems are likely the single most expensive component of many diesel engines. Caterpillar continued producing both turbocharged and naturally aspirated IDI diesel engines for some on-highway applications into the 1980s. Caterpillar and Deutz still produce engines of this type, primarily for use in underground mining applications. IDI combustion systems are still used in many small-displacement (<0.5 L/cylinder), very high-speed (>3,000 rpm rated speed) diesel engines for small nonroad equipment (small imported tractors, skid-steer loaders), auxiliary engines, and small generator sets, and they were prevalent in diesel automotive engines in the 1980s; IDI designs continue to be used in automotive diesel engines.

IDI engines have practically no premixed burn combustion and thus are often quieter and have somewhat lower NO_x emissions than DI engines. Electronic controls, high-pressure injection (e.g., GM 6.5), and four-valve/cylinder designs (e.g., the six-cylinder Daimler LD engine) can be equally applied to IDI diesel engines as in DI, but they negate advantages in cost over DI engines. DI diesel engines of the same power output consume 15% to 20% less fuel than IDI engines (Heywood, 1988). Considering the sensitivity of the HD truck market to fuel costs, this factor alone accounts for the demise of IDI diesel engines in these types of applications. Throttling and convective heat transfer through the chamber-connecting orifice, and heat rejection from the increased surface area of IDI combustion systems, decrease their efficiency and can cause cold-start difficulties when compared to DI designs. Most IDI diesel engine designs require considerably higher than optimum compression ratios (from an efficiency standpoint) to aid in cold-starting (19:1 to 21:1 for IDI engines vs. ~15:1 to 17:1 for DI engines).

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[2]The GM Powertrain/AM General 6.5L electronically controlled, turbocharged IDI-swirl chamber engine, certified as a light HD diesel truck engine, is the last remaining HD on-highway IDI engine sold in the United States.

Because of the early introduction of DI technology into truck fleets, it is likely that by the end of the 1960s, only a small fraction of the HD diesel engines sold for on-highway use were IDI engines. It is unlikely that the shift from IDI to DI engine designs through the 1950s and 1960s occurred rapidly and likely that this shift had little significant impact on emissions. Springer (1979) reports a comparison of nearly identical Caterpillar 3406 engines (turbocharged and aftercooled) in DI and IDI configurations tested on an engine dynamometer under steady-state conditions, which limits the usefulness of these data. There was no significant difference in emissions of DPM, SOF, aldehydes, or DPM-associated B[*a*]P (Table 2-8). Note that IDI designs continue to be used in automotive diesel engines.

2.2.6.2. *Injection Rate*

Decreasing the duration of diffusion combustion and promoting EC oxidation during the expansion stroke can reduce formation of EC agglomerates (Stone, 1995) and reduce the particulate carbon fraction at high load (Needham et al., 1989). Both of these effects are enhanced by increasing the fuel injection rate. The primary means of accomplishing this is by increasing fuel injection pressure. In 1977 Robert Bosch introduced a new type of high-pressure pump capable of producing injection pressures of 1,700 bar at the nozzle (Voss and Vanderpoel, 1977). This increased fuel injection pressure by roughly a factor of 10. Unit injection, which combines each fuel injection nozzle with individual cam-driven fuel pumps, can achieve very high injection pressures (>2,000 bar). The first combination of unit injectors with electronically controlled solenoids for timing control was offered in the United States by Detroit Diesel Corporation in the 1988 model year (Hames et al., 1985). Replacement of the injection cam with hydraulic pressure, allowing a degree of injection rate control, was made possible with the hydraulic-electronic unit injection jointly developed by Caterpillar and Navistar, introduced on the Navistar T444E engine (and variants) in 1993.

It is widely known that high fuel injection pressures have been used to obtain compliance with the PM standards that went into effect in 1988 (Zelenka et al., 1990). Thus, it is likely that a transition to this technology began in the 1980s, with the vast majority of new engine sales employing this technology by 1991, when the 0.25 g/bhp-hr Federal PM standard went into effect.

The use of electronic control of injection rate is rapidly increasing on medium HD diesel engines. Engines are currently under development, perhaps for 2002–2004 introduction, that use common-rail fuel injection systems with even more flexible control over injection pressure and timing than previous systems.

Increased injection rate and pressure can significantly reduce EC emissions, but it can also increase combustion temperatures and cause an increase in NO_x emissions (Springer, 1979;

Watson and Janota, 1982; Stone, 1995). Low NO_x, low DPM, and relatively good BSFC and brake mean engine pressure (BMEP) are possible when combined with turbocharging, aftercooling, and injection timing retard.

2.2.6.3. *Turbocharging, Charge-Air Cooling, and Electronic Controls*

Use of exhaust-driven turbochargers to increase intake manifold pressure has been applied to both IDI and DI diesel engines for more than 40 years. Turbocharging can decrease fuel consumption compared with a naturally aspirated engine of the same power output. Turbocharging utilizes otherwise wasted exhaust heat and pressure to generate intake boost. The boosted intake pressure effectively increases air displacement and increases the amount of fuel that can be injected to achieve a given fuel-air ratio. Turbocharging increases the power density of an engine. Boosting intake pressure via turbocharging and reducing fuel-to-air ratio at a constant power can significantly increase both intake temperatures and NO_x emissions. Increased boost pressure can significantly reduce ignition delay, which reduces VOC and DPM SOF emissions (Stone, 1995) and increases the flexibility in selection of injection timing. Injection timing on turbocharged engines can be retarded further for NO_x emission control with less of an effect on DPM emissions and fuel consumption. This allows a rough parity in NO_x emissions between turbocharged (non-aftercooled) and naturally aspirated diesel engines (Watson and Janota, 1982).

Turbocharging permits the use of higher initial injection rates (higher injection pressure),

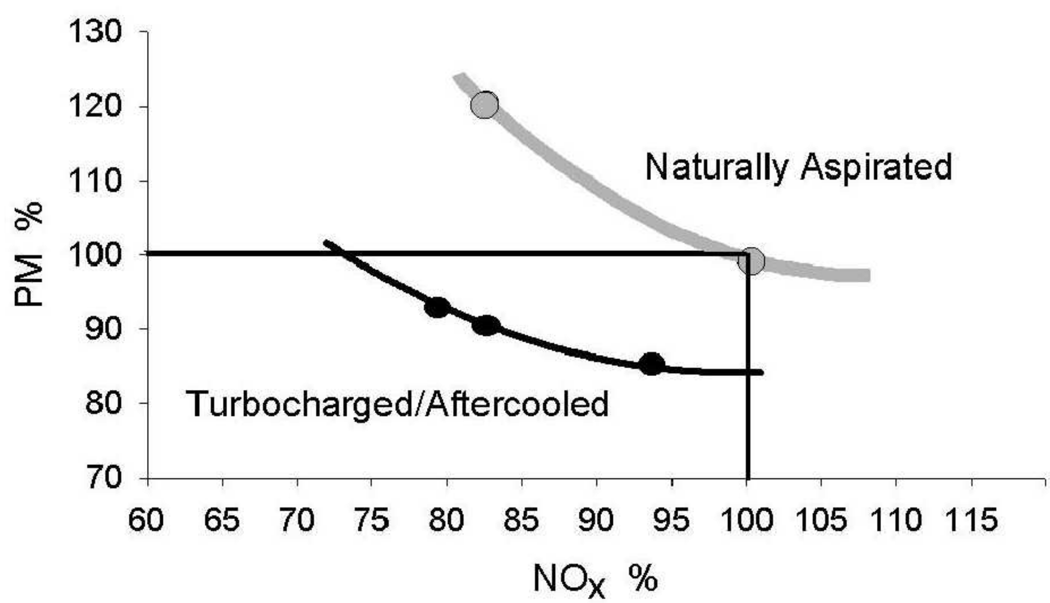

Figure 2-23. Effect of turbocharging and aftercooling on NO_x and PM.

Source: Mori, 1997.

which can reduce particulate emissions. Although this may offer advantages for steady-state operation, hard accelerations can temporarily cause overly fuel-rich conditions because the turbocharger speed lags behind a rapid change in engine speed (turbo-lag). This can cause significant increases in DPM emissions during accelerations. Before the advent of electronic controls, the effect of acceleration on DPM emissions could be limited by mechanically delaying demand for maximum fuel rate with a "smoke-puff eliminator." Because this device also limited engine response, there was considerable incentive for the end-users to remove or otherwise render the device inactive. Charge-air cooling, for example, using an air-to-air aftercooler (air-cooled heat exchanger) between the turbocharger compressor and the intake manifold, can greatly reduce intake air and peak combustion temperatures. When combined with injection timing retard, charge-air cooling allows a significant reduction in NO_x emissions with acceptable BSFC and DPM emissions when compared to either non-aftercooled or naturally aspirated diesel engines (Hardenberg and Fraenkle, 1978; Pischinger and Cartellieri, 1972; Stone, 1995). The use of charge-air cooling effectively shifts the NO_x-DPM tradeoff curve, as shown in Figure 2-23.

Electronic control of fuel injection timing allowed engine manufacturers to carefully tailor the start and length of the fuel injection events much more precisely than through mechanical means. Because of this, newer on-highway turbocharged truck engines have virtually no visible smoke on acceleration (although emissions of DPM are substantial during this driving mode). Electronic controls also allowed fuel injection retard under desirable conditions for NO_x reduction, while still allowing timing optimization for reduced VOC emissions on start-up, acceptable cold-weather performance, and acceptable performance and durability at high altitudes. Previous mechanical unit injected engines (e.g., the 1980s Cummins L10, the Non-Electronic Control Detroit Diesel 6V92) were capable of reasonably high injection pressures, but they had fixed injection timing that only varied based on the hydraulic parameters of the fuel system. Many other engines with mechanical in-line or rotary injection pumps had only coarse injection timing control or fixed injection timing.

Precise electronic control of injection timing over differing operating conditions also allowed HD engine manufacturers to retard injection timing to obtain low NO_x emissions during highly transient urban operation, similar to that found during emissions certification. HD engine manufacturers also advanced injection timing during less transient operation (such as freeway driving) for fuel consumption improvements (~3% to 5%) at the expense of greatly increased NO_x emissions (approximately three to four times regulated levels). This particular situation resulted in the recent consent decree settlements between the Federal Government and most HD engine manufacturers to ensure effective NO_x control in all driving conditions, including on-highway high-speed steady-state driving.

Turbocharged engines entered the market very slowly beginning in the 1960s. Data for DPM emissions from naturally aspirated engines of model years 1976 to 1983 are compared with DPM emissions from turbocharged engines in Figure 2-24. There is no consistent difference in DPM emissions between turbocharged and naturally aspirated engines. Although not plotted, the data also show no difference in emissions of NO_x, DPM SOF, or DPM-associated B[*a*]P and 1-nitropyrene (1-NP).

Charge-air cooling was introduced during the 1960s and was initially performed in a heat exchanger using engine coolant. Cooling of the charge air using ambient air as the coolant was introduced into heavy trucks by Mack in 1977 with production of the ETAY(B)673A engine (Heywood, 1988). Use of ambient air allowed cooling of the charge air to much lower temperatures. Most HD diesel engines sold today employ some form of charge air cooling, with air-to-air aftercooling being the most common. Johnson and co-workers (1994) have presented a comparison of similar engines that differ in that the charge air is cooled by engine coolant (1988 engine) and by ambient air, with a higher boost pressure for the second (1991 engine). The 1991 engine also used higher pressure fuel injectors. The 1991 engine exhibited both lower DPM emissions (50% lower than the 1988 engine) and lower NO_x emissions. Higher injection pressure is likely to have enabled the reduced DPM emissions, whereas the lower charge-air

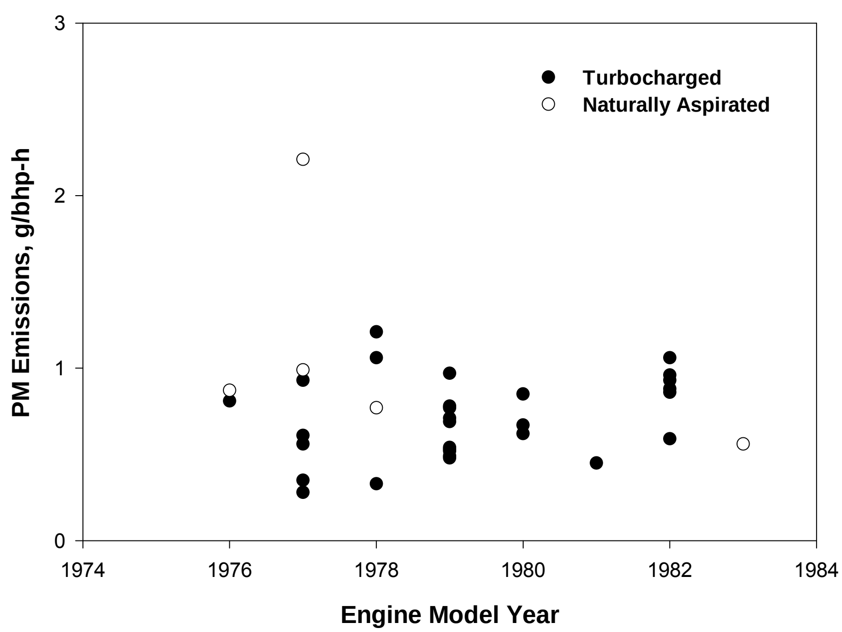

Figure 2-24. Comparison of diesel engine dynamometer PM emissions for four-stroke, naturally aspirated, and turbocharged engines.

Source: Data are from Table 2-8.

temperature and the ability to electronically retard the injection timing under some conditions likely enabled the lower NO_x emissions.

It is apparent on the basis of both the literature and certification data that turbochargers with aftercoolers can be used in HD engines in conjunction with other changes to produce a decrease in emissions. On the advent of a NO_x standard in 1985, NO_x was probably reduced on the order of 10% to 30% in turbocharged aftercooled engines with retarded injection timing. This decrease is not evident in the in-use chassis testing data because of deterioration and the use of illegal emissions devices as described above. Overall, it is expected that engines in the 1950s to mid-1970s timeframe would have similar DPM emission rates, whereas post-1970 engines would have somewhat lower DPM emission rates.

2.2.6.4. *Two-Stroke and Four-Stroke High-Speed Diesel Engines*

A detailed discussion of the two- and four-stroke engine cycles can be found in the literature (Heywood, 1988; Taylor, 1990; Stone, 1995). Nearly all high-speed two-stroke diesel engines utilize uniflow scavenging assisted by a positive-displacement blower (Figure 2-25). Uniflow-scavenged two-stroke diesels use poppet exhaust valves similar to those found in four-stroke engines. The intake air enters the cylinder through a pressurized port in the cylinder wall. A crankshaft-driven, positive-displacement blower (usually a roots-type) pressurizes the intake port to ensure proper scavenging. A turbocharger may be added to the system to provide additional boost upstream of the blower at higher speeds and to reduce the size and parasitic losses associated with the positive-displacement blower.

Two-stroke diesel engines can achieve efficiency comparable to four-stroke counterparts and have higher BMEP (torque per unit displacement) (Heywood, 1988). It is useful to note that two-stroke cycle fires each cylinder once every revolution, whereas the four-stroke cycle fires every other revolution. Thus, for a given engine size and weight, two-strokes can produce more power. However, two-stroke diesel engines are less durable than their four-stroke counterparts. Lubricating oil is transferred from the piston rings to the intake port, which causes relatively high oil consumption relative to four-stroke designs. Durability and low oil consumption are desirable for on-highway truck applications. This may be why four-stroke engines have been favored for these applications since the beginning of dieselization in the trucking industry, with the notable exception of urban bus applications. Although it is no longer in production, the Detroit Diesel 6V92 series of two-stroke diesel engines is still the most popular for urban bus applications, where the high power density allows the engine to be more easily packaged within limited spaces. The primary reason that two-stroke engines like the 6V92 are no longer offered for urban bus applications is excessive DPM emissions. The lubricating oil control with two-strokes tends to be lower than for four-stroke engines, and therefore, emissions have higher VOC

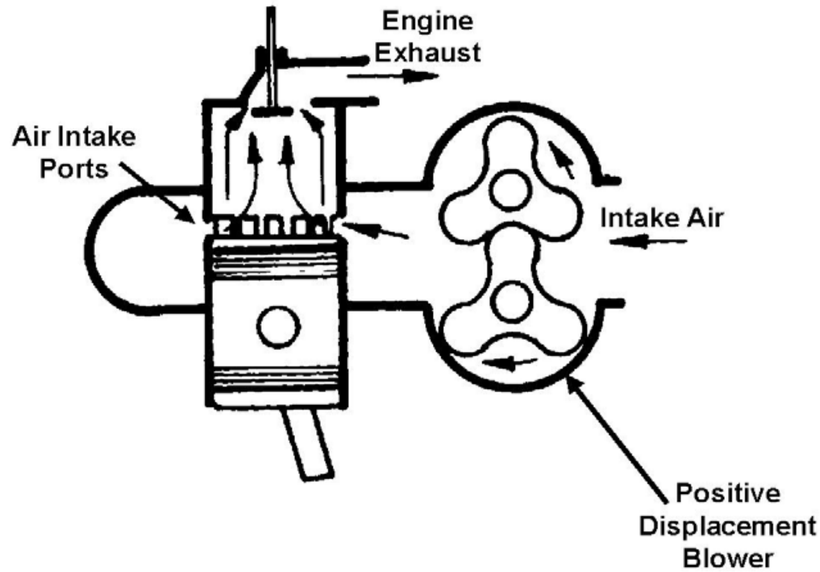

Figure 2-25. An example of uniflow scavenging of a two-stroke diesel engine with a positive displacement blower. Scavenging is the process of simultaneously emptying the cylinder of exhaust and refilling with fresh air.

Source: Adapted from Taylor, 1990.

and organic DPM emissions relative to four-stroke designs. This was particularly problematic for urban bus applications because urban bus engines must meet tighter Federal and California PM emissions standards. The current urban bus PM standard (0.05 g/bhp-hr) is one-half of the current on-highway HD diesel engine PM standard, although EPA is in the process of proposing more strict standards for HD diesel truck engines along with further reductions in diesel fuel sulfur levels. No two-stroke diesel engine designs have been certified to meet the most recent urban bus PM emissions standards, and Detroit Diesel Corporation has not certified a two-stroke diesel engine for on-highway truck use since 1995.

A comprehensive review of emissions from hundreds of vehicles (1976–98 model years) that had been tested on chassis dynamometers found that DPM emissions vary substantially within a given model year and that within that variation there are no discernible differences in DPM emissions between two- and four-stroke vehicles (Figure 2-26) (Yanowitz et al., 2000). DPM emission factors reported for engine tests also indicate that two- and four-stroke engines have comparable emission factors, as these engines all had to meet the same regulatory standard (Figure 2-27). In contrast to DPM emissions, evidence suggests that mid-1970s two-stroke engines exhibited very high SOF levels compared with four-stroke engines, with later model years showing similar SOF emissions for two- and four-stroke engines (Figure 2-28). For aldehydes, benzo[a]pyrene, and 1-nitropyrene, data are available for only one two-stroke engine,

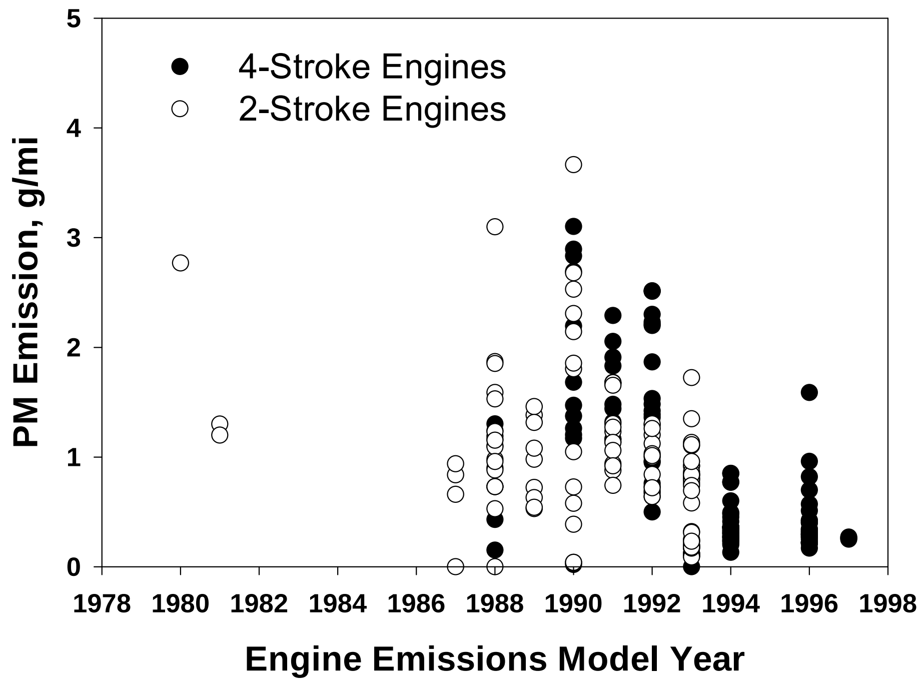

Figure 2-26. Comparison of two- and four-stroke vehicle diesel PM emissions from chassis dynamometer studies.

Source: Yanowitz et al., 2000.

but they indicate no significant difference in emissions from comparable model year four-stroke engines. Overall, regulated emissions changes attributable to changing proportions of two- and four-stroke engines in the in-use fleet do not appear to have influenced DPM emission levels, but the transition to four-stroke engines in the 1970s would have decreased the fraction of SOF associated with the DPM. It appears that the proportion of two-stroke engines in the in-use fleet was relatively constant until the late 1980s, when it began to decline.

2.2.7. Air Toxic Emissions

HD diesel vehicle exhaust contains several substances that are known, likely, or possible human or animal carcinogens, or that have serious noncancer health effects. These substances include, but are not limited to, benzene, formaldehyde, acetaldehyde, 1,3-butadiene, acrolein, dioxin, PAH, and nitro-PAH (the complete list of chemically characterized compounds present in DE is provided in Section 2.3.1). Very few historical data are available to examine changes in emission rates over time. In this section, trends in aldehyde emissions over time and a summary

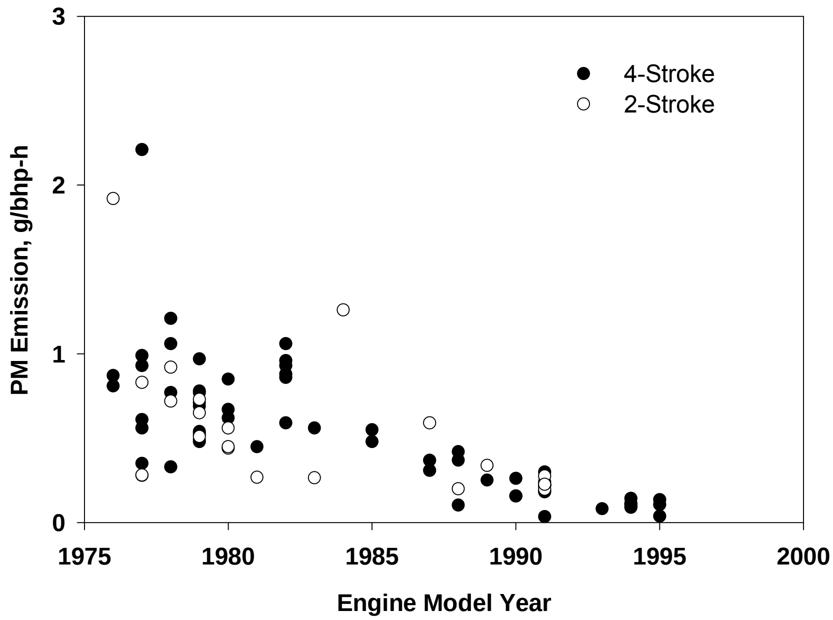

Figure 2-27. Comparison of two- and four-stroke engine diesel PM emissions from engine dynamometer studies.

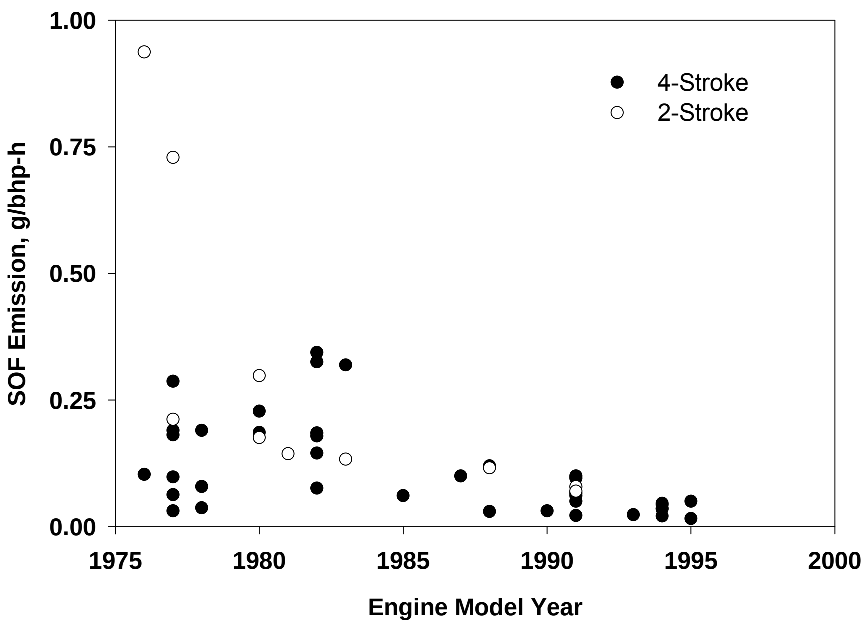

Figure 2-28. Diesel engine dynamometer SOF emissions from two- and four-stroke engines. SOF obtained by dichloromethane extraction in most studies.

Source: Data are from Table 2-8.

of dioxin emission factors are presented. PAH and nitro-PAH emission factors are discussed in Section 2.2.8.2.

2.2.7.1. *Aldehyde Emissions*

Among the gaseous components emitted by diesel engines, the aldehydes are particularly important because they constitute an important fraction of the gaseous emissions and they are probable carcinogens that also produce noncancer health effects. Formaldehyde makes up the majority of the aldehyde emissions (65% to 80%), with acetaldehyde being the second most abundant aldehyde in HD diesel emissions. Total aldehyde emissions reported from chassis dynamometer testing suggest that aldehyde emissions have declined since 1980; however, only two tests reported aldehydes from engines made after 1985 (Figure 2-29). Engine dynamometer studies also suggest a downward trend in the emissions of aldehydes in the time period from 1976 to 1994 (Figure 2-30). Engine dynamometer studies report aldehyde emission levels of 150–300 mg/bhp-hr for late 1970s engines with no significant effect of turbocharging, or IDI versus DI. High-pressure fuel injection may have resulted in a marginal increase in aldehyde emissions (Springer, 1979). By comparison, 1991 model year engines (DI, turbocharged) exhibited aldehyde emissions in the 30–50 mg/bhp-hr range (Mitchell et al., 1994).

2.2.7.2. *Dioxin and Furans*

Ballschmiter et al. (1986) reported detecting polychlorinated dibenzo-p-dioxins (CDDs) and polychlorinated dibenzofurans (CDFs) in used motor oil and thus provided some of the first evidence that CDDs and CDFs might be emitted by the combustion process in diesel-fueled engines. Incomplete combustion and the presence of a chlorine source in the form of additives in the oil or the fuel were speculated to lead to the formation of CDDs and CDFs. Since 1986, several studies have been conducted to measure or estimate CDD/CDF concentrations in emissions from diesel-fueled vehicles. These studies can be characterized as direct measurements from the engine exhaust and indirect measurements from the sampling of air within transportation tunnels.

Table 2-11 is a summary of various CDD/CDF emission characterization studies reported in the United States and Europe for diesel-fueled cars and trucks. Hagenmaier et al. (1990) reported an emission factor for LD diesel vehicles of 24 pg TEQ per liter of diesel fuel consumed. TEQ, or the toxic equivalency factor, rates each dioxin and furan relative to that of 2,3,7,8-TCDD, which is arbitrarily assigned a TEQ of 1.0 based on animal assays. Schwind et al. (1991) and Hutzinger et al. (1992) studied emissions of CDDs/CDFs from German internal combustion engines running on commercial diesel fuels and reported a range of CDD/CDF emission rates across the test conditions (in units of pg TEQ per liter of diesel fuel consumed) of 10–130 pg TEQ/L for diesel car exhaust and 70–81 pg TEQ/L for diesel truck exhaust.

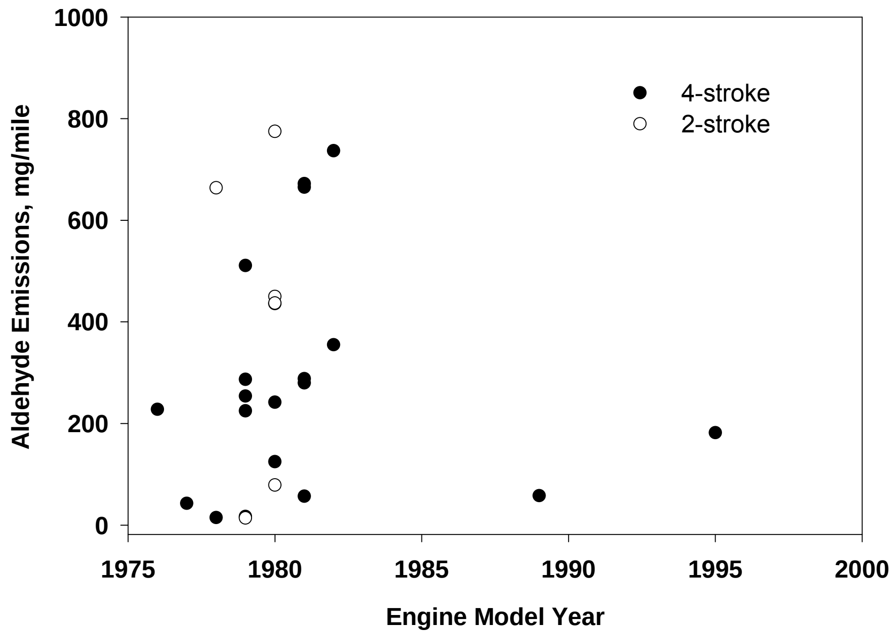

Figure 2-29. Diesel engine aldehyde emissions measured in chassis dynamometer studies.

Source: Data are from Warner-Selph and Dietzmann, 1984; Schauer et al., 1999; Unnasch et al., 1993.

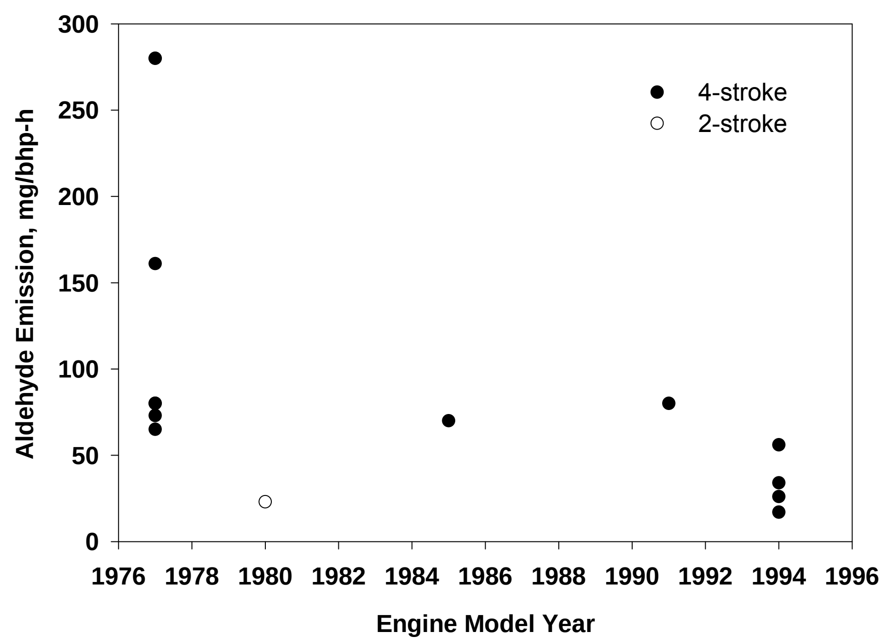

Figure 2-30. Diesel engine aldehyde emissions from engine dynamometer studies.

Source: Data from Table 2-8.

Table 2-11. Summary of CDD/CDF emissions from diesel-fueled vehicles

Study	Country	Vehicle tested	Number of test vehicles	Emission factor (pg TEQ/km driven)	Driving cycle; sampling location
CARB, 1987; Lew, 1996	United States	Diesel truck	1	663–1,300	6-hr dynamometer test at 50 km/hr
Marklund et al., 1990	Sweden	Diesel truck	1	not detected (<18)[a]	U.S. Federal mode 13 cycle; before muffler
Hagenmaier et al., 1990	Germany	Diesel car	1	2.4[a]	Comparable to FTP-73 test cycle; in tailpipe
Hagenmaier, 1994	Germany	Diesel bus	1	not detected (< 1 pg/L)	On-the-road testing
Oehme et al., 1991 (tunnel study)	Norway	—	(b)	520[c] 38[c] avg = 280 9,500[c] 720[c] avg = 5,100	Cars moving uphill (3.5% incline) at 60 km/hr Cars moving downhill (3.5% decline) at 70 km/hr Trucks moving uphill (3.5% incline) at 60 km/hr Trucks moving downhill (3.5% decline) at 70 km/hr
Schwind et al., 1991 Hutzinger et al., 1992	Germany	Diesel car Diesel truck	1 1	5.0–13[a] 13–15[a]	Various test conditions (i.e., loads and speeds) Various test conditions (i.e., loads and speeds)
Gertler et al., 1996 (tunnel study)	United States	Diesel trucks	(d)	mean = 172	Mean of seven 12-hour samples
Gullett and Ryan, 1997	United States	Diesel truck	1	mean - 29.0	Mean of five sample routes

[a]Results reported were in units of pg TEQ/liter of fuel. For purposes of this table, the fuel economy factor used by Marklund et al. (1990), 10 km/L or 24 miles/gal, was used to convert the emission rates into units of pg TEQ/km driven for the cars. For the diesel-fueled truck, the fuel economy factor reported in CARB (1987a) for a 1984 heavy-duty diesel truck, 5.5 km/L (or 13.2 miles/gal), was used.
[b]Tests were conducted over portions of 4 days, with traffic rates of 8,000-14,000 vehicles/day. Heavy-duty vehicles (defined as vehicles over 7 meters in length) ranged from 4% to 15% of total.
[c]Emission factors are reported in units of pg Nordic TEQ/km driven; the values in units of I-TEQ/km are expected to be about 3% to 6% higher.
[d]Tests were conducted over 5 days with heavy-duty vehicle rates of 1,800-8,700 vehicles per 12-hour sampling event. Heavy-duty vehicles accounted for 21% to 28% of all vehicles.

In 1994, Hagenmaier reported CDD/CDF emissions from a diesel-fueled bus and found no detectable levels in the exhaust (at a detection limit of 1 pg/L of fuel consumed) for individual congeners. In 1987, the California Air Resources Board (CARB) produced a draft report of a HD engine tested under steady-state conditions indicating a TEQ emission factor of 7,290 pg/L of fuel burned (or 1,300 pg/km driven) if nondetected values are treated as one-half the detection limit. Treating nondetected values as zeros yields a TEQ concentration equivalent to 3,720 pg/L of fuel burned (or 663 pg/km driven) (Lew, 1996). Norbeck et al. (1998c) reported emission factors for dioxin and furans from a Cummins L10 HD diesel engine running on pre-1993 fuel of 0.61 pg/L and 0.41 pg/L for the same engine running on reformulated fuel. The low emission factors reported by Norbeck et al. (1998c) were attributed to losses of dioxin and furan compounds to the dilution tunnel walls.

EPA has directly sampled the exhaust from a HD diesel truck for the presence and occurrence of CDDs/CDFs (Gullett and Ryan, 1997). The average of five tests (on highway and city street driving conditions) was 29.0 pg TEQ/km with a standard deviation of 38.3 pg TEQ/km; this standard deviation reflects the 30-fold variation in the two city driving route tests.

Tunnel studies are an indirect means of measuring contaminants that may be associated with emissions from cars and trucks. In these studies, scrapings of carbonaceous matter from the interior walls of the transportation tunnel or the tunnel air are sampled and analyzed for the target contaminants. Several European studies and one recent U.S. study evaluated CDD/CDF emissions from vehicles by measuring the presence of CDDs/CDFs in tunnel air. This approach has the advantage of allowing random sampling of large numbers of vehicles passing through the tunnel, including a range of ages and maintenance levels. The disadvantage of this approach is that it relies on indirect measurements (rather than tailpipe measurements), which may introduce unknown uncertainties into the interpretation of results.

Oehme et al. (1991) reported the emission rates associated with HD diesel trucks as follows: uphill = 9,500 pg TEQ/km; downhill = 720 pg TEQ/km; mean = 5,100 pg TEQ/km. The mean values are the averages of the emission rates corresponding to the two operating modes: vehicles moving uphill on a 3.5% incline at an average speed of 37 mi/hr and vehicles moving downhill on a 3.5% decline at an average speed of 42 mi/hr.

Wevers et al. (1992) measured the CDD/CDF content of air samples taken during the winter of 1991 inside a tunnel in Antwerp, Belgium. The results obtained indicated that the tunnel air had a dioxin TEQ concentration about twice as high as the outside air (80.3 fg TEQ/m^3 for tunnel air vs. 35 fg TEQ/m^3 for outside air for one set of measurements and 100 fg TEQ/m^3 for tunnel air vs. 58 fg TEQ/m^3 for outside air for a second set of measurements).

During October/November 1995, Gertler et al. (1996, 1998) measured CDDs/CDFs in the Fort McHenry Tunnel in Baltimore, Maryland. The emission factors calculated, assuming that all CDDs/CDFs emitted in the tunnel were from HD vehicles, are presented in Table 2-12. The average TEQ emission factor was reported to be 172 pg TEQ/km. The major uncertainties in the study were tunnel air volume measurement, sampler flow volume control, and analytical measurement of CDDs/CDFs (Gertler et al., 1996, 1998).

The relative strengths of the Gertler et al. (1996; 1998) study include: (1) The study is a recent study conducted in the United States and thus reflects current U.S. fuels and technology; (2) virtually no vehicle using the tunnel used leaded gasoline, which is associated with past emissions of CDDs and CDFs from gasoline-powered vehicles; (3) the tunnel walls and streets were cleaned 1 week before the start of sampling, and in addition, the study analyzed road dust and determined that resuspended road dust contributed only about 4% of the estimated emission factors; and (4) HD vehicles made up, on average 25.7% of vehicles using the tunnel.

Using the emissions factor from the Gertler et al. studies, the EPA Office of Research and Development's dioxin source emission inventory estimates that 33.5 g of dioxin TEQ (total 2,3,7,8-TCDD equivalents) were emitted from HD U.S. trucks in 1995. This is a very small contribution (1.2%) compared with the national annual emission of 2,800 g CDDs/CDFs.

2.2.8. Physical and Chemical Composition of Diesel Exhaust Particles

DPM is defined by the measurement procedures summarized in Title 40 CFR, Part 86, subpart N. This definition and the basic characteristics of DPM have been summarized in Section 2.2.2. As described there, DE particles are aggregates of primary spherical particles that consist of solid carbonaceous material and ash and contain adsorbed organic and sulfur compounds (sulfate) combined with other condensed material. The organic material includes unburned fuel, engine lubrication oil, and low levels of partial combustion and pyrolysis products.

The organic material is absorbed to the EC core and is also found in heterogeneously nucleated aerosol. This fraction of the DPM is frequently quantified as the SOF (i.e., the fraction that can be extracted by an organic solvent). Because of the toxicological significance of the organic components associated with DPM, it is important to understand, to the extent possible, the historical changes in the composition of SOF and potential changes in the fraction of SOF associated with DPM.

Various researchers have attempted to apportion the SOF to unburned oil and fuel sources by thermogravimetric analysis and have found that the results vary with test cycle and engine (Abbass et al., 1991; Wachter, 1990). Kittelson (1998) estimates that a typical composition of SOF is about one-fourth unburned fuel and three-fourths unburned

Table 2-12. Baltimore Harbor Tunnel Study: estimated CDD/CDF emission factors for HD vehicles

Congener/congener group	Run-specific emission factors							Mean emission factors (pg/km)
	Run no. 2 (pg/km)	Run no. 3 (pg/km)	Run no. 5 (pg/km)	Run no. 6 (pg/km)	Run no. 8 (pg/km)	Run no. 9 (pg/km)	Run no. 10 (pg/km)	
2,3,7,8-TCDD	24.5	61.6	0.0	21.2	37.8	40.1	54.9	34.3
1,2,3,7,8-PeCDD	40.2	20.6	15.4	5.6	38.4	0.0	83.0	29.0
1,2,3,4,7,8-HxCDD	18.2	25.2	46.5	8.3	64.5	0.0	123	40.8
1,2,3,6,7,8-HxCDD	37.5	28.2	64.3	19.6	153	71.1	186	80.0
1,2,3,7,8,9-HxCDD	53.6	56.5	91.6	48.4	280	126	370	147
1,2,3,4,6,7,8-HpCDD	0	401	729	111	2,438	963	2,080	960
OCDD	0	3,361	3,382	1,120	9,730	5,829	7,620	4,435
2,3,7,8-TCDF	0	94.3	67.6	152.8	155.8	73.4	61.7	86.5
1,2,3,7,8-PeCDF	0	48.9	72.6	23.6	53.3	0.0	43.3	34.5
2,3,4,7,8-PeCDF	24.5	75.7	131	46.6	85.0	63.9	108	76.4
1,2,3,4,7,8-HxCDF	15.4	139	204	93.8	124	164	166	129
1,2,3,6,7,8-HxCDF	0.3	75.1	73.7	51.0	61.3	54.4	95.5	58.8
1,2,3,7,8,9-HxCDF	27.7	14.8	75.6	0	20.6	37.2	63.5	34.2
2,3,4,6,7,8-HxCDF	15.2	82.5	152	55.7	93.0	86.8	111	85.2
1,2,3,4,6,7,8-HpCDF	12.6	280	445	154	313	354	308	267
1,2,3,4,7,8,9-HpCDF	0	58.5	60.8	31.1	25.0	2.3	34.9	30.4
OCDF	0	239	401	175	416	534	370	305
Total 2,3,7,8-CDD	174	3,954	4,328	1,335	12,743	7,028	10,515	5,725
Total 2,3,7,8-CDF	95.7	1,108	1,684	784	1,347	1,371	1,362	1,107
Total TEQ	73.8	175	170	96	235	153	303	172
Total TCDD	245	0	140	165	311	109	97.3	152
Total PeCDD	110	21.9	83.3	35.6	174	0.0	165	84.2
Total HxCDD	677	0	753	54.5	2,009	1,666	2,971	1,162
Total HpCDD	0	802	1,498	142	5,696	1,933	4,377	2,064
Total OCDD	0	3361	3,382	1,120	9,730	5,829	7,620	4,435
Total TCDF	0	901	1,314	656	2,416	1,007	687	997
Total PeCDF	124	119	1,152	78.4	1,055	282	626	491
Total HxCDF	136	319	852	67.6	444	719	619	451
Total HpCDF	0	223	814	144	513	354	637	384
Total OCDF	0	239	401	175	416	534	370	305
Total CDD/CDF	1,291	5,987	10,390	2,638	22,766	12,434	18,168	10,525
HD vehicles as % of total vehicles	21.2	22.0	22.6	34.0	28.8	24.2	27.4	25.7

Notes:
(1) Listed values are based on the difference between the calculated chemical mass entering the tunnel and the mass exiting the tunnel.
(2) All calculated negative emission factors were set equal to zero.
(3) All CDD/CDF emissions were assumed to result from heavy-duty diesel-fueled vehicles. The table presents in the last row the percent of total traffic that was heavy-duty vehicles.

Source: Gertler et al., 1996.

engine oil. Partial combustion and pyrolysis products represented a very small fraction of the SOF on a mass combustion and pyrolysis products represented a very small fraction of the SOF on a mass basis (Kittelson, 1998), which is confirmed in numerous other studies.

A number of investigators have tried to separate the organic fraction into various classes of compounds. Schuetzle (1983) analyzed the dichloromethane extract of DPM from a LD diesel engine and found that approximately 57% of the extracted organic mass is contained in the nonpolar fraction. About 90% of this fraction consists of aliphatic HCs from approximately C_{14} to about C_{40} (Black and High, 1979; Pierson and Brachaczek, 1983). PAHs and alkyl-substituted PAHs account for the remainder of the nonpolar mass. The moderately polar fraction (~9% w/w of extract) consists mainly of oxygenated PAH species, substituted benzaldehydes, and nitrated PAH. The polar fraction (~32% w/w of extract) is composed mainly of n-alkanoic acids, carboxylic and dicarboxylic acids of PAH, hydroxy-PAH, hydroxynitro-PAH, and nitrated N-containing heterocyclic compounds (Schuetzle, 1983; Schuetzle et al., 1985).

Rogge et al. (1993) reported the composition of the extractable portion of fine DPM emitted from two HD diesel trucks (1987 model year). The DPM filters were extracted twice with hexane, then three times with a benzene/2-propanol mixture. The extract was analyzed by capillary gas chromatography/mass spectrometry (GC/MS) before and after derivatization to convert organic acids and other compounds having an active H atom to their methoxylated analogues. Unidentified organic compounds made up 90% of the eluted organic mass and were shown to be mainly branched and cyclic HCs. From the mass fraction that was resolved as discrete peaks by GC/MS, ~42% were identified as specific organic compounds. Most of the identified resolved organic mass (~60%) consisted of n-alkanes, followed by n-alkanoic acids (~20%). PAH accounted for ~3.5% and oxy-PAH (ketones and quinones) for another ~3.3%.

The distribution of the emissions between the gaseous and particulate phases is determined by the vapor pressure of the individual species, by the amount and type of the DPM present (adsorption surface available), and by the temperature (Ligocki and Pankow, 1989). Two-ring and smaller compounds (e.g., naphthalene) exist primarily in the gas phase, whereas five-ring and larger compounds (e.g., benzo[a]pyrene) are almost completely adsorbed on the particles. Three- and four-ring compounds are distributed between the two phases. The vapor pressures of these intermediate PAHs can be significantly reduced by their adsorption on various surfaces. Because of this phenomenon, the amount and type of DPM present play an important role, together with temperature, in the vapor-particle partitioning of semivolatile organic compounds (SOCs).

The measurements of gas/particulate phase distribution are often accomplished by using a high-volume filter followed by an adsorbent such as polyurethane foam (PUF), Tenax, or XAD-2 (Cautreels and Van Cauwenberghe, 1978; Thrane and Mikalsen, 1981; Yamasaki et al., 1982).

The pressure drop behind a high-volume filter or cascade impactor can contribute to volatilization of the three- to five-ring PAHs from the PM proportional to their vapor pressures. The magnitude of this blow-off artifact depends on a number of factors, including sampling temperature and the volume of air sampled (Van Vaeck et al., 1984; Coutant et al., 1988). Despite these problems from volatilization, measurements with the high-volume filters followed by a solid adsorbent have provided most estimates of vapor-particle partitioning of SOCs in ambient air, as well as insights into the factors influencing SOC adsorption onto aerosols. Significant fractions of phenanthrene, anthracene, and their alkylated derivatives, along with fluoranthene and pyrene, exist in the gas phase. PAHs with molecular weight greater than that of pyrene are typically not observed on PUF samples. During the collection of particulate organic compounds, adsorption of semivolatile PAHs can also occur, as well as chemical transformation of the semivolatile compounds (Schauer et al., 1999; Cantrell et al., 1988; Feilberg et al., 1999; Cautreels and Van Cauwenberghe, 1978).

Most of the sulfur in the fuel is oxidized to SO_2, but a small amount (1% to 4%) is oxidized to sulfuric acid in the exhaust. Sulfate emissions are roughly proportional to sulfur in the fuel. Since the reduction of the allowable sulfur content in diesel fuel in 1993, sulfate emissions have declined from roughly 10% of the DPM mass to around 1%. Particulate emissions from numerous vehicles tested using low-sulfur fuel were found to have a sulfate content of only about 1% (Yanowitz et al., 1999). Water content is on the order of 1.3 times the amount of sulfate (Wall et al., 1987).

Metal compounds and other elements in the fuel and engine lubrication oil are exhausted as ash. Hare (1977) examined 1976 Caterpillar 3208 and Detroit Diesel Corporation 6V-71 engines and found the most abundant elements emitted from the 6V-71 engine were silicon, copper, calcium, zinc, and phosphorus. From the Caterpillar engine the most abundant elements were lead, chlorine, manganese, chromium, zinc, and calcium. Calcium, phosphorus, and zinc were present in the engine lubrication oil. The two-stroke 6V-71 engine had higher engine lubrication oil emissions and therefore emitted higher levels of zinc, calcium, and phosphorus than the Caterpillar 3208 engine. Other elements may have been products of engine wear or contaminants from the exhaust system. Springer (1979), in his study of 1977 Mack ETAY(B)673A and Caterpillar 3208 (EGR) engines, found that calcium was the most abundant metallic element in DPM samples, with levels ranging from 0.01 to 0.29 wt% of the DPM. Phosphorus and silica were the next most abundant elements reported, and sodium, iron, nickel, barium, chromium, and copper were either present at very low levels or were below detection limits. Roughly 1 wt% of the total DPM was represented by the analyzed metals. There was no consistent difference in metal emissions between the engines tested by Springer or between modes. Springer tested both engines on a 13-mode steady-state test. Dietzmann and co-workers

(1980) examined metal emission rates from four HD vehicles tested using the UDDS chassis cycle. For the single two-stroke engine tested (1977 Detroit Diesel Corporation 8V-71), calcium, phosphorus, and zinc emission rates were more than 10 times higher than metal levels observed for three 1979 model year four-stroke engines because of higher engine lubrication oil emissions. Metals accounted for 0.5% to 5% of total DPM, depending on engine model. In addition to these studies, other source profiles for HD diesel engine emissions report levels of chromium, manganese, mercury compounds, and nickel at levels above the detection limit (Cooper et al., 1987).

In more recent studies, Hildemann and co-workers (1991) examined metals in DPM from the same two 1987 trucks (four-stroke engines) studied by Rogge and co-workers (1993). Aluminum, silicon, potassium, and titanium were the only metals observed at statistically significant levels. Taken together these made up less than 0.75 wt% of total DPM mass. Lowenthal and co-workers (1994) also report metals emission rates for a composite sample of several diesel vehicles. The most abundant metals were zinc, iron, calcium, phosphorus, barium, and lanthanum. Together these represented less than 0.3% of total DPM mass, with an emissions rate of 3.3 mg/mi. Norbeck and co-workers (1998b) report engine transient test emissions of metals for a 1991 Cummins L10 engine. Silicon, iron, zinc, calcium, and phosphorus were observed and together made up about 0.5% of total DPM, with an emissions rate of 1.2 mg/bhp-hr.

2.2.8.1. *Organic and EC Content of Particles*

2.2.8.1.1. ***Measurement of the organic and EC fraction.*** Various methods have been used to quantify the organic fraction of DPM. The most common method has been Soxhlet extraction with an organic solvent. Following extraction, the solvent can be evaporated and the mass of extracted material (the SOF) determined, or alternatively the PM filter is weighed before and after extraction and the extracted material can be further analyzed to determine concentrations of individual organic compounds. Vacuum oven sublimation is used to measure a comparable quantity, the volatile organic fraction (VOF), which can be further speciated by GC with a flame ionization detector. Other methods have also been employed, including thermal methods, microwave extraction, sonication with an organic solvent, supercritical fluid extraction, thermogravimetric analysis, and thermal desorption GC. Abbass et al. (1991) compared various methods, including vacuum oven sublimation and 8 hours of Soxhlet extraction, with 4:1 benzene/methanol solvent for determination of SOF and found reasonably good agreement between the two methods. The VOF value was typically 10% higher; however, this variation was less than the coefficient of variation between measurements using the same method.

Levson (1988) reviewed literature regarding the extraction efficiency of various solvents and found contradictory results in many cases. He concluded that there is strong evidence that the most commonly used solvent, dichloromethane, leads to poor recoveries of higher molecular weight PAH. More recently, Lucas et al. (1999) reported the effect of varying dichloromethane/benzene ratios in the solvent (from 25% to 100% dichloromethane) and changing extraction times and found that the most effective extraction (i.e., the largest extracted mass) utilized a 70% dichloromethane/30% benzene mixture and extraction times several times longer than the commonly used 8-hour extraction period. Extractions of 70 hours using pure dichloromethane were found to result in about twice as much SOF as extractions of only 12 hours. Between 6 and 24 hours of extraction time (the typical range of extraction times used), the SOF recovered increased by about one-third. Using the most effective extraction conditions (Soxhlet, 70 hours, 70:30 dichloromethane:benzene ratio), Lucas et al. (1999) were able to extract more than 90% of the total particulate mass.

Other researchers have investigated the relative quantities of mass removed by sequential extraction by polar, moderately polar, and nonpolar solvents. The extracted nonpolar fraction (cyclohexane) ranged from 56% to 90% of the SOF, the moderately polar (dichloromethane) from 6% to 22%, and the polar fraction (acetonitrile) from 4% to 29% (Dietzmann et al., 1980). Water and sulfate are not soluble in cyclohexane or dichloromethane but are soluble in acetonitrile.

Although the reports on the extraction efficiencies for PAHs are in part contradictory, it appears that Soxhlet extraction and the binary solvent system composed of aromatic solvent and alcohol yield the best recovery of PAHs, as determined by C-B[*a*]P^{14} (benzo[a]pyrene) spiking experiments (Schuetzle and Perez, 1983). Limited recovery studies have shown that there is little degradation or loss of diesel POM on the HPLC column. More than 90% of the mass and 70% to 100% of the Ames *S. typhimurium*-active material injected onto the column has been recovered (Schuetzle et al., 1985).

Two thermal methods of organic and EC analysis include thermal optical reflectance (TOR) and thermal optical transmittance (TOT). The extractable portion of total carbon, although commonly used as a measure of organic compound content, is not equivalent to the OC fraction as measured by TOR or TOT. In addition, methodological differences between TOR and TOT also give rise to significant differences in the fraction of total carbon reported as organic and EC (Birch, 1998; Norris et al., 2000; Chow et al., 2000). Although total carbon reported using TOR or TOT provides results that are comparable (within 10%) (Norris et al., 2000) the EC content of samples analyzed by TOR is higher than that measured by TOT. This difference is primarily attributed to the temperature used to evolve carbon from the quartz filter onto which it is collected. In an analysis of urban $PM_{2.5}$ samples, Norris et al. (2000) found that the EC content of samples analyzed by TOR was a factor of two higher than the EC content of the same samples analyzed by TOT. Experiments are ongoing to test specific source materials (including DPM) because some of the difference between methods appears to depend on the type of OC present on the sample.

The analytical technique used to measure OC and EC can have a significant effect on the quantity of reported. In the discussion that follows, every effort has been made to compare only studies using comparable methods and to state the analysis method employed.

2.2.8.1.2. ***Trends in SOF emissions.*** SOF emission values are highly dependent on the test cycle used. Various studies have shown that SOF generally increases at light engine loads and high engine speeds because these conditions lead to low exhaust temperatures, where fuel and oil are not as effectively oxidized (Scholl et al., 1982; Kittelson, 1998; Springer, 1979; Schuetzle and Perez, 1983; Martin, 1981b; Shi et al., 2000). These conditions are more typically observed in LD diesel vehicle applications, and thus DPM from these vehicles typically has a higher SOF component than HD diesel vehicles (Norbeck et al., 1998c). Acceleration modes normally cause increased emission of EC and an increase in total DPM emissions, whereas organic components are more dominant when motoring (Wachter, 1990). Additionally, cold-start test emissions of SOF have been shown to be approximately 25% higher than hot-start emissions (Wachter, 1990).

The quantity of sulfur in diesel fuel has been suggested to have a role in the quantity of SOF emitted (Sienicki et al., 1990; Tanaka et al., 1998). Sienicki et al. (1990) reported an approximate 25% increase in SOF when sulfur concentrations are increased from 0.08% to 0.33%. The cause is unclear but several explanations have been put forth, including increased absorption of organic compounds from the vapor phase onto the DPM by sulfates or sorbed sulfuric acid. Alternatively, it has been proposed that the measured SOF may include some sulfate, so that the apparent increase in organic material is due instead to sulfate. Other fuel effects include an increase in SOF emissions with a higher T90 (or T95) and with an increase in aromatic content (Barry et al., 1985; Sienicki et al., 1990; Tanaka et al., 1998; Rantanen et al., 1993).

Figures 2-31 and 2-32 show SOF emissions as a function of year for transient emissions tests on chassis and engines, respectively. Both figures suggest a significant decline in SOF emissions of approximately a factor of 5 since about 1980. The highest SOF emissions are for two-stroke engines built in the 1970s (up to approximately 1.2 g/mi). These data indicate that SOF emission factors for newer model year vehicles are lower than SOF emission factors for pre-1990 model year vehicles and that this decrease is similar to that observed for emissions of total DPM by model year. In a recent test of six pre-1976 HDDVs, Fritz et al. (2001) reported

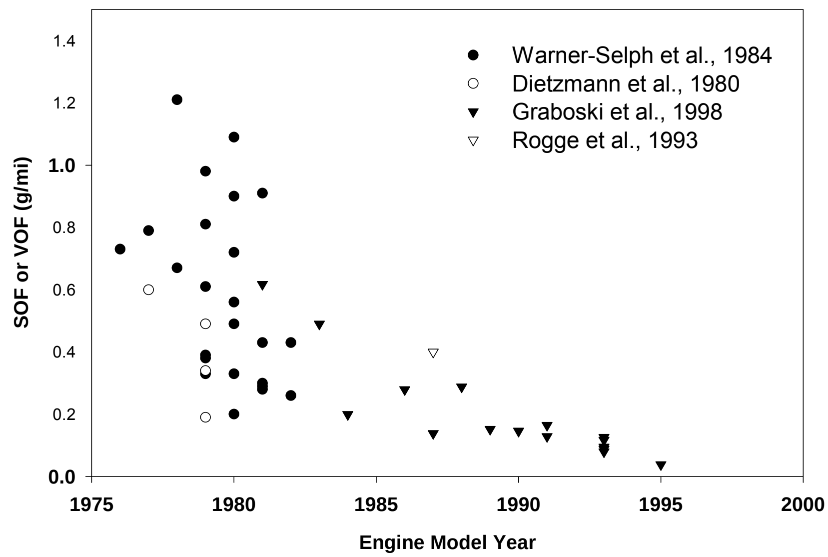

Figure 2-31. Trend in SOF emissions based on chassis dynamometer testing of HD diesel vehicles. Warner-Selph and co-workers: dichloromethane for 8 hours. Dietzman and co-workers: hexane followed by dichloromethane, extraction times not reported. Graboski and co-workers: VOF by vacuum sublimation at 225° C for 2.5 to 3 hours. Rogge and co-workers: cyclohexane followed by a benzene/2-propanol mixture that may extract significantly more organic matter.

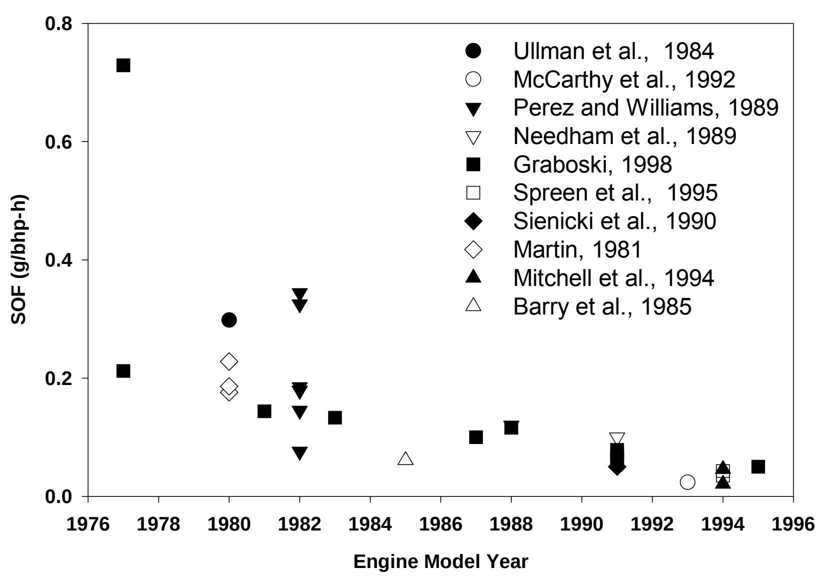

Figure 2-32. Trend in SOF emissions for transient engine dynamometer testing of HD diesel engines. Various extraction methods used; see Table 2-8.

the volatile organic fraction (VOF) ranged from 0.4 g/mi to 4.5 g/mi. These data highlight the wide range in emission rates for of OC, as have been observed for total PM.

Steady-state testing conducted on late-1970s engines reported SOF at levels between 0.1 and 0.9 g/bhp-hr, whereas engines from the late 1980s and 1990s all emitted 0.03 g/bhp-hr or less (Table 2-8). Hori and Narusawa (1998) measured emissions from engines produced two decades apart, using identical analytical procedures, and found that SOF emission factors and the percentage contribution of SOF to DPM were lower in the new engine compared with the old engine, under all tested engine load and speed conditions and with different fuels. The authors reported that the decrease in SOF was due to lower emissions of both lubricating oil and unburned fuel. To meet the 1991 and 1994 U.S. emission standards, SOF emission rates would need to be reduced from the levels of the previous decade, although one may expect differences in SOF fractions of DPM with transient cycles used to determine compliance with emission standards verus steady-state conditions used in earlier test programs (Kawatani et al., 1993; Wachter, 1990). Finally, in the past three decades, for economic reasons engine manufacturers have made efforts to reduce oil consumption and increase the fuel efficiency of diesel engines, both of which would be expected to reduce SOF emissions. Problems in achieving SOF reductions from two-stroke engines were one factor leading to the phaseout of these engines for on-road use during the 1990s. No data are available prior to 1976 on SOF emissions from HD diesel vehicles. The engine technology changes that occurred between the mid-1950s and mid-1970s (high-pressure direct injection and turbocharging, primarily) might be expected to increase the efficiency of combustion and thereby reduce fuel-related SOF. SOF emissions levels in the mid- to late 1970s may be used as a conservative (low) estimate of SOF emissions during the preceding two decades.

The fraction of DPM attributed to SOF from chassis dynamometer studies also shows a decreasing trend over time, from SOFs that ranged up to approximately 50% in the 1980s to 20% SOF or less in the 1990s (Figure 2-33). The recent study by Fritz et al. (2001) reported the fraction of DPM attributed to VOF from 10% to 60% for HDDVs of model years 1951-1974. The wide range in SOF as a percent of DPM displayed in Figure 2-33 is suspected to result from factors such as engine deterioration and test cycle. The vehicle emissions data reported in Figure 2-33 do not overrepresent buses that are likely to emit DPM with a greater fraction of SOF than other vehicles. Figure 2-34 presents SOF as a fraction of DPM from the same engine dynamometer studies reported in Figure 2-32. These data do not reflect a downward trend in SOF as a fraction of DPM. Because similar extraction methods were used in reports of the SOF in both the chassis and engine dynamometer studies, this does not appear to be a source of the wide variability observed in the fraction of SOF reported. In some of the engine studies, improved air:fuel ratio control was tested in an attempt to lower carbonaceous DPM formation.

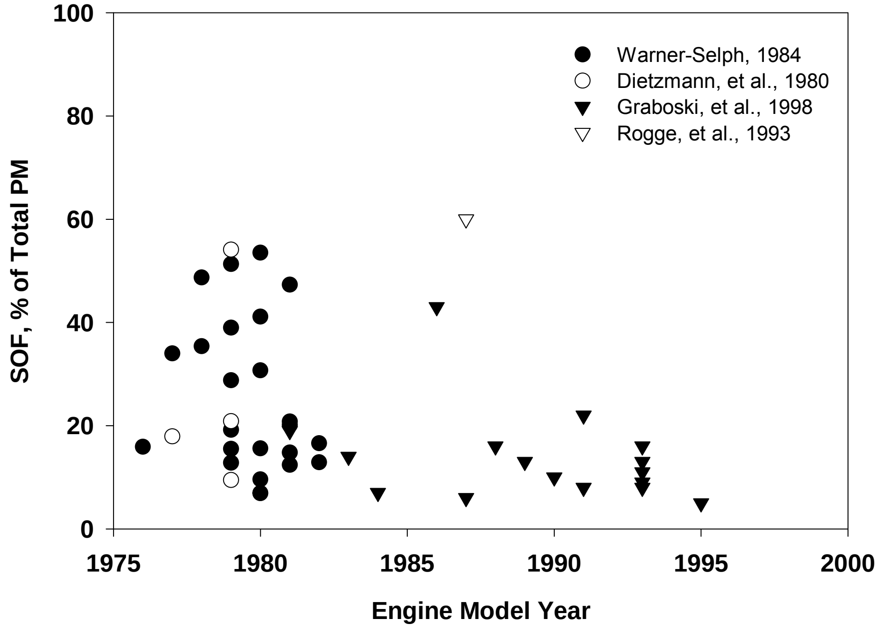

Figure 2-33. Trend in SOF emissions as a percent of total PM based on chassis dynamometer testing of HD diesel vehicles. Warner-Selph and co-workers: dichloromethane for 8 hours. Dietzman and co-workers: hexane followed by dichloromethane, extraction times not reported. Graboski and co-workers: VOF by vacuum sublimation at 225° C for 2.5 to 3 hours. Rogge and co-workers: cyclohexane followed by a benzene/2-propanol mixture that may extract significantly more organic matter.

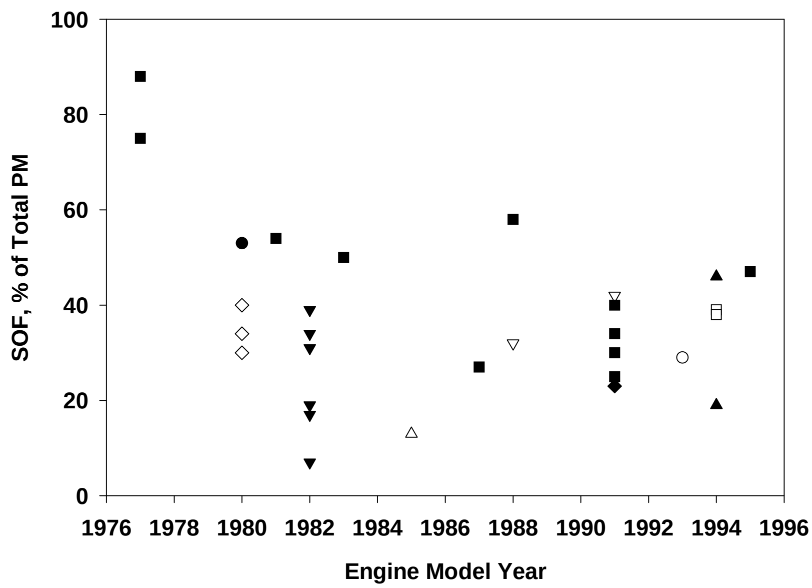

Figure 2-34. Trend in SOF emissions as a percentage of total PM from engine dynamometer testing. Data are from Table 2-8. (See Figure 2-32 for figure key.)

Therefore, substantial differences in SOF as a percent of total DPM could be the result of different engine technology or test conditions. The engine dynamometer results presented in Figures 2-32 and 2-34 are from new, or relatively new, engines, that is, engines with no deterioration, whereas the older engines tested on a chassis dynamometer may have experienced significant deterioration that would increase SOF emissions as a percent of DPM. One of the main differences suspected for the lack of a decreasing trend in the percent of SOF in the engine dynamometer studies is the test cycle used. The engine dynamometer tests typically include test modes, such as high speed and low load, or low-speed lugging modes, that produce much higher SOF relative to DPM than the driving cycles used on the chassis tests.

It appears that as a fraction of total DPM, SOF from new model year HD diesel vehicles is lower than that from older (pre-1990) HD diesel vehicles. However, as with total DPM emissions, a wide range in the fraction of SOF can be observed under different driving conditions and from vehicles with extensive engine wear. In general, DPM emissions have a lower fraction of organic matter compared to gasoline PM (Table 2-13). Recent testing of HD engines at the Desert Research Institute suggests that the OC fraction of DPM is approximately 19%, whereas earlier studies reported in the U.S. EPA SPECIATE database suggest a slightly higher organic fraction of DPM from HD diesel vehicles, ranging from 21% to 36%. The SPECIATE database represents older vehicles that, as discussed above, tend to have higher SOF emissions. The OC emissions from LD diesel vehicles recently reported by Norbeck et al. (1998c) and those reported by the U.S. EPA SPECIATE suggest that LD diesel vehicles emit DPM with a slightly higher organic content than that from HD diesel vehicles, ranging from 22% to 43%. Gasoline engine PM emissions have recently been analyzed at the Desert Research Institute by Fujita et al. (1998) and Watson et al. (1998) for hot stabilized, visibly smoking vehicles, and cold-starts. These data all indicate that LD gas vehicles emit PM with a higher fraction of organic matter than diesel vehicles, with the highest organic content measured from smoking and high-emitting gasoline vehicles (averaging 76% OC). One new finding from the data reported by Fujita et al. (1998) is the roughly equivalent emission of organic and EC from cold-start emissions of gasoline vehicles. Additional information is needed to characterize a range of OC for DPM from smoking and high-emitting diesel vehicles as well as cold-start HD diesel vehicles.

2.2.8.1.3. ***Trends in EC content.*** Because EC is a major component of the chemical source profile of DE, it is commonly used to determine the contribution of diesel vehicles to ambient PM samples (i.e., in source apportionment via chemical mass balance modeling). EC is not, strictly speaking, a regulated pollutant, and so EC emissions are not routinely measured in tests of diesel vehicles and engines. The scant data available on measured EC emissions from HD

Table 2-13. Organic and elemental carbon fractions of diesel and gasoline engine PM exhaust

Engine type	% OC	% Elemental carbon
HD diesel engines[a]	19 ± 8	75 ± 10
HD diesel engines (SPECIATE)[b]	21-36	52-54
LD diesel engines[c]	30 ± 9	61 ± 16
LD diesel engines (SPECIATE)[b]	22-43	51-64
Gasoline engines (hot stabilized)[a]	56 ± 11	25 ± 15
Gasoline engines (smoker and high emitter)[a,c]	76 ± 10	7 ± 6
Gasoline engines (cold start)[a]	46 ± 14	42 ± 14

[a] Fujita et al., 1998, and Watson et al., 1998.
[b] U.S. EPA SPECIATE database.
[c] Norbeck et al., 1998c.

diesel vehicles are plotted in Figure 2-35. Different analytical methods were employed for these studies, making the comparison of emission rates difficult. Results from the three studies, all performed on HD trucks, suggest a decline in EC emission rates by model year since the early 1980s. In a study conducted in 1992, four HD vehicles of unknown vintage were tested and a combined EC emission rate of 0.81 g/mi was reported, which is consistent with the 1990 timeframe in Figure 2-35 (Lowenthal et al., 1994). EC as a percentage of total DPM in these studies ranged from 30% to 90%, most likely as a result of different testing cycles and different engines and different analytical methods.

Figure 2-36 presents these data as EC fraction of total fine PM. The EC content of DPM varied widely in the 1980s from approximately 20% to 90%, whereas in more recent years, the data suggest a smaller range in the EC fraction, from approximately 50% to 90% (with one data point at 30%). Recent emission profiles for HD diesel vehicles suggest that 75% ± 10% of the DPM is attributable to EC, whereas approximately 25% of gasoline PM is composed of EC, except for PM emissions during gasoline vehicle cold-starts, which were found to have an EC content of approximately 42% (Table 2-13). These data also provide evidence that newer model year HD engines generally emit DPM that is more rich in EC than older HD engines.

2.2.8.2. *PAHs and Nitro-PAH Emissions*

PAHs, nitro-PAHs, and oxidized derivatives of these compounds have attracted considerable attention because of their known mutagenic and, in some cases, carcinogenic

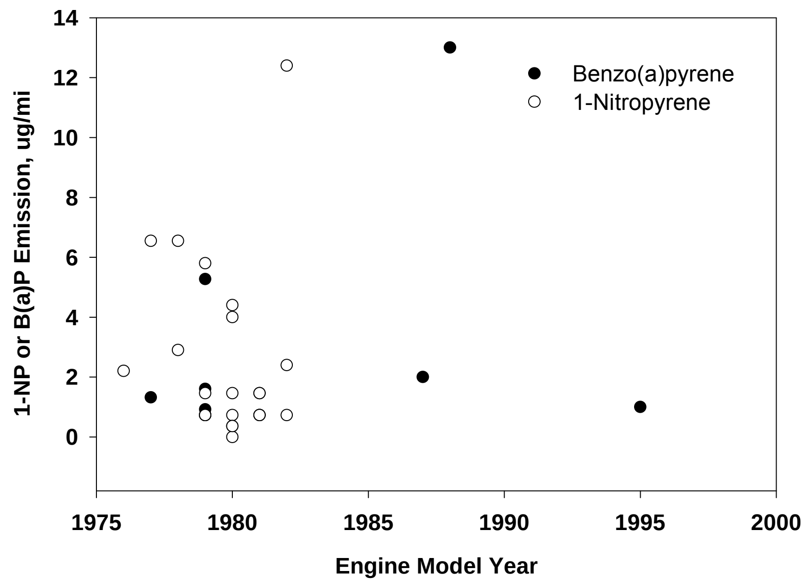

Figure 2-35. EC emission rates for diesel vehicles.

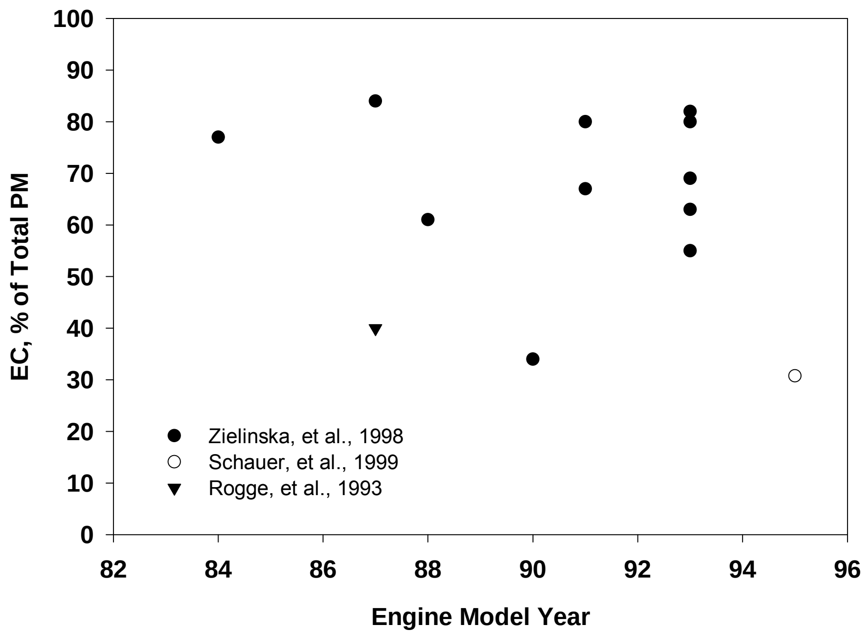

Figure 2-36. EC content as percent of fine PM for DPM samples obtained in chassis dynamometer studies.

character (National Research Council, 1982). In this section, PAH and nitro-PAH concentrations and emission rates and trends in emissions over time are presented.

2.2.8.2.1. ***PAHs identified in DE.*** At least 32 PAHs have been identified in the exhaust of LD diesel vehicles and HD diesel vehicles (Table 2-14) (Watson et al., 1998; Zielinska et al., 1998). Table 2-15 lists the PAHs and thioarenes identified in three LD diesel vehicles' DPM extracts, reported as ng/g of DPM (Tong et al., 1984). SOF fractions accounted for 11% to 15% of the total DPM mass for the LD diesel vehicles reported by Tong et al. (1984), which is lower than the LD diesel vehicles organic fraction reported by Norbeck et al. (1998c) in Table 2-13. Among the PAHs reported by Watson et al. (1998) and Zielinska et al. (1998), the higher molecular weight compounds (pyrene through coronene) that are expected to partition to the particle phase have emission rates from HD diesel vehicles ranging from below detection limits up to 0.071 mg/mi. HD diesel vehicle emission rates for the lower molecular weight PAHs ranged up to 2.96 mg/mi for dimethylnaphthalenes. In general, among the vehicles tested, PAH emission rates were higher for LD diesel vehicles compared with HD diesel vehicles. Table 2-16 presents emission rates of four representative particle-phase PAHs from HD diesel vehicles, LD diesel vehicles, and gasoline (with and without catalytic converter) engines. Emission rates for benzo[a]pyrene were higher in diesel emissions compared with gasoline emissions, except for the report by Rogge et al. (1993), who used extraction methods different from those in other studies (discussed above).

2.2.8.2.2. ***Nitro-PAHs identified in DE.*** Positive isomer identification for 16 nitro-PAHs has been made utilizing the GC retention times of authentic standards and low- and high-resolution mass spectra as identification criteria. These include 1-nitropyrene; 2-methyl-1-nitronaphthalene; 4-nitrobiphenyl; 2-nitrofluorene; 9-nitroanthracene; 9-methyl-10- nitroanthracene; 2-nitroanthracene; 2-nitrophenanthrene; 1-methyl-9-nitroanthracene; 1-methyl-3-nitropyrene; 1-methyl-6-nitropyrene; 1-methyl-8-nitropyrene; 1,3-, 1,6-, and 1,8-dinitropyrene; and 6-nitrobenzo[a]pyrene. In addition, two nitrated heterocyclic compounds were identified, 5- and 8-nitroquinoline. Forty-five additional nitro-PAHs were tentatively identified in this diesel particulate extract (Paputa-Peck et al., 1983). The concentration of nitro-PAHs adsorbed on diesel particles varies substantially from sample to sample. Usually 1-nitropyrene is the predominant component, and concentrations ranging from 7 to 165 μg/g of particles are reported (Levson, 1988).

Table 2-17 gives the approximate concentrations of several of the abundant nitro-PAHs quantified in the early 1980s LD diesel particulate extracts (with the exception of

Table 2-14. Emission rates of PAH (mg/mi) from LD and HD diesel vehicles

PAH	Light-duty diesel	Heavy-duty diesel
Naphthalene	5.554 ± 0.282	2.451 ± 0.154
2-Menaphthalene	3.068 ± 0.185	2.234 ± 0.152
1-Menaphthalene	2.313 ± 0.134	1.582 ± 0.103
Dimethylnaphthalenes	5.065 ± 0.333	2.962 ± 0.488
Biphenyl	0.743 ± 0.041	0.505 ± 0.037
2-Methylbiphenyl	0.203 ± 0.015	0.049 ± 0.024
3-Methylbiphenyl	1.048 ± 0.063	0.401 ± 0.036
4-Methylbiphenyl	0.447 ± 0.028	0.144 ± 0.021
Trimethylnaphthalenes	6.622 ± 0.563	1.940 ± 0.221
Acenaphthylene	0.422 ± 0.024	0.059 ± 0.087
Acenaphthene	0.096 ± 0.008	0.030 ± 0.040
Phenanthrene	1.411 ± 0.072	0.084 ± 0.011
Fluorene	0.442 ± 0.038	0.066 ± 0.022
Methylfluorenes	1.021 ± 0.091	0.071 ± 0.055
Methylphenanthrenes	1.115 ± 0.064	0.124 ± 0.069
Dimethylphenanthrenes	0.637 ± 0.047	0.090 ± 0.096
Anthracene	0.246 ± 0.025	0.052 ± 0.016
9-Methylanthracene	0.013 ± 0.002	0.434 ± 0.082
Fluoranthene	0.213 ± 0.014	0.044 ± 0.026
Pyrene	0.245 ± 0.020	0.071 ± 0.017
Methyl(pyrenes/fluoranthenes)	0.548 ± 0.045	0.022 ± 0.082
Benzonaphthothiophene	0.002 ± 0.002	0.001 ± 0.027
Benz[a]anthracene	0.020 ± 0.005	0.066 ± 0.046
Chrysene	0.029 ± 0.005	0.009 ± 0.021
Benz[b+j+k]fluoranthene	0.056 ± 0.005	0.009 ± 0.022
Benzo[e]pyrene	0.019 ± 0.003	0.010 ± 0.014
Benzo[a]pyrene	0.013 ± 0.004	0.013 ± 0.044
Indeno[1,2,3-cd]pyrene	0.010 ± 0.003	0.001 ± 0.037
Dibenzo[a]anthracene	0.002 ± 0.003	0.000 ± 0.053
Benzo[b]chrysene	0.001 ± 0.002	0.001 ± 0.027
Benzo[ghi]perlyne	0.018 ± 0.004	0.013 ± 0.048
Coronene	0.006 ± 0.006	0.001 ± 0.095

Table 2-15. Polycyclic aromatic hydrocarbons identified in extracts of diesel particles from LD diesel engine exhaust

Compound	Molec. wt.	Concentration ng/mg extract
Acenaphthylene	152	30
Trimethylnaphthalene	170	140–200
Fluorene	166	100–168
Dimethylbiphenyl	182	30–91
C_4 -Naphthalene	184	285–351
Trimethylbiphenyl	196	50
Dibenzothiophene	184	129–246
Phenanthrene	178	2,186–4,883
Anthracene	178	155–356
Methyldibenzothiophene	198	520–772
Methylphenanthrene	192	2,028–2,768
Methylanthracene	192	517–1,522
Ethylphenanthrene	206	388–464
4H-Cyclopenta[*def*]phenanthrene	190	517–1,033
Ethyldibenzothiophene	212	151–179
2-Phenylnaphthalene	204	650–1,336
Dimethyl(phenanthrene/anthracene)	206	1,298–2,354
Fluoranthene	202	3,399–7,321
Benzo[*def*]dibenzothiophene	208	254–333
Benzacenaphthylene	202	791–1,643
Pyrene	202	3,532–8,002
Ethylmethyl (phenanthrene/anthracene)	220	590–717
Methyl(fluoranthene/pyrene)	216	1,548–2,412
Benzo[*a*]fluorene/benzo[*b*]fluorene	216	541–990
Benzo[*b*]naphtho[2,1-*d*]thiophene	234	30–53
Cyclopentapyrene	226	869–1,671
Benzo[*ghi*]fluoranthene	226	217–418
Benzonaphthothiophene	234	30–126
Benz[*a*]anthracene	228	463–1,076
Chrysene or triphenylene	228	657–1,529
1,2-Binapthyl	254	30–50
Methylbenz[*a*]anthracene	242	30–50
3-Methylchrysene	242	50–192
Phenyl(phenanthrene/anthracene)	254	210–559
Benzo[*j*]fluoranthene	252	492–1,367
Benzo[*b*]fluoranthene	252	421–1,090
Benzo[*k*]fluoranthene	252	91–289
Benzo[*e*]pyrene	252	487–946
Benzo[*a*]pyrene	252	208–558
Benzo[*ah*]anthracene	278	50–96
Indeno[1,2,3-[*cd*]pyrene	276	30–93
Benzo[*ghi*]perylene	276	443–1,050
Dibenzopyrene	302	136–254

Source: Tong et al., 1984.

Table 2-16. Emission rates of particle-bound PAH (μg/mi) from diesel and gasoline engines

PAH	Diesel engines					Gasoline engines			
	HDD			LDD		Noncatalyst		Catalyst	
	(a)	(b)	(c)	(a)	(d)	(c)	(e)	(a)	(c)
Pyrene	71	17.6	36.2	245	66	49.6	45	248	4.0
Fluoranthene	44	27.2	20.8	213	50	77.3	32	196	3.6
Benzo[a]pyrene	13	<0.1	2.1	13	NA	69.6	3.2	1.0	3.0
Benzo[e]pyrene	10	0.24	4.2	19	NA	73.3	4.8	1.0	3.6

(a) Watson et al., 1998 included gas-phase PAH .
(b) Westerholm et al., 1991.
(c) Rogge et al., 1993.
(d) Smith, 1989; 1986 Mercedes Benz.
(e) Alsberg et al., 1985.

3-nitrobenzanthrone, reported recently) in μg/g of particles. Concentrations for some of the nitro-PAHs identified range from 0.3 μg/g for 1,3-dinitropyrene to 8.6 μg/g for 2,7-dinitro-9-fluorenone and 75 μg/g for 1-nitropyrene. More recent nitro-PAH and PAH data for HD diesel engines are reported in units of g/bhp-hr or mass/volume of exhaust, making it impossible to directly compare them to the older data (Norbeck et al., 1998b; Bagley et al., 1996, 1998; Baumgard and Johnson, 1992; Opris et al., 1993; Hansen et al., 1994; Harvey et al., 1994; Kantola et al., 1992; Kreso et al., 1998; McClure et al., 1992; Pataky et al., 1994).

2.2.8.2.3. ***PAH and nitro-PAH emission changes over time.*** It is difficult to compare PAH emissions from different studies because not all investigators analyze for total PAH or the same suite of PAH compounds. Most studies have reported emissions of B[*a*]P or 1-nitropyrene (1-NP) because of their toxicological activity. The results of chassis dynamometer studies in which B[*a*]P or 1-NP were measured are displayed in Figure 2-37. Dietzmann and co-workers (1980) examined four vehicles equipped with late 1970s turbocharged DI engines. Emissions of B[*a*]P from particle extracts ranged from 1.5 to 9 μg/mi. No relationship between engine technology (one of the engines was two-stroke) and B[*a*]P emissions was observed. Rogge and co-workers (1993) reported total particle-associated PAH and B[*a*]P emissions from two 1987 model year trucks (averaged together, four-stroke and turbocharged engines). The total particle-phase PAH emission rate was 0.43 mg/mi and the B[*a*]P emission rate was 2.7 μg/mi. Particle-phase PAH in the Rogge et al. (1993) study accounted for approximately 0.5% of total DPM mass. Schauer and co-workers (1999) recently reported a particle-phase PAH emission rate of 1.9 mg/mi (accounting for about 0.7% of total DPM mass) for a 1995 MD turbocharged and aftercooled truck. B[*a*]P emissions were not reported, but emissions of individual species of similar

Table 2-17. Concentrations of nitro-PAHs identified in LD diesel particulate extracts

Nitro-PAH[a]	Concentration (µg/g of particles)
4-nitrobiphenyl	2.2
2-nitrofluorene	~1.8
2-nitroanthracene	4.4
9-nitroanthracene	1.2
9-nitrophenanthrene	1.0
3-nitrophenanthrene	4.1
2-methyl-l-nitroanthracene	8.3
1-nitrofluoranthene	1.8
7-nitrofluoranthene	0.7
3-nitrofluoranthene	4.4
8-nitrofluoranthene	0.8
1-nitropyrene	18.9; 75[b]
6-nitrobenzo[a]pyrene	2.5
1,3-dinitropyrene[b]	0.30
1,6-dinitropyrene[b]	0.40
1,8-dinitropyrene[b]	0.53
2,7-dinitrofluorene[c]	4.2; 6.0
2,7-dinitro-9-fluorenone[c]	8.6; 3.0
3-nitrobenzanthrone[d]	0.6 to 6.6

[a]From Campbell and Lee (1984) unless noted otherwise. Concentrations recalculated from µg/g of extract to µg/g of particles using a value of 44% for extractable material (w/w).
[b]From Paputa-Peck et al, 1983.
[c]From Schuetzle, 1983.
[d]From Enya et al., 1997 (Isuzu Model 6HEL 7127cc).

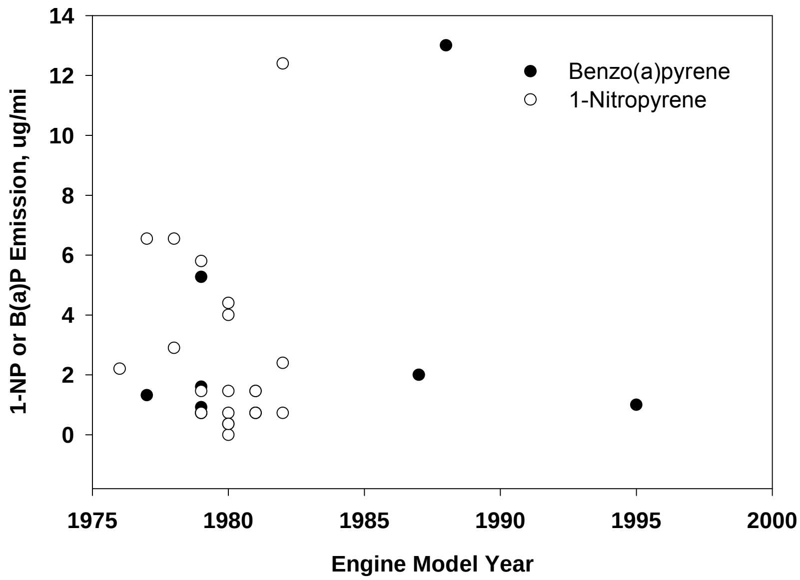

Figure 2-37. Diesel engine emissions of benzo[*a*]pyrene and 1-nitropyrene measured in chassis dynamometer studies.

Source: Schuetzle and Perez, 1983; Zielinska et al., 1988; Kado et al., 1996; Dietzmann et al., 1980; Warner-Selph and Dietzmann, 1984; Rogge et al., 1993; Schauer et al., 1999.

molecular weight were approximately 10 µg/mi. Schauer et al. (1999) also reported a gas-phase PAH emission rate of 6.9 mg/mi for the same truck. Measurements of particle- and gas-phase PAHs conducted for the Northern Front Range Air Quality Study in Colorado (Zielinska et al., 1998) showed an average B[*a*]P emission rate of 13 µg/mi for 15 vehicles ranging from 1983 to 1993 model years. The combined gas- and particle-phase PAH emission rate reported for the NFRAQS study was 13.5 mg/mi. B[*a*]P emissions from chassis studies are summarized in Figure 2-37. Zielinska (1999) reports a decreasing trend in particle-associated DE PAH from 11 measurements made on vehicles from model year 1984 to 1993 with a low correlation coefficient of 0.29.

B[*a*]P emissions reported from diesel engine dynamometer studies are summarized in Figure 2-38. Springer (1979) compared B[*a*]P emissions from naturally aspirated and turbocharged engines and found that naturally aspirated engines emitted about 1 µg B[*a*]P/bhp-hr, and DI and IDI engines emitted about 0.15 µg B[*a*]P/bhp-hr (Table 2-8). The difference between 1 and 0.15 µg/bhp-hr could not be attributed to specific technology changes. The majority of engine test data indicate that B[*a*]P emissions have generally ranged from approximately 1 to 4 µg/bhp-hr over the past 25 years.

Emissions reported for 1-NP from diesel engines tested by chassis dynamometer range from 0.1 to 12 µg/mi (Figure 2-37), and diesel engine dynamometer studies report 1-NP emission factors ranging from 1 to 4 µg/bhp-hr (Figure 2-38). Too few measurements are available to discern trends in the emission rates of these compounds.

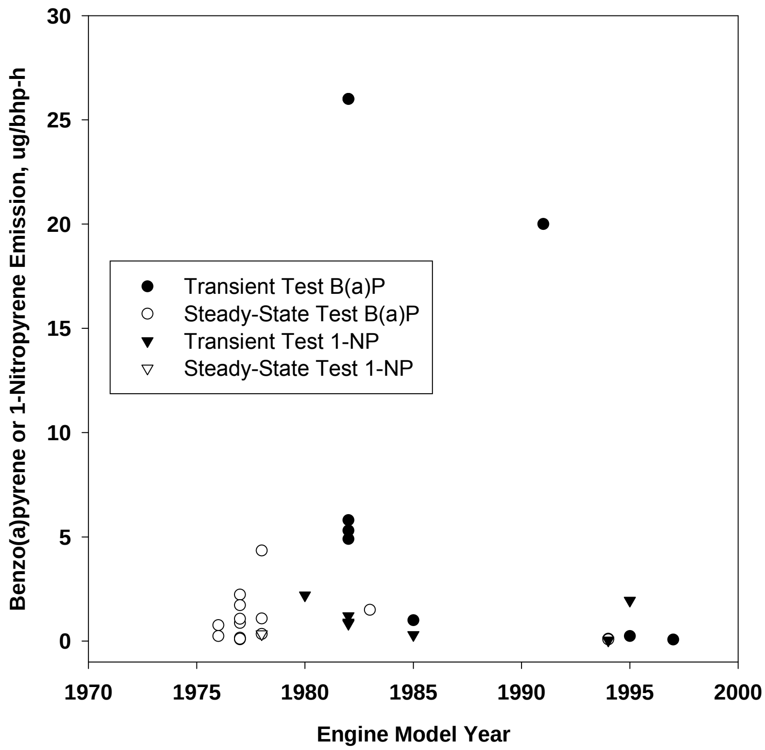

Figure 2-38. Diesel engine dynamometer measurements of benzo[*a*]pyrene and 1-nitropyrene emissions from HD diesel engines.

Source: Data are from Table 2-8.

As discussed in Section 2.2.4, Williams et al. (1987) and Andrews et al. (1998) of the University of Leeds have demonstrated that the solvent-extractable PAH from diesel particulate originates primarily in the fuel. PAH molecules are relatively refractory, so a significant fraction survives the combustion process and is exhausted as DPM. These studies have been confirmed by other research groups (Crebelli et al., 1995; Tancell et al., 1995) that included the use of isotopic labeling of fuel PAH. Additionally, engine oil was found to be a reservoir for PAH that originates in the fuel. Pyrosynthesis of PAH occurs during very high temperature conditions in a diesel engine, and under these conditions many of the DPM and other pyrolysis products are ultimately oxidized before exiting the cylinder. Thus, pyrogenic formation of PAH is thought to contribute a small fraction of the total PAH in diesel engine exhaust. As discussed above, fuel

PAH content is expected to have slowly increased over a 30-year period until 1993, after which PAH content of diesel fuel is expected to have remained constant. Increasing use of catalytic cracking over time may lead to increasing proportions of PAH in distillates; however, fuel standards limit the aromaticity of fuel to 35% (Section 2.2.4).

Recently, Norbeck et al. (1998a) reported on the effect of fuel aromatic content on PAH emissions. Three diesel fuels were used in a Cummins L10 engine: pre-1993 fuel containing 33% aromatic HC and 8% PAH; low aromatic fuel containing a maximum content of 10% aromatic HC and maximum of 1.4% PAH; and a reformulated fuel containing 20% to 25% aromatic HC and 2% to 5% PAH. The investigators found that emission rates for the low-molecular-weight PAHs (PAHs with three or fewer rings) were significantly lower when the engine was tested using the low aromatic fuel compared to when the engine was run on the pre-1993 or reformulated fuel (Table 2-18). Although emission rates reported for several higher molecular weight (particle-associated) PAHs were lower (ranging from 4% to 28% lower) for the low aromatic fuel compared with the other two fuels, the differences were not statistically significant except for coronene.

On the basis of these limited data it is difficult to draw a precise, quantitative conclusion regarding how PAH, B[*a*]P, or 1-NP emissions have changed over time and in response to fuel and engine changes. A decrease in the emissions of PAH from post-1990 model year vehicles and engines compared with pre-1990 vehicles and engines is suggested by the data; however, the data also suggest that differences in a vehicle's engine type and make, general engine condition, fuel composition, and test conditions can influence the emission levels of PAH.

2.2.8.3. *Particle Size*

Figure 2-39 shows a generic size distribution for diesel particulate based on mass and particle number. Approximately 50% to 90% of the number of particles in DE are in the ultrafine size range (nuclei-mode), with the majority of diesel particles ranging in size from 0.005-0.05 μm and the mode at about 0.02 μm. These aerosol particles are formed from exhaust constituents and consist of sulfuric acid droplets, ash particles, condensed organic material, and primary carbon spherules (Abdul-Khalek et al., 1998; Baumgard and Johnson, 1996). Although it accounts for the majority of particles, ultrafine DPM accounts for only 1% to 20% of the mass of DPM.

Approximately 80% to 95% of diesel particle mass is in the size range from 0.05 to 1.0 μm, with a mean particle diameter of about 0.2 μm. The EC core has a high specific surface area of approximately 30 to 50 m^2/g (Frey and Corn, 1967), and Pierson and Brachaczek (1976) report

that after the extraction of adsorbed organic material, the surface area of the diesel particle core

Table 2-18. Average emission rates for polycyclic aromatic hydrocarbons for different fuel types (units are µg/bhp-hr)

PAH	**Pre-1993 diesel fuel** Cetane No. >40 Aromatic 33% v. PAH 8% wt.	**Low aromatic diesel fuel** Cetane No. >48 Aromatic 10% v. PAH 1.4% wt.	**Reformulated diesel blend** Cetane No. 50-55 Aromatic 20%-25% v. PAH 2%-5% wt.
2,3,5-trimethyl naphthalene	283.68 ± 5.27	14.77 ± 2.42	56.21 ± 2.82
Phenanthrene	336.71 ± 9.08	160.92 ± 15.54	220.73 ± 52.68
Anthracene	38.89 ± 1.43	18.54 ± 2.13	26.16 ± 6.86
Methylphenanthrenes/anthracenes	331.32 ± 16.07	25.17 ± 1.41	111.98 ± 28.74
Fluoranthene	128.45 ± 7.60	132.36 ± 18.30	123.07 ± 26.21
Pyrene	193.03 ± 16.51	211.19 ± 37.35	206.82 ± 39.04
Benzo[c]phenanthrene	3.03 ± 0.24	1.74 ± 0.14	1.54 ± 0.26
Benzo[ghi]fluoranthene	24.84 ± 2.68	18.93 ± 2.14	16.94 ± 2.31
Cyclopenta[cd]pyrene	21.44 ± 4.11	26.15 ± 3.12	21.25 ± 3.46
Benz[a]anthracene	16.42 ± 1.67	10.57 ± 1.15	10.96 ± 2.42
Chrysene + triphenylene	17.36 ± 1.66	10.38 ± 0.54	12.20 ± 2.72
Benzo[b+j+k]fluoranthene	31.05 ± 4.17	23.17 ± 1.98	29.18 ± 7.93
Benzo[e]pyrene	16.71 ± 2.72	14.55 ± 1.34	18.99 ± 5.58
Benzo[a]pyrene	20.46 ± 3.27	16.48 ± 1.56	20.59 ± 5.75
Perylene	4.32 ± 0.88	3.71 ± 0.74	4.18 ± 1.16
Indeno[1,2,3-cd]fluoranthene	0.34 ± 0.07	0.21 ± 0.02	0.17 ± 0.00
Benzo[c]chrysene	0.29 ± 0.05	0.18 ± 0.05	0.14 ± 0.04
Dibenz[a,h]anthracene	0.93 ± 0.05	0.55 ± 0.10	0.67 ± 0.09
Indeno[1,2,3-cd]pyrene	19.45 ± 2.71	14.04 ± 1.99	22.16 ± 9.11
Dibenz[a,h+a,c]anthracene	1.54 ± 0.15	0.87 ± 0.12	1.48 ± 0.67
Benzo[b]chrysene	0.40 ± 0.01	0.15 ± 0.05	0.27 ± 0.05
Benzo[ghi]perylene	49.17 ± 9.63	39.81 ± 7.22	60.74 ± 26.60
Coronene	9.49 ± 3.13	4.93 ± 0.47	7.48 ± 1.59
Dibenzo[a,l]pyrene	2.84 ± 0.45	1.25 ± 0.15	2.31 ± 0.48
Dibenzo[a,e]pyrene	1.10 ± 0.29	0.61 ± 0.06	1.13 ± 0.15
Dibenzo[a,i]pyrene	0.91 ± 0.21	0.27 ± 0.09	0.71 ± 0.15
Dibenzo[a,h]pyrene	1.33 ± 0.25	0.75 ± 0.07	0.84 ± 0.20

Source: Norbeck et al., 1998a.

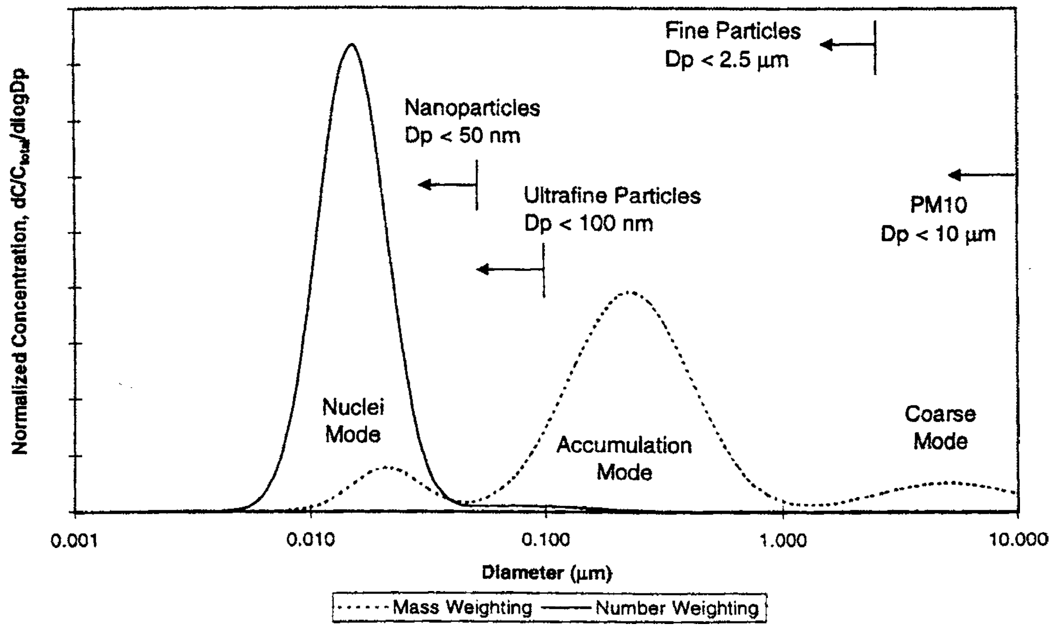

Figure 2-39. Particle size distribution in DE.

Source: Kittelson, 1998.

is approximately 90 m^2/g. Because these particles have a very large surface area per gram of mass, it makes them excellent carriers for adsorbed inorganic and organic compounds; potentially enhancing penetration of such compounds to lower portions of the respiratory tract upon inhalation. In addition, ultrafine aerosols can also reach the same areas of the lung.

Considerable caution is required when reporting particle size measurements from diesel engine exhaust because dilution conditions during the measurement process significantly affect size distributions (i.e., the size distribution is largely a function of how it was measured), and DPM size distributions obtained in dilution tunnel systems may not be relevant to size distributions resulting from the physical transformation of engine exhaust in the atmosphere. Measurements made on diluted DE typically show higher numbers of nuclei-mode particles than do measurements made on raw exhaust because of condensation to form nuclei-mode aerosol upon cooling of the exhaust. To understand particle size distributions emitted from diesel engines, investigators employ various dilution techniques, none of which have been standardized. Dilution ratio, sampling temperature, humidity, relative concentrations of carbon and volatile matter, and other sampling factors can therefore have a large impact on the number and makeup of nuclei-mode particles (Abdul-Khalek et al., 1999; Shi and Harrison, 1999; Lüders et al., 1998; Brown et al., 2000). Dilution air temperature and humidity can have a large effect on particle number and size distribution, especially in the size range below 0.05 μm (also referred to as nanoparticles). Shi and Harrison (1999) report that a high dilution ratio and high relative humidity favor the production of ultrafine particles in diesel engine exhaust. Abdul-Khalek et al. (1998) report that an increase in the residence time of the exhaust during dilution resulted in an increase in the number of particles in exhaust. Khatri et al. (1978) report increased gas-phase HC condensation to DPM with a decrease in dilution air temperature. Some studies report no peak in diesel particles in the ultrafine size range (Kleeman et al., 2000). Kittelson (2000) reports that nanoparticle formation can be prevented by an oxidizing catalyst, which burns organic components of the exhaust, making them unavailable for nucleation or condensation to form an aerosol.

Experiments conducted in a dilution tunnel represent the atmospheric behavior of DE only under the conditions specific to the dilution tunnel and do not represent the full range of atmospheric conditions. Gertler (1999) demonstrated an increase in 0.02 μm particles as the fraction of diesel vehicles in the Tuscarora Mountain tunnel increased from 13% to 78%. These data suggest that the mode at 0.02 μm for ultrafine DPM from DE is evidenced under some real-world conditions.

Several groups have shown that decreasing sulfur content decreases the number of nuclei-mode particles measured in the exhaust, assuming temperature is low enough and residence time is long enough for nucleation and condensation of sulfate aerosol and water in the dilution tunnel (Baumgard and Johnson, 1992, 1996; Opris et al., 1993; Abdul-Khalek et al., 1999). The application of this finding to real-world conditions is difficult to predict, as the number of nuclei-mode particles formed from sulfate and water in the atmosphere will be determined by atmospheric conditions, not by dilution tunnel conditions. With all other factors held constant, it appears that reducing fuel sulfur content reduces the number of sulfate nuclei-mode particles. Thus, the reduction in on-road fuel sulfur content that occurred in 1993 reduced the amount of sulfur dioxide and sulfate available for particle formation. As discussed above, the contribution of sulfate to total DPM mass ranges from 1% to 5% and is therefore not a substantial portion of DPM mass.

More controversial is the suggestion that the DPM emission size distribution from newer technology engines (1991 and later) may be shifted to a much higher number concentration of nuclei-mode particles, independent of fuel sulfur content (Kreso et al., 1998; Abdul-Khalek et al., 1998; Baumgard and Johnson, 1996; Bagley et al., 1996). For example, Kreso and co-workers (1998) compared emissions from a 1995 model year engine with measurements made on 1991 and 1988 model year engines in earlier studies (Bagley et al., 1993, 1996). Nuclei-mode particles made up 40% to 60% of the number fraction of DPM emissions for the 1988 engine and

97%+ of the DPM from the 1991 and 1995 engines. Number concentrations were roughly two orders of magnitude higher for the newer engines. SOF made up 25% to 30% of DPM mass in the 1988 engine and 40% to 80% of DPM mass for the newer engines. Total DPM mass was significantly reduced for the newer engines. It was suggested that increased fuel injection pressure leads to improved fuel atomization and evaporation, in turn leading to smaller primary carbonaceous particles. Dilution conditions (relatively low temperature, low primary dilution ratio, long residence time of more than 3 seconds) strongly favor the formation of nucleation products. The 1991 and 1988 engines were tested with 100 ppm sulfur fuel whereas the 1995 engine was tested with 310 ppm sulfur fuel, which may confound the results to some extent.

The results of Kreso and co-workers (1998) and of Bagley and co-workers (1993, 1996) have been called into question because the high level of SOF emitted by the 1991 engine, particularly at high-load test modes, was inconsistent with SOF values measured for other engines using similar types of technology (Last et al., 1995; Ullman et al., 1995). Kittelson (1998) notes that there is far less carbonaceous DPM formed in newer engines compared with older engines. Accumulation-mode particles may have provided a high surface area for adsorption of sulfate and unburned organic compounds. In the absence of this surface area for adsorption, higher number concentrations of small particles are formed from nucleation of HCs and sulfuric acid.

A study performed at EPA by Pagan (1999) suggested that increased injection pressure can lead to the formation of more nuclei-mode particles in the exhaust. Particle size distributions were measured for diluted exhaust from an engine in which injection pressure could be varied from roughly 35 to 110 MPa (about 5,000–16,000 psi), comparable to pressures obtained with injection technology introduced in the 1980s. The dilution system and particle size measurement setup were identical in all experiments, removing some of the uncertainty in earlier studies that compared engine tests performed years apart. The results showed a clear increase in the number of nuclei-mode particles and a decrease in the number of accumulation-mode particles as injection pressure was increased. This shift did not occur, however, at high engine speeds and loads, but only at low to intermediate speeds and loads. The increase in number concentration of nuclei-mode particles was much lower than the two orders of magnitude increase reported by Kreso et al. (1998) or Bagley et al. (1996). One must use caution in applying the results of Pagan to modern high-injection pressure diesel engines with turbocharging/charge-air cooling because the engine used by Pagan was a naturally aspirated engine to which high-pressure common rail injection was applied. This would likely preclude this particular engine from meeting current on-highway PM or NO_x standards. Although some studies have suggested that increased injection pressure can lead to elevated ultrafine DPM number counts, Kittelson et al.

(1999) cite a German study that reported a decrease in ultrafine DPM number and mass with increasing injection pressure.

Although the majority of particles in DE from modern on-road diesel engines are in the ultrafine size range, evidence regarding a change in the size distribution over time is unclear. To understand the size distribution of DPM to which people are exposed will require measurements under conditions that more closely resemble ambient conditions.

2.3. ATMOSPHERIC TRANSFORMATION OF DIESEL EXHAUST

Primary diesel emissions are a complex mixture containing hundreds of organic and inorganic constituents in the gas and particle phases, the most abundant of which are listed in Table 2-19. The more reactive compounds with short atmospheric lifetimes will undergo rapid transformation in the presence of the appropriate reactants, whereas more stable pollutants can be transported over greater distances. A knowledge of the atmospheric transformations of gaseous and particulate components of diesel emissions and their fate is important in assessing environmental exposures and risks. This section describes some of the major atmospheric transformation processes for gas-phase and particle-phase DE, focusing on the primary and secondary organic compounds that are of significance for human health. For a more comprehensive summary of the atmospheric transport and transformation of diesel emissions, see Winer and Busby (1995).

2.3.1. Gas-Phase Diesel Exhaust

Gas-phase DE contains organic and inorganic compounds that undergo various chemical and physical transformations in the atmosphere, depending on the abundance of reactants and meteorological factors such as wind speed and direction, solar radiation, humidity, temperature, and precipitation. Gaseous DE will react primarily with the following species (Atkinson, 1988):

- Sunlight, during daylight hours
- Hydroxyl (OH) radical, during daylight hours
- Ozone (O_3), during daytime and nighttime
- Hydroperoxyl (HO_2) radical, typically during afternoon/evening hours
- Gaseous nitrate (NO_3) radicals or dinitrogen pentoxide (N_2O_5), during nighttime hours
- Gaseous nitric acid (HNO_3) and other species such as nitrous acid (HONO) and sulfuric acid (H_2SO_4).

Table 2-19. Classes of compounds in diesel exhaust

Particulate phase		Gas phase	
Heterocyclics, hydrocarbons (C_{14}-C_{35}), and PAHs and derivatives:		Heterocyclics, hydrocarbons (C_1-C_{10}), and derivatives:	
Acids	Cycloalkanes	Acids	Cycloalkanes, Cycloakenes
Alcohols	Esters	Aldehydes	Dicarbonyls
Alkanoic acids	Halogenated cmpds.	Alkanoic acids	Ethyne
n-Alkanes	Ketones	n-Alkanes	Halogenated cmpds.
Anhydrides	Nitrated cmpds.	n-Alkenes	Ketones
Aromatic acids	Sulfonates	Anhydrides	Nitrated cmpds.
	Quinones	Aromatic acids	Sulfonates
			Quinones
Elemental carbon		Acrolein	
Inorganic sulfates and nitrates		Ammonia	
Metals		Carbon dioxide, carbon monoxide	
Water		Benzene	
		1,3-Butadiene	
		Formaldehyde	
		Formic acid	
		Hydrogen cyanide, hydrogen sulfide	
		Methane, methanol	
		Nitric and nitrous acids	
		Nitrogen oxides, nitrous oxide	
		Sulfur dioxide	
		Toluene	
		Water	

Sources: Mauderly, 1992, which summarized the work of Lies et al., 1986; Schuetzle and Frazier, 1986; Carey, 1987; Zaebst et al., 1988, updated from recent work by Johnson, 1993; McDonald, 1997; Schauer et al., 1999.

The major loss process for most of the DE emission constituents is oxidation, which occurs primarily by daytime reaction with OH radical (Table 2-20). For some pollutants, photolysis, reaction with O_3, and reactions with NO_3 radicals during nighttime hours are also important removal processes. The atmospheric lifetimes do not take into consideration the potential chemical or biological importance of the products of these various reactions. For example, the reaction of gas-phase PAHs with NO_3 appears to be of minor significance as a PAH loss process, but it is more important as a route of formation of mutagenic nitro-PAHs. The reaction products for some of the major gaseous DE compounds are listed in Table 2-21 and are discussed briefly below.

2.3.1.1. *Organic Compounds*

The organic fraction of diesel is a complex mixture of compounds, very few of which have been characterized. The atmospheric chemistry of several organic constituents of DE (which are also produced by other combustion sources) has been studied. A few of these

Table 2-20. Calculated atmospheric lifetimes for gas-phase reactions of selected compounds present in automotive emissions with important reactive species

Compound	Atmospheric lifetime resulting from reaction with:				
	OH^a	$O_3{}^b$	$NO_3{}^c$	$HO_2{}^d$	hv^e
NO_2	1.3 days	12 h	24 min	2 h	2 min
NO	2.5 days	1 min	1.2 min	20 min	—
HNO_3	110 days	—	—	—	—
SO_2	16 days	>200 years	>1.4×10^4 years	>600 years	—
NH_3	90 days	—	—	—	—
Propane	12 days	>7,000 years	—	—	—
n-Butane	5.6 days	>4,500 years	3.6 years	—	—
n-Octane	1.9 days	—	1.2 years	—	—
Ethylene	1.9 days	9 days	1.2 years	—	—
Propylene	7 h	1.5 days	6 days	—	—
Acetylene	19 days	6 years	>5.6 years	—	—
Formaldehyde	1.9 days	>2 - 104 years	84 days	23 days	4 h
Acetaldehyde	0.6 day	>7 years	20 days	—	60 h
Benzaldehyde	1.2 days	—	24 days	—	—
Acrolein	0.6 day	60 days	—	—	—
Formic acid	31 days	—	—	—	—
Benzene	11 days	600 years	>6.4 years	—	—
Toluene	2.5 days	300 years	3.6 years	—	—
m-Xylene	7 h	75 years	0.8 years	—	—
Phenol	6 h	—	8 min	—	—
Naphthalene[f]	6.8 h	>80 days	1.5 years	—	—
2-Methylnaphthalene[f]	2.8 h	>40 days	180 days		—
1-Nitronaphthalene[f]	2.3 days	>28 days	1 8 years		1.7 h
Acenaphthene[f]	1.5 h	>30 days	1.2 h	—	—
Acenaphthylene[f]	1.3 h	~43 min	6 min	—	—
Phenanthrene[f]	11.2 h	41 days	4.6 h	—	—
Anthracene[f]	8.6 h	—	—	—	—
Fluoranthene[f]	~2.9 h	—	~1 year	—	—
Pyrene[f]	~2.9 h	—	~ 120 days	—	—

[a] For 12-h average concentration of OH radical of 1.6×10^6 molecule/cm^3 (Prinn et al., 1992).
[b] For 24-h average O_3 concentration of 7×10^{11} molecule/cm^3.
[c] For 12-h average NO_3 concentration of 5×10^8 molecule/cm^3 (Atkinson, 1991).
[d] For 12-h average HO_2 concentration of 10^8 molecule/cm^3.
[e] For solar zenith angle of 0°.
[f] Lifetimes from Arey (1998), for 12-h concentration of OH radical of 1.9×10^6 molecule/cm^3.

Source: Winer and Busby, 1995, unless noted otherwise.

Table 2-21. Major components of gas-phase diesel engine emissions, their known atmospheric transformation products, and the biological impact of the reactants and products

Gas-phase emission component	Atmospheric reaction products	Biological impact
Carbon dioxide	—	Major contributor to global warming.
Carbon monoxide	—	Highly toxic to humans; blocks oxygen uptake.
Oxides of nitrogen	Nitric acid, ozone	Nitrogen dioxide is a respiratory tract irritant and major ozone precursor. Nitric acid contributes to acid rain.
Sulfur dioxide	Sulfuric acid	Respiratory tract irritation. Contributor to acid rain.
Hydrocarbons:		
Alkanes ($\leq C_{18}$)	Aldehydes, alkyl nitrates, ketones	Respiratory tract irritation. Reaction products are ozone precursors (in the presence of NO_x).
Alkenes ($\leq C_4$) (e.g., 1,3-butadiene)	Aldehydes, ketones	Respiratory tract irritation. Some alkenes are mutagenic and carcinogenic. Reaction products are ozone precursors (in the presence of NO_x).
Aldehydes:		
Formaldehyde	Carbon monoxide, hydroperoxyl radicals	Formaldehyde is a probable human carcinogen and an ozone precursor (in the presence of NO_x).
Higher aldehydes (e.g., acetaldehyde, acrolein)	Peroxyacyl nitrates	Respiratory tract and eye irritation; causes plant damage.
Monocyclic aromatic compounds (e.g., benzene, toluene)	Hydroxylated and hydroxylated-nitro derivatives[a]	Benzene is toxic and carcinogenic in humans. Some reaction products are mutagenic in bacteria (Ames assay).
PAHs (≤4 rings) (e.g., phenanthrene, fluoranthene)[b]	Nitro-PAHs (4 rings)[c]	Some of these PAHs and nitro-PAHs are known mutagens and carcinogens.
Nitro-PAHs (2 and 3 rings) (e.g., nitronaphthalenes)	Quinones and hydroxylated-nitro derivatives	Some reaction products are mutagenic in bacteria (Ames assay).

[a]Some reaction products expected to partition into the particle phase.
[b]Nitro-PAHs with more than two rings will partition into the particle phase.
[c]PAHs containing four rings are usually present in both the vapor and particle phases.

Source: Health Effects Institute, 1995.

2.3.1.1. *Organic Compounds*

The organic fraction of diesel is a complex mixture of compounds, very few of which have been characterized. The atmospheric chemistry of several organic constituents of DE (which are also produced by other combustion sources) has been studied. A few of these reactions and their products are discussed below. For a complete summary of the atmospheric chemistry of organic combustion products, see Seinfeld and Pandis (1998).

Acetaldehyde forms peroxyacetyl nitrate (via formation of peroxyl radicals and reaction with NO_2), which has been shown to be a direct-acting mutagen toward *S. typhimurium* strain TA100 (Kleindienst et al., 1985) and is phytotoxic. Benzaldehyde, the simplest aromatic aldehyde, forms peroxybenzoyl nitrate or nitrophenols following reaction with oxides of nitrogen (Table 2-21).

For those PAHs present in the gas phase, reaction with the OH radical is the major removal route, leading to atmospheric lifetimes of a few hours in daylight. The gas-phase reaction of PAHs containing a cyclopenta-fused ring such as acenaphthene, acenaphthylene, and acephenanthrylene with the nitrate radical may be an important loss process during nighttime hours. Relatively few data are available concerning the products of these gas-phase reactions. It has been shown that in the presence of NO_x, the OH radical reactions with naphthalene, 1- and 2-methylnaphthalene, acenaphthylene, biphenyl, fluoranthene, pyrene, and acephenanthrylene lead to the formation of nitroarenes (Arey et al., 1986; Atkinson, 1986; Atkinson et al., 1990; Zielinska et al., 1988, 1989a; Arey, 1998). In addition, in a two-step process involving OH radical reaction and NO_2 addition, 2-nitrofluoranthene and 2-nitropyrene can be formed and eventually partition to the particle phase, as will other nitro-PAHs.

The addition of the NO_3 radical to the PAH aromatic ring leads to nitroarene formation (Sweetman et al., 1986; Atkinson et al., 1987, 1990; Zielinska et al., 1989a). The gas-phase reactions of NO_3 radical with naphthalene, 1- and 2-methylnaphthalene, acenaphthene, phenanthrene, anthracene, fluoranthene, and pyrene produce, in general, the same nitro-PAH isomers as the OH radical reaction, but with different yields (Arey et al., 1989; Sweetman et al., 1986; Atkinson et al., 1987, 1990; Zielinska et al., 1986, 1989a). For example, the same 2-nitrofluoranthene is produced from both OH radical and NO_3 gas-phase reactions, but the reaction with NO_3 produces a much higher yield. The production of several nitroarene compounds has been studied in environmental chambers (Arey et al., 1989; Zielinska et al., 1990; Atkinson and Arey, 1994; Arey, 1998; Feilberg et al., 1999), and generally the same nitro-PAH isomers formed from reaction with OH and NO_3 radicals are observed in ambient air samples. Secondary formation of nitroarenes through the gas-phase reactions of the 2-, 3-, and 4-ring PAHs is the major source for many of the nitroarenes observed in ambient air (Pitts et al., 1985a-c; Arey et al., 1986; Zielinska et al., 1988). Photolysis is the major removal pathway for nitroarenes with lifetimes of approximately 2 hours (Feilberg et al., 1999; Nielsen and Ramdahl, 1986).

2.3.1.2. *Inorganic Compounds*

SO_2 and oxides of nitrogen (primarily NO) are emitted from diesel engines. SO_2 is readily oxidized by the OH radical in the atmosphere, followed by formation of the HO_2 radical and HSO_3, which rapidly reacts with water to form H_2SO_4 aerosols. Because SO_2 is soluble in water, it is scavenged by fog, cloud water, and raindrops. In aqueous systems, SO_2 is readily oxidized to sulfate by reaction with hydrogen peroxide (H_2O_2), O_3, or O_2 in the presence of a metal catalyst (Calvert and Stockwell, 1983). Sulfur emitted from diesel engines is predominantly (~98%) in the form of SO_2, a portion of which will form sulfate aerosols by the reaction described above. Nonroad equipment, which typically uses fuel containing 3,300 ppm sulfate, emits more SO_2 than on-road diesel engines, which use fuels currently containing an average of 340 ppm sulfur because of EPA regulations effective in 1993 decreasing diesel fuel sulfur levels. EPA estimates that mobile sources are responsible for about 7% of nationwide SO_2 emissions, with diesel engines contributing 74% of the mobile source total (the majority of the diesel SO_2 emissions originate from nonroad engines) (U.S. EPA, 1998b).

NO is also oxidized in the atmosphere to form NO_2 and particulate nitrate. The fraction of motor vehicle NO_x exhaust converted to particulate nitrate in a 24-hour period has been calculated using a box model to be approximately 3.5% nationwide, a portion of which can be attributed to DE (Gray and Kuklin, 1996). EPA estimates that in 1997, mobile sources were responsible for about 50% of nationwide NO_x emissions, with diesel engines being responsible for approximately one-half of the mobile source total (U.S. EPA, 1998b).

2.3.1.3. *Atmospheric Transport of Gas-Phase DE*

Gas-phase DE can be dry deposited, depending on the deposition surface, atmospheric stability, and the solubility and other chemical properties of the compound. Dry deposition of organic species is typically on the order of weeks to months, with dry deposition velocities of approximately 10^{-4} cm/sec (Winer and Busby, 1995). In contrast, inorganic species such as SO_2 and nitric acid have relatively fast deposition rates (0.1–2.5 cm/sec) and will remain in the atmosphere for shorter time periods compared with the organic exhaust components. Some gas-phase species will also be scavenged by aqueous aerosols and potentially deposited via precipitation. These processes can greatly reduce the atmospheric concentration of some vapor-phase species. Atmospheric lifetimes for several gas-phase components of DE are on the order of hours or days, during which time atmospheric turbulence and advection can disperse these pollutants widely.

2.3.2. Particle-Phase Diesel Exhaust

Particle-associated DE is composed of primarily carbonaceous material (organic and EC) with a very small fraction composed of inorganic compounds and metals. The OC fraction adsorbed on DPM is composed of high-molecular-weight compounds, such as PAHs, which are generally more resistant to atmospheric reactions than PAHs in the gas phase. The EC component of DE is inert to atmospheric degradation, whereas the PAH compounds are degraded by reaction with the following species:

- Sunlight, during daytime hours
- O_3, during daytime and nighttime
- NO_3 and N_2O_5, during nighttime hours
- OH and HO_2
- NO_2, during nighttime and daytime hours
- H_2O_2
- HNO_3 and other species such as HONO and H_2SO_4.

Because many of the PAH derivatives formed by reaction with some of the reactants listed above have been found to be highly mutagenic, a brief discussion of PAH photolysis, nitration, and oxidation follows. Some of the major degradation products from particulate DE and their biological impact are listed in Table 2-22.

2.3.2.1. *Particle-Associated PAH Photooxidation*

Laboratory studies of photolysis of PAHs adsorbed on 18 different fly ashes, carbon black, silica gel, and alumina (Behymer and Hites, 1985, 1988) and several coal stack ashes (Yokely et al., 1986; Dunstan et al., 1989) have shown that the extent of photodegradation of PAHs depends very much on the nature of the substrate to which they are adsorbed. The dominant factor in the stabilization of PAHs adsorbed on fly ash was the color of the fly ash, which is related to the amount of carbon black present. It appears that PAHs were stabilized if the carbon black content of the fly ash was greater than approximately 5%. On black substrates, half-lives of PAHs studied were on the order of several days (Behymer and Hites, 1988). The environmental chamber studies of Kamens et al. (1988) on the daytime decay of PAHs present on residential wood smoke particles and on gasoline internal combustion emission particles showed PAH half-lives of approximately 1 hour at moderate humidities and temperatures. At very low angle sunlight, very low water vapor concentration, or very low temperatures, PAH daytime half-lives increased to a period of days. The presence and

Table 2-22. Major components of particle-phase diesel engine emissions, their known atmospheric transformation products, and the biological impact of the reactants and products

Particle-phase emission component	Atmospheric reaction products	Biological impact
Elemental carbon	—	Nuclei adsorb organic compounds; size permits transport deep into the lungs (alveoli)
Inorganic sulfate and nitrate	—	Respiratory tract irritation
Hydrocarbons (C_{14}-C_{35})	Little information; possibly aldehydes, ketones, and alkyl nitrates	Unknown
PAHs (≥4 rings) (e.g., pyrene, benzo[a]pyrene)	Nitro-PAHs (≥4 rings)[a] Nitro-PAH lactones	Larger PAHs are major contributors of carcinogens in combustion emissions. Many nitro-PAHs are potent mutagens and carcinogens.
Nitro-PAHs (≥3 rings) (e.g., nitropyrenes)	Hydroxylated-nitro derivatives	Many nitro-PAHs are potent mutagens and carcinogens. Some reaction products are mutagenic in bacteria (Ames assay).

[a]Nitro-PAHs with more than two rings will partition into the particle phase.
Source: Health Effects Institute, 1995.

composition of an organic layer on the aerosol seems to influence the rate of PAH photolysis (Jang and McDow, 1995; McDow et al., 1994; Odum et al., 1994).

Because of limited understanding of the mechanisms of these complex heterogeneous reactions, it is currently impossible to draw any firm conclusion concerning the photostability of particle-bound PAHs in the atmosphere. Because DPM contains a relatively high quantity of EC, it is reasonable to speculate that PAHs adsorbed onto these particles might be relatively stable under standard atmospheric conditions, leading to an anticipated half-life of 1 or more days.

2.3.2.2. *Particle-Associated PAH Nitration*

Since 1978, when Pitts et al. (1978) first demonstrated that B[*a*]P deposited on glass-fiber filters exposed to air containing 0.25 ppm NO_2 with traces of HNO_3 formed nitro-B[*a*]P, numerous studies of the heterogeneous nitration reactions of PAHs adsorbed on a variety of substrates in different simulated atmospheres have been carried out (Finlayson-Pitts and Pitts, 1986). PAHs deposited on glass-fiber and Teflon-impregnated glass-fiber filters react with gaseous N_2O_5, yielding their nitro derivatives (Pitts et al., 1985b,c). The most abundant isomers formed were 1-NP from pyrene, 6-nitro-B[*a*]P from B[*a*]P, and 3-nitroperylene from perylene.

The formation of nitro-PAHs during sampling may be an important consideration for DPM collection because of the presence of NO_2 and HNO_3 (Feilberg et al., 1999). However, Schuetzle (1983) concluded that the artifact formation of 1-NP was less than 10% to 20% of the 1-NP present in the diesel particles if the sampling time was less than 23 min (one FTP cycle) and if the sampling temperature was not higher than 43 °C. The formation of nitroarenes during ambient high-volume sampling conditions has been reported to be minimal, at least for the most abundant nitropyrene and nitrofluoranthene isomers (Arey et al., 1988).

DPM contains a variety of nitroarenes, with 1-NP being the most abundant among identified nitro-PAHs. The concentration of 1-NP was measured in the extract of particulate samples collected at the Allegheny Mountain Tunnel on the Pennsylvania Turnpike as 2.1 ppm and ~5 ppm by mass of the extractable material from diesel and SI vehicle PM, respectively. These values are much lower than would be predicted on the basis of laboratory measurements for either diesel or SI engines (Gorse et al., 1983). Several nitroarene measurements have been conducted in airsheds heavily affected by motor vehicle emissions (Arey et al., 1987; Atkinson et al., 1988; Zielinska et al., 1989a,b; Ciccioli et al., 1989, 1993). Ambient PM samples were collected at three sites in the Los Angeles Basin during two summertime periods and one wintertime period. Concentrations of 1-NP ranged from 3 pg/m^3, to 60 pg/m^3, and 3-nitrofluoranthene was also present in DPM at concentrations ranging from not detectable to 70 pg/m^3.

2.3.2.3. *Particle-Associated PAH Ozonolysis*

Numerous laboratory studies have shown that PAHs deposited on combustion-generated fine particles and on model substrates undergo reaction with O_3 (Katz et al., 1979; Pitts et al., 1980, 1986; Van Vaeck and Van Cauwenberghe, 1984; Finlayson-Pitts and Pitts, 1986). The dark reaction toward O_3 of several PAHs deposited on model substrates has been shown to be relatively fast under simulated atmospheric conditions (Katz et al., 1979; Pitts et al., 1980, 1986). Half-lives on the order of 1 to several hours were reported for the more reactive PAHs, such as B[*a*]P, anthracene, and benz[a]anthracene (Katz et al., 1979).

The reaction of PAHs deposited on diesel particles with 1.5 ppm O_3 under high-volume sampling conditions has been shown to be relatively fast, and half-lives on the order of 0.5 to 1 hour have been reported for most PAHs studied (Van Vaeck and Van Cauwenberghe, 1984). The most reactive PAHs include B[*a*]P, perylene, benz[a]anthracene, cyclopenta[cd]pyrene, and benzo[ghi]perylene. The benzofluoranthene isomers are the least reactive of the PAHs studied, and benzo[e]perylene is less reactive than its isomer B[*a*]P. The implications of this study for the high-volume sampling ambient POM are important: reaction of PAHs with O_3 could possibly occur under high-volume sampling conditions during severe photochemical smog episodes, when the ambient level of O_3 is high. However, the magnitude of this artifact is difficult to assess from available data.

2.3.2.4. *Atmospheric Transport of DE Particulate Matter*

Ultrafine particles emitted by diesel engines undergo nucleation, coagulation, and condensation to form fine particles. DPM can be removed from the atmosphere by dry and wet deposition. Particles of small diameter (<1 μm), such as DPM, are removed less efficiently than larger particles by wet and dry deposition and thus have longer atmospheric residence times. Dry deposition rates vary depending on the particle size. Because of their small size, DE particles have residence times of several days (dry deposition velocities of approximately 0.01 cm/sec) (Winer and Busby, 1995). Diesel particulates may be removed by wet deposition if they serve as condensation nuclei for water vapor deposition or are scavenged by precipitation in- or below-cloud.

In a study designed to assess the atmospheric concentrations and transport of DE particles, Horvath et al. (1988) doped the sole source of diesel fuel in Vienna with an organometallic compound of the heavy earth element dysprosium. The authors found that in some of the more remote sampling areas, DPM composed more than 30% of the particulate mass, indicating that DPM can be dispersed widely.

2.3.3. Diesel Exhaust Aging

Primary DE is considered "fresh," whereas "aged" DE is considered to have undergone chemical and physical transformation and dispersion over a period of a day or two. Laboratory dilution tunnel measurements represent a homogeneous environment compared to the complex and dynamic system into which real-world DE is emitted. The physical and chemical transformation of DE will vary depending on the environment into which it is emitted. In an urban or industrial environment, DE may enter an atmosphere with high concentrations of oxidizing and nitrating radicals, as well as nondiesel organic and inorganic compounds that may influence the toxicity, chemical stability, and atmospheric residence time.

In general, secondary pollutants formed in an aged aerosol mass are more oxidized, and therefore have increased polarity and water solubility (Finlayson-Pitts and Pitts, 1986). Kamens et al. (1988) reported that photooxidation of particle-bound PAH is enhanced as relative humidity is increased. Weingartner et al. (1997a) and Dua et al. (1999) have reported that unlike many other types of particles, diesel particles do not appear to undergo hygroscopic growth once emitted to the atmosphere and may even shrink in size to some extent under increasing relative humidity conditions. Weingartner et al. (1997a) evaluated the hygroscopic growth of diesel particles and found that freshly emitted diesel particles demonstrated minimal hygroscopic growth (2.5%), whereas aged particles subjected to UV radiation and ozonolysis exhibited somewhat greater but still minimal hygroscopic growth. An increase in the sulfur content of diesel fuel has also been observed to result in somewhat greater water condensation onto diesel particles. To the extent that DE components are oxidized or nitrated in the atmosphere, they may be removed at rates different from their precursor compounds and may exhibit different biological reactivities. Data suggesting that minimal hygroscopic growth of DPM occurs also has implications for the dosimetry of these particles in the lung because the smaller particles will reach the lowest airways of the lung, whereas growth of the particle would result in deposition in the upper airways. The dosimetry of DPM is discussed in Chapter 3.

In a recent experiment, the biological activity of DPM exposed to 0.1 ppm ozone for 48 hours was compared with that of DPM not exposed to ozone (Ghio et al., 2000). Instillations of the ozonated DPM in rat lung resulted in an increase in biological activity (neutrophil influx, increased protein, and lactate dehydrogenase activity) compared with DPM that had not been treated with ozone. These data suggest that ambient levels of ozone can alter DPM constituents causing an increase in toxicity compared with nonozonated DPM.

In addition to changes in particle composition with aging, particle size distributions may vary depending on aggregation and coagulation phenomena in the aging process. People in vehicles, near roadways (e.g., cyclists, pedestrians, people in nearby buildings), and on motorcycles will be exposed to more fresh exhaust than the general population. In some settings where emissions are entrained for long periods through meteorological or other factors, exposures would be expected to include both fresh and aged DE. The complexities of transport and dispersion of emission arising from motor vehicles have been the subject of extensive modeling and experimental studies over the past decades and have been summarized by Sampson (1988); exposures to DPM are discussed in the next section of this chapter.

The major organic constituents of DE and their potential degradation pathways described above provide evidence for (1) direct emission of PAHs, (2) secondary formation of nitroarenes, and (3) secondary sulfate and nitrate formation. Because nitro-PAH products are often more mutagenic than their precursors, the formation, transport, and concentrations of these compounds in an aged aerosol mass are of significant interest.

2.4. AMBIENT DIESEL EXHAUST CONCENTRATIONS AND EXPOSURES

2.4.1. Diesel Exhaust Gases in the Ambient Atmosphere

Although emissions of several DE components have been measured, few studies have attempted to elucidate the contribution of diesel-powered engines to atmospheric concentrations of these components. The emission profile of gaseous organic compounds is different for diesel and SI vehicles; the low-molecular-weight aromatic HCs and alkanes ($<C_9$) are more

characteristic of SI engine emissions, whereas the heavier alkanes ($>C_{10}$) and aromatic HCs (such as naphthalene, methyl- and dimethyl- naphthalenes, methyl- and dimethyl-indans) are more characteristic of diesel engine emissions. These differences were the basis for apportionment of gasoline- and diesel-powered vehicle emissions to ambient nonmethane hydrocarbon (NMHC) concentrations in the Boston and Los Angeles (South Coast Air Basin) urban areas.

The chemical mass balance receptor model (described below) was applied to ambient samples collected in these areas, along with appropriate fuel, stationary, and area source profiles (Fujita et al., 1997). The average of the sum of NMHC attributed to DE, gasoline-vehicle exhaust, liquid gasoline, and gasoline vapor was 73% and 76% for Boston and the South Coast Air Basin (SoCAB), respectively. The average source contributions of DE to NMHC concentrations were 22% and 13% for Boston and the SoCAB, respectively. Diesel vehicles emit lower levels of NMHC in the exhaust compared with gasoline vehicles. The relative contribution of DE clearly depends on several factors, including fleet composition, sampling location (e.g., near a bus station vs. near a highway or other sources), and the contribution from point and area sources. The contribution of DE to ambient NMHC showed large variations among sampling sites in the Boston area. The source apportionment in the Fujita et al. (1997) study indicates that mobile vehicle-related emissions account for the majority of ambient NMHC in the two urban areas studied, and the results can likely be extrapolated to other urban areas with similar source compositions. Other source apportionment methods such as those used by Henry et al. (1994) have been applied to speciated HC data to separate the mobile source direct emission from gasoline evaporative emissions. This method uses a combination of graphical analysis (Graphical Ratio Analysis for Composition Estimates, GRACE) and multivariate receptor modeling methods (Source Apportionment by Factors with Explicit Restrictions, SAFER) and was not used to identify the diesel engine contribution to the HCs measured.

2.4.2. Ambient Concentrations of DPM

Because DPM is chemically complex, an assessment of ambient DPM concentrations relies primarily on (1) studies that collect ambient samples and adequately characterize their chemical composition, or (2) modeling studies that attempt to recreate emissions and atmospheric conditions. Ambient concentrations of DPM also have been reported from studies using surrogate species. The results of these studies are summarized below. Studies conducted in Europe and Japan were reviewed, but for the most part were not included because of questions surrounding the applicability of measurements in locations that use different diesel technology and control measures from those in the United States.

2.4.2.1. *Source Apportionment Studies*

Receptor models are used to infer the types and relative contributions of sources to pollutant measurements made at a receptor site. Receptor models assume that the mass is conserved between the source and receptor site and that the measured mass of each pollutant is a sum of the contributions from each source. Receptor models are referred to as “top-down” in contrast to “bottom-up” methods, which use emission inventory data, activity patterns, and dispersion modeling from the source to predict concentrations at a receptor site.

The most commonly used receptor model for quantifying concentrations of DPM at a receptor site is the chemical mass balance (CMB) model. Input to the CMB model includes measurements of PM mass and chemistry made at the receptor site as well as measurements made of each of the source types suspected to impact the site. Because of problems involving the elemental similarity between diesel and gasoline emission profiles and their co-emission in time and space, chemical molecular species that provide markers for separation of these sources have been identified (Lowenthal et al., 1992). Recent advances in chemical analytical techniques have facilitated the development of sophisticated molecular source profiles, including detailed speciation of PM-associated organic compounds that allow the apportionment of PM to gasoline and diesel sources with increased confidence. CMB analysis that uses speciation of organic compounds in the source profiles is typically referred to as extended species CMB. Older studies that made use of only EC, total OC, trace elements, and major ions in the source profiles (conventional CMB) have been published and are summarized here, but they are subject to more uncertainty. It should be noted that because receptor modeling is based on the application of source profiles to ambient measurements, estimates of DPM concentration generated by this method include the contribution from on-road and nonroad sources to the extent the source profiles are similar (which would include military sources depending on the sampling locations and fleet composition). In addition, this method identifies sources of primary emissions of DPM only, and the contribution of secondary aerosols is not attributed to sources.

The CMB model has been used to assess concentrations of DPM in areas of California, Phoenix, Denver, and Manhattan (Table 2-23). DPM concentrations reported by Schauer et al. (1996) for samples collected in California in 1982 ranged from 4.4 $\mu g/m^3$ in west Los Angeles to 11.6 $\mu g/m^3$ in downtown Los Angeles. The average contribution of DPM to total $PM_{2.5}$ mass ranged from 13% in Rubidoux to 36% in downtown Los Angeles. As mentioned above, this model accounts for primary emissions of DPM only; the contribution of secondary aerosol formation (both acid and organic aerosols) is not included. In sites downwind from urban areas, such as Rubidoux in this study, secondary nitrate formation can account for a substantial fraction of the mass (25% of the fine mass measured in Rubidoux was attributed to secondary nitrate), a portion of which comes from DE (Gray and Kuklin, 1996).

Table 2-23. Ambient DPM concentrations reported from chemical mass balance modeling

Reference	Location	Year of sampling	Location type	Diesel $PM_{2.5}$ $\mu g/m^3$ mean, (range)	Average DPM % of total PM (range)	Source profile used
Schauer et al., 1996	West LA, CA	1982, annual average (~60 samples at each site)	Urban	4.4	18	EC, OCS, elements
	Pasadena, CA		Urban	5.3	19	
	Rubidoux, CA		Urban	5.4	13	
	Los Angeles, CA		Urban	11.6	36	
Chow et al., 1991	West Phoenix, AZ	1989-90, winter 11 days at each site	Urban	13 (max. 22)	18	EC, OCT, MI, elements
	Central Phoenix, AZ		Urban	13 (max. 16)	20	
	South Scottsdale, AZ		Urban	10 (max. 12)	17	
	Estrella Park, AZ		Nonurban	5	9	
	Gunnery Park, AZ		Nonurban	3	10	
	Pinnacle Peak, AZ		Nonurban	2	12	
California EPA, 1998a	California, 6 air basins	1988-92, annual	Urban[c]	1.8–3.6[a]	[b]	EC, OCT, MI, elements
	California, 9 air basins		Nonurban[c]	0.2–2.6[a]	[b]	EC, OCT, MI, elements
Wittorff et al., 1994	Manhattan, NY	1993, spring 3 days	Urban	29.2(13.2–46.7)[a]	53 (31–68)	EC, OCT, MI, elements
Maricopa Association of Governments, 1999	Phoenix, AZ	1994–95, winter 12 days	Urban	2.4 (0–5.3)	15 (0–27)	EC, OCS, MI, elements
Fujita et al., 1998	Welby, CO	1996–97, winter 60 days	Urban	1.7 (0–7.3)	10 (0–26)	EC, OCS, MI, elements
	Brighton, CO		Suburban	1.2 (0–3.4)	10 (0–38)	

[a]PM_{10}.
[b]Not available.
[c]Urban air basins are qualitatively defined as those areas that are moderately or largely urbanized, and nonurban air basins are those areas that are largely nonurban, but may have one or more densely populated areas.
Abbreviations: EC: Elemental carbon; OCT: OC total; OCS: OC species; MI: Major ions including nitrate, sulfate, chloride and, in some cases, ammonium, sodium, potassium.

The California Environmental Protection Agency (Cal EPA) reported ambient DPM concentrations for 15 air basins in California based on ambient measurements taken statewide from 1988 to 1992 (Cal EPA, 1998a). Cal EPA used CMB analysis of ambient measurements from the San Joaquin Valley (1988-89), South Coast (1986), and San Jose (winters for 1991–92 and 1992–93) to determine mobile source contributions and then applied the California 1990 PM_{10} emissions inventory to determine the fraction of mobile source PM_{10} attributable to diesel emissions. The results of this analysis indicate that annual average basin-wide levels of direct DPM may be as low as 0.2 μg/m^3 and may range up to 2.6 μg/m^3 for basins that are largely nonurban but may have one or more densely populated areas (such as Palm Springs in the Salton Sea basin). DPM concentrations for air basins that are moderately or largely urbanized ranged from 1.8 μg/m^3 to 3.6 μg/m^3.

Two studies using CMB analysis that report DPM concentrations have been conducted in the Phoenix area. A wintertime study in 1989–90 reported DPM concentrations for nonurban areas ranging from 2 μg/m^3 to 5 μg/m^3 and DPM concentrations for central and south Phoenix urban areas ranging from 10 μg/m^3 to 13 μg/m^3 (Chow et al., 1991). Chow et al. (1991) reported that DPM levels on single days can range up to 22 μg/m^3 at the central Phoenix site. A more recent study conducted from November 1994 through March 1995 reported DPM concentrations for Phoenix averaging 2.4 μg/m^3 and reaching 5.3 μg/m^3 (Maricopa Association of Governments, 1999). The extended species CMB was used for this study, providing a more confident identification of DPM separate from gasoline PM emissions than the earlier Phoenix study. DPM accounted for an average 15% of ambient $PM_{2.5}$, and gasoline PM accounted for an average of 52% of ambient $PM_{2.5}$ in the 1994–95 Phoenix study.

In a recently published study designed to investigate the ability of a new type of factor analysis, positive matrix factorization, to separate sources contributing to the urban aerosol in Phoenix, Ramadan et al. (2000) report their success in separating the DE PM from other motor vehicle PM. Fine PM samples were collected by two different types of samplers in Phoenix, one set collected from March 1995 through June 1998 and a second set from June 1996 through June 1998. Elemental and OC were analyzed using TOT. Particles of DE origin were identified by their high EC content in addition to specific trace elements, including manganese, sulfur, and iron. DPM concentrations exceeding 5 μg/m^3 were reported for winter months during the study period. The investigators concluded that motor vehicles, vegetative burning, and HD DE were the three major sources contributing to ambient fine PM in Phoenix, with higher contributions in the winter than in summer.

During the winter of 1997, a study assessed DPM concentrations at two urban sites in the Denver area (Fujita et al., 1998). The Northern Front Range Air Quality Study (NFRAQS), initiated to assess the sources of the “brown cloud” observed along Colorado’s Front Range, conducted air quality sampling during the winter of 1996, summer of 1996, and winter of 1997. For a 60-day period from December 1996 through January 1997, ambient samples collected at two urban Denver sites were analyzed for OC species for use in the extended-species CMB. The average DPM concentrations reported for the urban site at Welby, CO, and the suburban site at Brighton, CO, were 1.7 $\mu g/m^3$ and 1.2 $\mu g/m^3$, respectively. During the study period, DPM concentrations exceeded 5 $\mu g/m^3$ on two occasions in Welby, with reported DPM concentrations of 5.7 $\mu g/m^3$ and 7.3 $\mu g/m^3$. DPM accounted for an average of 10% of ambient $PM_{2.5}$, and gasoline PM accounted for an average of 27% of ambient $PM_{2.5}$.

One of the major claims from the NFRAQS was a substantial contribution of EC from gasoline-powered vehicles, mainly from cold-start and high-emitting vehicles. At the Welby site, the contribution of diesel and gasoline emissions to EC measurements was 52% and 42%, respectively. At the Brighton site, the contribution of diesel and gasoline emissions to EC measurements was 71% and 26%, respectively. The findings from the NFRAQS are compelling and suggest the need for further investigations to quantify the contribution from cold-start and high-emitting vehicle emissions for both gasoline and diesel vehicles. Geographical, temporal, and other site-specific parameters that influence PM concentrations, such as altitude, must be considered when extrapolating the NFRAQS findings to other locations.

In addition to the need for urban and rural average DPM concentrations, an assessment of potential health effects resulting from DPM exposure includes an assessment of people in environments with potentially elevated levels of DPM. Limited data are available to allow a characterization of DPM concentrations in "hotspots" such as near heavily traveled roadways, bus stations, train stations, and marinas. Only one CMB study has attempted to apportion PM measured in an urban hotspot. Wittorff et al. (1994) reported results of conventional CMB performed on PM samples collected in the spring of 1993 over a 3-day period at a site adjacent to a major bus stop on Madison Avenue in midtown Manhattan. Buses in this area idle for as long as 10 minutes, and PM emissions are augmented by the elevated levels of DPM emitted during acceleration away from the bus stop (discussed in Section 2.2.5). DPM concentrations reported from this study ranged from 13.0 $\mu g/m^3$ to 46.7 $\mu g/m^3$. This study attributed, on average, 53% of the PM_{10} to DE. The DPM concentrations resulting from the source apportionment method used in this study require some caution because the CMB model overpredicted PM_{10} concentrations by an average 30%, which suggests that additional sources of the mass were not accounted for in the model. The relevance of the Manhattan bus stop concentrations and potential exposure for large urban populations provide strong motivation for further studies in the vicinity of such hotspots.

In summary, source apportionment studies of ambient samples collected before 1990 suggest that seasonal and annual average DPM concentrations for nonurban areas ranged from 2 μg/m^3 to 5 μg/m^3. DPM concentrations reported from CMB studies for urban areas in the pre-1990 timeframe ranged from 4.4 μg/m^3 to 13 μg/m^3, with concentrations on individual days ranging up to 22 μg/m^3. Source apportionment applied to ambient measurements taken in 1990 or later suggest that seasonal or annual average DPM levels in suburban/nonurban locations can range from 0.2 μg/m^3 to 2.6 μg/m^3, with maximum reported values ranging up to 3.4 μg/m^3. DPM concentrations reported from CMB studies in urban areas during 1990 or later range from 1.7 μg/m^3 to 3.6 μg/m^3, with maximum concentrations up to 7.3 μg/m^3. The highest DPM concentrations reported from CMB analysis of ambient measurements were those in the vicinity of a bus stop in midtown Manhattan, which ranged from 13.2 μg/m^3 to 46.7 μg/m^3.

2.4.2.2. *EC Surrogate for DPM*

EC is a major component of DE, contributing approximately 50% to 85% of diesel particulate mass, depending on engine technology, fuel type, duty cycle, engine lubrication oil consumption, and state of engine maintenance (Graboski et al., 1998b; Zaebst et al., 1991; Pierson and Brachaczek, 1983; Warner-Selph and Dietzmann, 1984). In urban ambient environments, DE is one of the major contributors to EC, with other potential sources including spark-engine exhaust; combustion of coal, oil, or wood; charbroiling; cigarette smoke; and road dust. Although cold-start emissions from gasoline combustion vehicles were reported to be an important source of EC in wintertime samples collected in two cities in the Denver area (Fujita et al., 1998), it is currently unclear to what extent these results are transferable to other locations. It is noteworthy that the EC content of the cold-start emissions from gasoline combustion vehicles was lower than that from diesel combustion engines in the same study by almost a factor of 2.

Fowler (1985) evaluated several components of DE and concluded that EC is the most reliable overall measure of ambient DE exposure. Because of the large portion of EC in DPM, and the fact that DE is one of the major contributors to EC in many ambient environments, DPM concentrations can be bounded using EC measurements. Surrogate calculations of DPM have been based on the fraction of ambient EC measured in a sample that is attributable to diesel engine exhaust and the fraction of the diesel particle mass accounted for by EC. In the recent Multiple Air Toxics Exposure Study in the South Coast Air Basin (MATES-II, SCAQMD, 2000), EC measurements were used to estimate DPM concentrations by the following relationship: approximately 67% of fine EC in the ambient air in the Los Angeles area originates from diesel engine exhaust (Gray, 1986), and the average EC fraction of diesel particles measured was 64%. Therefore, in the MATES-II study, the South Coast Air Quality Management District calculated DPM concentrations from EC measurements by multiplying a measured EC concentration by 67% and dividing by the fraction of DPM mass accounted for by EC of 64%, for example, DPM concentration = (EC * 0.67)/0.64, or DPM = EC * 1.04 (not appreciably different from EC≈DPM). This calculation, used in the MATES-II study, relies on data collected in the 1982 timeframe and may not accurately represent the current day contributions of diesel engines to the ambient EC inventory. Using a 1998 emissions inventory for the South Coast Air Basin, it is now estimated that a more appropriate conversion from EC to DPM is to multiply EC by 1.24 (MATES-II, SCAQMD, 2000).

An alternative calculation can be derived using data from recent studies in Colorado and Arizona (Fujita et al., 1998; Maricopa Association of Governments, 1999). The fraction of EC attributable to DE can be estimated from detailed source profiles applied to a CMB model as discussed above. The contribution of diesel engines to EC averaged 68% ± 20% for Brighton, CO, and 49% ± 26% at Welby, CO, as part of the winter 1996-1997 NFRAQS. In Phoenix, diesel engine exhaust was estimated to account for approximately 46% ± 22% of the ambient EC. For some environments, such as certain occupational settings in which diesel engines are in proximity to workers, all the EC may realistically be attributed to DE as a reasonable upper bound estimate of DPM concentrations.

As discussed in Section 2.2, the EC content of DPM can vary widely depending on engine type, load conditions, and the test cycle. However, typical profiles for HD and LD diesel engines have been determined and the typical EC fraction of DPM ranges from approximately 52% to 75%.

Ambient EC attributed to DE in the studies described above ranges from 46% to 68%. A lower-bound estimate of DPM from ambient EC measurements in areas with similar source contributions to those in the Phoenix and Denver areas can be derived using the equation:

$$DPM = (EC * 0.46)/0.75 \text{ or } DPM = EC * 0.62$$

An upper-bound estimate uses the equation:

$$DPM = (EC * 0.68)/0.52 \text{ or } DPM = EC * 1.31$$

Using the average of the ranges provides the equation:

$$DPM = EC * 0.89.$$

Clearly the choice of a point estimate can provide a surrogate calculation of DPM that can vary by at least a factor of two. Although a recommended surrogate DPM calculation method is not provided here, the surrogate DPM calculation is used to illustrate the usefulness of this approach for estimating DPM in the absence of a more sophisticated receptor modeling analysis for locations where fine PM EC concentrations are available.

One source of variability in EC concentrations reported for ambient studies is the measurement method used to quantify EC. As discussed in Section 2.2.8.1, EC and OC are operationally defined. Ambient samples are typically analyzed for EC using thermal optical reflectance or thermal optical transmittance. The measurement technique used in the NFRAQS and Phoenix studies was TOR, which, as discussed in Section 2.2.8.2, often results in higher EC levels compared to TOT analyses.

Table 2-24 provides a lower- and upper-bound DPM estimate from annual average EC concentrations for three urban areas, in addition to DPM concentrations reported from EC measurements for the MATES- II (SCAQMD, 2000). Under an EPA research grant with the Northeastern States for Coordinated Air Use Management (NESCAUM), $PM_{2.5}$ samples were collected every 6 days for 1 year (1995) in Boston (Kenmore Square), MA, and Rochester, NY, and were analyzed for EC using TOT (Salmon et al., 1997). DPM concentrations were estimated to be in the range from 0.8 μg/m^3 to 1.7 μg/m^3 in Boston, and from 0.4 μg/m^3 to 0.8 μg/m^3 in Rochester (Table 2-24).

Table 2-24. Ambient diesel particulate matter concentrations from elemental carbon measurements in urban locations

Reference	Year of sampling	Location	$DPM_{2.5}$ μg/m^3 lower-upper bound range (point estimate)[a]	DPM % of total PM
Salmon et al., 1997	1995, annual	Boston, MA	0.8–1.7 (1.1)	6-12
		Rochester, NY	0.4-0.8 (0.5)	3-6
Sisler, 1996	1992-1995, annual	Washington, DC	0.9-2.2 (1.5)	4-12
		MATES II [c]	Diesel $PM_{2.5}$ μg/m^3 avg± std dev.	
South Coast Air Quality Management District, 1999	1995-6, annual	Anaheim, CA	2.4 ± 1.8	[b]
		Burbank, CA	3.3 ± 1.9	[b]
		Los Angeles, CA	3.5 ± 1.9	[b]
		Fontanta, CA	3.4 ± 2.3	[b]
		Huntington Park, CA	4.5 ± 2.4	[b]
		Long Beach, CA	2.5 ± 1.7	[b]
		Pico Rivera, CA	4.4 ± 2.2	[b]
		Rubidoux, CA	3.4 ± 2.0	[b]

[a] Lower-bound range: DPM=EC*0.62; upper-bound range: DPM=EC*1.31; point estimate: DPM=EC*0.89.
[b] Not available.
[c]The Multiple Air Toxics Exposure Study in the South Coast Air Basin reported DPM calculated from EC concentrations as DPM=EC*1.04. Standard deviations are reported.

The Interagency Monitoring of Protected Visual Environments (IMPROVE) project being conducted by the National Park Service includes an extensive aerosol monitoring network mainly in rural or remote areas of the country (national parks, national monuments, wilderness areas, national wildlife refuges, and national seashores), and also in Washington, DC (Sisler, 1996). $PM_{2.5}$ samples, collected from March 1992 through February 1995 twice weekly for 24-hour duration at 43 sites (some co-located in the same rural park area), were analyzed for a suite of chemical constituents, including EC (using TOR). EC concentrations in these rural locations may have EC source contributions quite different from those in the urban areas in which the fraction of EC attributable to DE has been reported. The lack of information regarding EC sources in these rural locations makes the application of the EC surrogate highly uncertain. It is noteworthy that annual average EC concentrations in the rural and remote regions reported as part of the IMPROVE network range from 0.1 $\mu g/m^3$ for Denali National Park, AK, to 0.9 $\mu g/m^3$ for the Lake Tahoe, CA, area. In Washington, DC, the annual average EC concentration of 1.7 $\mu g/m^3$ is estimated as an annual average DPM concentration of 1.4 $\mu g/m^3$.

The annual average EC measurements in Washington, DC, suggest that the DPM concentrations are in the range from 1.0 $\mu g/m^3$ to 2.2 $\mu g/m^3$, accounting for 5% to 12% of ambient $PM_{2.5}$. Seasonally averaged data for the Washington, DC, site indicate that EC concentrations and, by extension, DPM concentrations peak in the autumn and winter (2.0 $\mu g/m^3$ and 0.9 $\mu g/m^3$ EC, respectively).

DPM concentrations reported recently as part of the MATES-II study at eight locations ranged from 2.4 $\mu g/m^3$ to 4.5 $\mu g/m^3$. DPM concentrations at Huntington Park and Pico Rivera, CA, were higher than other DPM concentrations in the South Coast Air Basin, perhaps because of higher diesel truck traffic, proximity to nonroad diesel sources, or nondiesel sources of EC, including gasoline vehicle traffic.

In a recent study of the trends in fine particle and EC concentrations in Southern California, Christoforou et al. (2000) report that EC concentrations measured in 1993 were 29%-40% of EC concentrations measured in 1982 at four urban Los Angeles sites. The authors credit lower PM emission rates from on-road diesel engines as well as cleaner-burning diesel fuel for the observed EC decrease. The extent to which nonroad diesel equipment impacts a given site will influence the trend in ambient EC concentrations because fewer regulations have been promulgated to control the PM emissions from these engines.

2.4.2.3. *Dispersion Modeling Results*

Dispersion models estimate ambient levels of PM at a receptor site on the basis of emission factors for the relevant sources and parameters that simulate atmospheric processes such as the advection, mixing, deposition, and chemical transformation of compounds as they are transported from the source to the receptor site(s). Cass and Gray (1995), Gray and Cass (1998), and Kleeman and Cass (1998) have applied dispersion models to the South Coast Air Basin to estimate DPM concentrations. The models used by these investigators applied emission factors from 1982 and consequently are representative of concentrations prior to the implementation of DPM emission controls. In addition to offering another approach for estimating ambient DPM concentrations, dispersion models can provide the ability to distinguish on-highway from nonroad diesel source contributions and have presented an approach for quantifying the concentrations of secondary aerosols from DE.

Cass and Gray (1995) used a Lagrangian particle-in-cell model to estimate the source contributions to atmospheric fine carbon particle concentrations in the Los Angeles area, including diesel emission factors from on-highway and off-highway sources. Their dispersion model indicates that for 1982, the annual average ambient concentrations of DPM ranged from 1.9 $\mu g/m^3$ in Azusa, CA, to 5.6 $\mu g/m^3$ in downtown Los Angeles (Table 2-25). The contribution of on-highway sources to DPM ranged from 63.3% in downtown Los Angeles to 89% in west Los Angeles. Of the on-highway diesel contribution, the model predicted that for southern California, HD trucks made up the majority (85%) of the DPM inventory, and overall they contributed 66% of the DPM in the ambient air. Nonroad sources of DE include pumping stations, construction sites, shipping docks, railroad yards, and heavy equipment repair facilities. Cass and Gray (1995) also report that wintertime peaks in DPM concentrations can reach 10 $\mu g/m^3$.

Table 2-25. Ambient diesel particulate matter concentrations from dispersion modeling

Reference	Location	Year of sampling	Location type	$DPM_{2.5}$ g/m^3 (mean)	DPM % of total PM
Cass and Gray, 1995	Azusa, CA	1982, annual	Nonurban	1.4[a]	5
	Lennox, CA	1982, annual	Nonurban	3.8[a]	13
	Anaheim, CA	1982, annual	Urban	2.7[a]	12
	Pasadena, CA	1982, annual	Urban	2.0[a]	7
	Long Beach, CA	1982, annual	Urban	3.5[a]	13
	Downtown LA, CA	1982, annual	Urban	3.5[a]	11
	West LA, CA	1982, annual	Urban	3.8[a]	16
Kleeman and Cass, 1998	Claremont, CA	18-19 Aug 1987	Nonurban	2.4 (4.0)[a,b]	8 (6)[b]
Kleeman et al., 2000	Long Beach, CA	24 Sept 1996	Urban	1.9(2.6)[b]	8 (7)[b]
	Fullerton, CA	24 Sept 1996	Nonurban	2.4(3.9)[b]	9 (8)[b]
	Riverside, CA	25 Sept 1996	Suburban	4.4(13.3)[b]	12 (13)[b]

[a] On-road diesel vehicles only; all other values are for on-road plus nonroad diesel emissions.
[b] Value in parentheses includes secondary DPM (nitrate, ammonium, sulfate and hydrocarbons) attributable to atmospheric reactions of primary diesel emissions of NO_X, SO_2 and hydrocarbons. For the fraction of ambient PM attributable to DPM, the value in parenthesis reports total DPM (primary plus secondary) as a fraction of total ambient PM (primary plus secondary).

Kleeman and Cass (1998) developed a Lagrangian model that examines the size and chemical evolution of aerosols, including gas-to-particle conversion processes during transport. This model was applied to one well-characterized episode in Claremont, CA, on August 27-28, 1987. The model provided reasonable predictions of PM_{10} (overpredicting PM_{10} by 13%), EC, and OC, and it adequately reconstructed the size distribution of the aerosols. The model indicated that on August 27-28, 1987, the $PM_{2.5}$ concentration was 76.7 $\mu g/m^3$, 13.2% (10.1 $\mu g/m^3$) of which was attributable to diesel engine emissions. This estimate includes secondary aerosol formation for sulfate, ammonium, nitrate, and organic compounds, which accounted for 4.9 $\mu g/m^3$ of the total estimated DPM mass. The secondary organic aerosol was estimated to be 1.1 $\mu g/m^3$, or 31% of the total secondary aerosol mass, with the remainder composed of nitrate, ammonium, and sulfate aerosols.

Dispersion modeling estimates of diesel PM concentrations from on-highway and nonroad sources have recently been developed as part of the EPA National Air Toxics Assessment (NATA) National Scale Assessment. This assessment uses the Assessment System for Population Exposure Nationwide (ASPEN) dispersion model to estimate ambient concentrations for the year 1996. The NATA national scale assessment reports concentrations of DPM and 32 additional urban air toxic compounds at the county, State, and national level (NATA, 2001).

ASPEN makes a number of simplifying assumptions in order to model concentrations on a nationwide scale. For instance, concentration estimates at the census tract level were estimated using modeling assumptions to allocate emissions from the county level, and the model is very sensitive to the assumptions used. In addition, dispersion of emissions from nonpoint sources (e.g., on-highway and nonroad vehicles) was treated simplistically. For resident tracts that have radii greater than 0.3 km, non-point-source ambient concentrations are estimated on the basis of five pseudo-point sources. The average concentration for the census tract is determined by spatially averaging the ambient concentrations associated with the receptors defined for the five pseudosources that fall within the bounds of the tract. Other limitations include the following: terrain impacts on dispersion were not included; the study relied on long-term climate summary data, and no long-range transport was included for DPM (medium-range transport for DPM, within 300 km, was included). Because of the limitations, the results are most meaningfully interpreted when viewed over large geographic areas. The 1996 results from ASPEN compare well (generally within a factor of 1.5) with estimated concentrations from EC measurements and receptor modeling, as well as data from other dispersion modeling studies. The complete results of the assessment are available at http://www.epa.gov/ttn/uatw/nata.

Table 2-26 presents 25th percentile, average, and 75th percentile nationwide concentrations from the 1996 National-Scale Assessment as well as the contribution of on-road and nonroad DE the sources to the nationwide average. The national average DPM concentration reported in the National-Scale Assessment is 2.1 $\mu g/m^3$, of which nonroad sources are estimated to contribute 67% and on-road sources contribute the remainder. Less than 2% of the nationwide DE inventory is attributed to point sources, and these were not included in the modeling as part of National-Scale Assessment. A wide range in average State-specific ambient DPM concentrations was reported by the National-Scale Assessment with the lowest values for mainly rural States with few DE sources, such as Wyoming (annual average of 0.2 $\mu g/m^3$), and the highest values for States with large urban centers such as New York (annual average of 5.4 $\mu g/m^3$).

Table 2-26. Nationwide ambient diesel particulate matter concentrations for 1996 from the National Air Toxics Assessment National-Scale Assessment dispersion modeling

Location	25th percentile, DPM_{10} mg/m^3	Average, DPM_{10} mg/m^3	75th percentile, DPM_{10} mg/m^3	Contribution to average from on-road sources, DPM_{10} mg/m^3	Contribution to average from nonroad sources, DPM_{10} mg/m^3
Nationwide	0.9	2.1	2.5	0.6	1.4
All urban counties	1.2	2.4	2.7	0.7	1.7
All rural counties	0.4	0.7	1.0	0.3	0.5

Source: NATA, 2001. Data available at http://www.epa.gov/ttn/uatw/nata.

2.4.3. Exposures to Diesel Exhaust

Ultimately, it is personal exposure that determines health impacts. In the following sections, modeled average exposures and some information reflecting potential exposures for those who spend a large portion of their time outdoors are presented. Occupational exposures to DPM are summarized for the variety of workplaces in which diesel engines are used. These occupational exposures are placed into context with equivalent environmental exposures to understand the potential for overlap in average occupational and average ambient exposures. Because DE is a mixture of particles and gases, one must choose a measure of exposure (i.e., dosimeter); $\mu g/m^3$ of DPM has historically been used in many studies as the dosimeter for the entire DE mixture.

2.4.3.1. *Occupational Exposure to DE*

The National Institute for Occupational Safety and Health (NIOSH, 1988) estimates that approximately 1.35 million workers are occupationally exposed to DE emissions. Such workers emissions include mine workers, railroad workers, bus and truck drivers, truck and bus maintenance garage workers, loading dock workers, firefighters, heavy equipment operators, and farm workers.

Measurements of DPM exposure in occupational environments have included respirable particulate (<3.5 μm), smoking-corrected respirable particulate, combustible respirable particulate, and EC, among other methods. The measurement method used in each of the studies discussed below is listed in Table 2-27. Occupational exposures to DPM as well as breathing zone concentrations of DPM have been described in some detail by Watts (1995), Groves and Cain (2000), Hammond (1998), the World Health Organization (1996), and Birch and Cary (1996) and are briefly, but not comprehensively, summarized here.

The highest occupational exposures to DPM are for workers in coal mines and noncoal mines using diesel-powered equipment. These exposures, reported by several investigators, range from approximately 10 $\mu g/m^3$ to 1,280 $\mu g/m^3$ (Table 2-27). Rogers and Whelan (1999) report exposures to specific DPM-associated PAHs (including naphthalene, fluorene, phenanthrene, pyrene, and benz[a]anthracene) for mine workers using diesel fuels containing low and high levels of sulfur, aliphatic, and aromatic compounds. Results of this study indicate that the composition of DPM to which workers were exposed varies considerably based on engine condition, fuel, and other operating parameters. Mine worker exposures to PAH compounds were highest for naphthalene, ranging from 1,312 μg/g to 3,228 μg/g of organics, and exposures were lowest for benz[a]anthracene, ranging from less than 3 μg/g up to 18 μg/g of organics.

Other investigators have reported DPM-associated PAH concentrations that do not necessarily represent personal exposures but are a snapshot of short periods of elevated concentration that make up a portion of a worker's daily exposure. Bagley et al. (1991, 1992) reported levels of B[*a*]P ranging from below the detection limit of 0.05 ng/m^3 to 61 ng/m^3 collected only during periods of mining activity. Watts (1995) reported DPM concentrations in four mines collected during significant diesel activity, ranging from 850 $\mu g/m^3$ to 3,260 $\mu g/m^3$. Heino (1978) reports DPM concentrations for locomotive engineers reaching 2,000 $\mu g/m^3$.

In a study of four railroads, Woskie et al. (1988) reported concentrations of respirable dust (corrected for cigarette smoke particulate) that ranged from 39 $\mu g/m^3$ for engineers/firers to 134 $\mu g/m^3$ for locomotive shop workers and 191 $\mu g/m^3$ for hostlers. Woskie et al. (1988) also reported smoking-corrected respirable dust for railroad clerks (17 $\mu g/m^3$), who are considered to be not exposed to DE. Although these exposures may have included nondiesel PM (background

Table 2-27. Occupational exposure to DPM

Author	Year of sample	Location/job type, typical work schedule of 8 hours	n	Sample type	Range in DPM, μg/m³
Gangal and Dainty, 1993[a]	NA	Noncoal mine workers	~200	RCD	100–900
Säverin, 1999	1992	Noncoal mine workers	255[b]	RTC	38–1,280
Rogers and Whelan, 1999	1990-99	Coal mine workers	>1,300	DPSMM	10–640
Haney, 1990[a]	1980s	Coal mine workers (five mines)	NA	SJI	180–1,000
Ambs, 1991a[a]	NA	Coal mine workers (four mines)	NA	PDEAS	750–780
Woskie et al., 1988	3-years in mid-1980s	Railroad engineer/frier	128	ARP	39–73
		Railroad braker/conductor	158	ARP	52–191
		Railroad shop workers	176	ARP	114–134
Groves and Cain, 2000	NA	Railway repair	64	EC(U)	7-50
Froines et al., 1987	1985	Firefighters (two stations)	238	TSP	63–748
NIOSH, 1992[a]	NA	Firefighters (three stations)	18	EC(T)	6–70
Birch and Cary, 1996	NA	Firefighters	NA	EC(U)	20–79
	NA	Fire station employees (four stations)	NA	EC(U)	4–52
Birch and Cary, 1996	NA	Airport ground crew	NA	EC(U)	7–15
	NA	Public transit workers	NA	EC(U)	15–98
NIOSH, 1990	1990	Diesel forklift dockworkers	24	EC(T)	12–61
Zaebst et al., 1991	1990	Dockworkers	75	EC(T)	9–20
		Mechanics	80	EC(T)	5–28
		Long- and short-haul truckers	128	EC(T)	2–7
Groves and Cain, 2000	NA	Bus garage/repair Forklift trucks	53 27	EC(U) EC(U)	7-217 7-403
Kittelson et al., 2000	1999-2000	Bus drivers	39	EC(T)	1–3
		Parking ramp attendants	12	EC(T)	2 ± 0.4

[a] Cited in Watts (1995). NA: not available.
[b] Personal exposure and area samples were not reported separately for this study.
RCD: respirable combustible dust; RTC: respirable total carbon SPM: submicrometer PM; DPSMM: diesel particulate submicron mass (two-stage impaction sampler used to separate PM by size); EC(T): elemental carbon analyzed by TOT; EC(R) elemental carbon analyzed by TOR; EC(U) elemental carbon analyzed by colouremetric method or method not reported; SJI: single-jet impactor agreed within 10% with simultaneous PDEAS measurements; PDEAS: personal DE aerosol sampler collects DPM <0.8 μm, SPM: particulate matter; ARP: respirable particulate adjusted to remove the influence of cigarette smoke; TSP: total suspended particulate matter.

respirable dust levels have been estimated to have contributed approximately 10 $\mu g/m^3$ to 33 $\mu g/m^3$ for this study), the majority of the respirable PM is believed to have originated from diesel locomotive emissions. Groves and Cain (2000) reported EC exposures among railway repair workers averaging 21 $\mu g/m^3$ with a range from 7-50 $\mu g/m^3$. DPM exposures reported for firefighters operating diesel engine vehicles range from 4 $\mu g/m^3$ to 748 $\mu g/m^3$, which also encompasses the range of DPM exposures reported for airport ground crew and public transportation system personnel (7 $\mu g/m^3$ to 98 $\mu g/m^3$).

Studies reporting DE exposure among fire station employees typically report particulate levels below 100 $\mu g/m^3$ (ranging from 4 $\mu g/m^3$ to 79 $\mu g/m^3$) (NIOSH, 1992; Birch and Cary, 1996). In a study by Froines et al. (1987), DPM exposures for firefighters in two stations ranged from 39 $\mu g/m^3$ to 73 $\mu g/m^3$. Birch and Cary (1996) also reported DPM exposures for airport ground crew and public transit workers, ranging from 7 $\mu g/m^3$ to 15 $\mu g/m^3$ for airport ground crews and 15 $\mu g/m^3$ to 98 $\mu g/m^3$ for public transit workers. Dock workers using diesel-powered forklifts have been reported to have DPM exposures ranging from 6 $\mu g/m^3$ to 403 $\mu g/m^3$ (NIOSH, 1990; Zaebst et al., 1991; Groves and Cain, 2000). In studies by NIOSH (1990) and Fowler (1985), the organic material measured accounted for about one-half to almost all of the carbonaceous DPM exposures, providing evidence that some pieces of nonroad equipment (forklifts and construction equipment) emitted DPM with a significant OC fraction in the 1980s and early 1990s.

Zaebst et al. (1991) also reported DPM exposures for mechanics, road drivers, and local drivers for 8-hour shifts at each of six large hub truck terminals. Residential background and highway background samples at fixed sites were also collected during warm-weather and cold-weather periods, and the geometric mean for DPM concentrations ranged from 1 $\mu g/m^3$ to 5 $\mu g/m^3$. DPM exposures for road and local truckers in warm- and cold-weather periods ranged from 2 $\mu g/m^3$ to 7 $\mu g/m^3$, whereas exposure levels for mechanics were reported between 5 $\mu g/m^3$ and 28 $\mu g/m^3$ (geometric means).

Kittelson et al. (2000) are measuring DPM exposures for bus drivers, parking garage attendants, and mechanics using TOT to quantify EC. Personal exposures for bus drivers on four different routes range from 1 $\mu g/m^3$ to 3 $\mu g/m^3$ and exposure among parking ramp attendants averaged 2 $\mu g/m^3$. These results are preliminary, and data for the mechanics have not yet been analyzed. This study will also characterize PAH compounds to which these workers are exposed.

Bus garage workers have also been assessed for exposure to DE using urinary excretion of 8-oxo-2'-deoxyguanosine (Loft et al., 1999). Other biomarkers of DE exposure in occupational workers have included measurements of urinary 1-hydroxypyrene, adducts of DNA and hemoglobin, and 8-hydroxyguanosine in lung tissue (Nielsen et al., 1996; Tokiwa et al., 1999; Zwirner-Baier and Neumann, 1999; Hara et al., 1997).

To estimate an environmental exposure that is equivalent to an occupational lifetime exposure, the fraction of lifetime worker inhalation exposure (calculated as the amount of air breathed on the job multiplied by the typical amount of time spent on the job) is calculated relative to 70-year lifetime inhalation exposure: (10 m^3/shift/20 m^3/day) * (5 days/7 days) * (48 weeks/52 weeks) * (45-year career/70-year lifetime) = 0.21. Using this calculation, 21% of an annual average occupational lifetime exposure is roughly equivalent to a 70-year annual average lifetime environmental exposure. The equivalent environmental exposures for the occupational exposures presented in Table 2-28 range from 0.6 µg/m^3 to 14 µg/m^3 for truckers, dock workers, and mechanics, and from 2 µg/m^3 to 269 µg/m^3 for miners. The low end of the range of environmental equivalent exposures for several of the occupational settings overlaps with average modeled exposures and with ambient concentrations of DPM in urban areas in the 1990–1996 timeframe. The overlap between some occupational exposures and environmental exposures, as well as the small difference between occupational environmental equivalent exposures and environmental exposures, is a significant concern and suggests the potential for significant risk in the general population. The possible magnitude of the cancer risk in the general population is discussed in Chapter 8, Section 8.3.

Table 2-28. Ranges of occupational exposure to DPM by job category with estimates of equivalent environmental exposures

Year of sampling	Occupations	Occupational DPM, µg/m^3	Environmental equivalent[a] exposure, µg/m^3
1980s and 1990s	Miners	10–1,280	2–269
1980s	Railroad workers	39–191	8–40
1985 and later	Firefighters	4–748	1–157
NA	Airport crew, public transit workers	7–98	2–21
1990	Dockworkers, mechanics	5–61	1–13
1990	Long- and short-haul truckers	2–7	0.4–2

[a]Environmental equivalent exposure is calculated as the occupational exposure * (10 m^3/shift / 20 m^3/day)* (5 days / 7days) * (48 weeks / 52 weeks) * (45 year career / 70 year lifetime), or occupational exposure * 0.21 (discussed in section 2.4.3.1.

2.4.3.2. *Ambient Exposure to DE*

Modeled estimates of population exposures to DPM integrate exposure in various indoor and outdoor environments and also account for the demographic distribution, time-activity patterns, and DPM concentrations in various environments, including job-related exposures. Two modeling efforts have been developed to determine DPM exposures in the general population: the Hazardous Air Pollutant Exposure Model for Mobile Sources, version 3 (HAPEM-MS3) and the California Population Indoor Exposure Model (CPIEM). EPA has also developed version 4 of the HAPEM, which provides State-specific average exposures for DPM and 32 other urban air toxic compounds. The draft exposure assessment using HAPEM version 4 (HAPEM4) has been conducted as part of the National Air Toxics Assessment National-Scale Analysis described in Section 2.4.2.3 above and results are provided here.

2.4.3.2.1. ***The Hazardous Air Pollutant Exposure Model.*** To estimate population exposures to DPM, EPA has used HAPEM-MS3 (U.S. EPA, 1999b). This model provides national and urban-area-specific exposures to DPM from on-road sources only. HAPEM-MS3 is based on the CO probabilistic National Ambient Air Quality Standards (NAAQS) exposure model (pNEM/CO), which is used to estimate the frequency distribution of population exposure to CO and the resulting carboxyhemaglobin levels (Law et al., 1997). HAPEM simulates the CO exposure scenario of individuals in 22 demographic groups for 37 microenvironments. CO concentrations are based on ambient measurements made in 1990 and are related to exposures of individuals in a 10-km radius around the sampling site. DPM exposures are calculated as in Equation 2-5, using a ratiometric approach to CO.

$$DPM_{\mu g/m^3} = (CO_{\mu g/m^3} / CO_{g/mi}) \times DPM_{g/mi} \qquad (2\text{-}5)$$

Data provided to the model include CO monitoring data for 1990; time-activity data collected in Denver, Washington, DC, and Cincinnati from 1982 to 1985; microenvironmental data; and 1990 census population data. Motor vehicle DPM and CO emission rates reported by EPA (1999c) are used to calculate mobile-source DPM exposures, and exposures in future years are projected based on the increase in vehicle miles traveled. EPA's PART5 model is used to estimate DPM emission rates (g/mi) for the fleet as a whole in any given calendar year. PART5 is currently being modified to account for deterioration, actual in-use emissions, poor maintenance, and tampering effects, all of which increase emission factors. As a result, HAPEM-MS3 exposure estimates based on PART5 emission factors may underestimate true exposures from on-road sources. A comparison of PART5 HD diesel vehicle emission factors with those presented earlier in this chapter suggests that PART5 may underestimate HD diesel vehicle emissions by up to 50%.

HAPEM-MS3 assumes that the highway fleet (gasoline plus diesel) emissions ratio of CO to DPM can be used as an adjustment factor to convert estimated CO personal exposure to

DPM exposure estimates. This assumption is supported by the observation that even though gasoline vehicles emit the large majority of CO, gasoline and diesel highway vehicles travel on the same roadways. DPM and CO are both relatively long-lived atmospheric species (1–3 days) except under certain conditions (Seinfeld and Pandis, 1998); therefore, the model does not account for chemical and physical differences between the DPM and CO, and the model assumes that for the average person in a modeled air district, CO and DPM are well mixed. Exposure in microscale environments in which these assumptions may not be valid were not modeled.

A validation study conducted for the pNEM/CO model on which HAPEM-MS3 is based indicates that CO exposures for the population in the 5^{th} percentile were overestimated by approximately 33%, whereas those with exposures in the 98^{th} percentile were underestimated by about 30%. This validation study is considered applicable to the HAPEM-MS3 model. To address the underestimate of exposures for the most highly exposed, Brodowicz (1999) used CO concentrations relevant to the most highly exposed populations to determine DPM exposures for different demographic groups within this population; the results are discussed below.

Annual average DPM exposures from on-road vehicles and nonroad sources nationwide for the general population, rural and urban population, outdoor workers, and urban children are reported in Tables 2-29 and 2-30. The modeled annual average DPM exposure nationwide (urban and rural areas) in 1996 from on-road sources only was 0.8 $\mu g/m^3$. The modeled annual average exposure in urban areas for the same year was 0.8 $\mu g/m^3$, and the modeled exposure for rural areas was 0.4 $\mu g/m^3$. Among the demographic groups modeled, urban outdoor workers in general were found to have the highest average exposure to DPM, averaging 1.0 $\mu g/m^3$ from on-road sources in 1996. DPM exposures attributable to on-road sources are projected to decrease until approximately 2007 because of fleet turnover and the full implementation of Federal regulations that are currently in place. Full implementation of the recently finalized Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements would significantly lower DPM exposures from on-road sources in the post-2007 timeframe (U.S. EPA, 2000b).

Because diesel vehicle traffic, and therefore exposure to DPM, varies for different urban areas, HAPEM-MS3 was used to estimate annual average population exposures for 10 urban areas. Modeled 1996 DPM exposures in the cities ranged from 0.6 $\mu g/m^3$ in Chicago and St. Louis to 1.3 $\mu g/m^3$ in Phoenix (Table 2-31). In 1996, estimated average DPM exposure from on-road sources was higher than the national average in five cities: Atlanta, Minneapolis, New York, Phoenix, and Spokane. Nationally in 1996, 97% of DPM exposure from on-road vehicles was attributable to HD diesel vehicles, and the rest was generated mainly by LD diesel trucks.

Table 2-29. Annual average nationwide DPM exposure estimates (μg/m^3) from on-road sources for rural and urban demographic groups in 1990, 1996, and 2007 using HAPEM-MS3

Demographic group	1990	1996	2007
50-State population	0.8	0.8	0.4
Rural population	0.5	0.4	0.2
Urban population	0.9	0.8	0.4
Urban outdoor workers	1.1	1.0	0.5
Urban children (0-17)	0.9	0.8	0.4

Source: U.S. EPA, 1999b, adjusted to reflect HDDV VMT described in U.S. EPA, 2000b.

Table 2-30. Draft annual average, 25th, and 75th percentile nationwide DPM exposure estimates (μg/m^3) from on-road and nonroad sources for rural and urban counties in 1996 using HAPEM4

Demographic group	25th Percentile, DPM_{10} mg/m^3	Average, DPM_{10} mg/m^3	75th Percentile, DPM_{10} mg/m^3	Contribution to average from on-road sources, DPM_{10} mg/m^3	Contribution to average from nonroad sources, DPM_{10} mg/m^3
Nationwide	0.6	1.4	1.8	0.5	0.9
Rural population	0.3	0.6	0.7	0.2	0.3
Urban population	0.8	1.6	2.0	0.5	1.1

Source: NATA, 2001. Data available at http://www.epa.gov/ttn/uatw/nata.

Because HAPEM-MS3 is suspected to underestimate exposures in highly exposed populations, 1990 CO concentrations relevant to the most highly exposed populations were used to determine 1990 DPM exposures for different demographic groups in this population. The highest DPM exposures ranged from 0.8 μg/m^3 for outdoor workers in St. Louis to 2.0 μg/m^3 for outdoor workers in Spokane and up to 4.0 μg/m^3 for outdoor children in New York (Table 2-31). The highest exposed demographic groups were those who spend a large portion of their time outdoors. It is important to note that these exposure estimates are lower than the total exposure to DPM because they reflect only DPM from on-road sources and not exposure to nonroad DPM emissions.

Table 2-31. Annual average DPM exposures for 1990 and 1996 in the general population and among the highest exposed demographic groups in nine urban areas and nationwide from on-road sources only using HAPEM-MS3

Urban area	1990 Population average exposure, μg/m^3	1996 Population average exposure, μg/m^3	Highest DPM exposure in 1990, μg/m^3 (demographic group experiencing this exposure)
Nationwide	*0.8*	*0.8*	*NA*
Atlanta, GA	0.8	0.9	NA
Chicago, IL	0.8	0.6	1.3 (outdoor workers)
Denver, CO	0.7	0.8	1.2 (outdoor workers)
Houston, TX	0.6	0.9	0.8 (outdoor workers)
Minneapolis, MN	1.0	1.0	1.5 (outdoor workers)
New York, NY	1.6	1.2	4.0 (outdoor children)
Philadelphia, PA	0.7	0.7	1.2 (outdoor children)
Phoenix, AZ	1.4	1.3	2.4 (nonworking men 18-44)
Spokane, WA	1.3	1.1	2.0 (outdoor workers)
St. Louis, MO	0.6	0.6	0.8 (outdoor workers)

NA - Not available.
Source: U.S. EPA, 1999b, adjusted to reflect HDDV VMT described in U.S. EPA, 2000b.

The HAPEM4 modeling approach provides exposure estimates from on-road and nonroad sources as well as point and area sources for pollutants other than DPM. In addition, HAPEM4 incorporates technical advancements over previous Agency exposure assessments. Instead of using a surrogate pollutant such as CO to estimate exposure, HAPEM4 uses census tract DPM concentrations provided by the ASPEN dispersion model described in Section 2.4.2.3 to estimate DPM exposure for individuals in each census tract in the United States. The exposure modeling results are aggregated to provide county, State, and nationwide exposure estimates. HAPEM4 also incorporates the latest data regarding time-activity patterns from the Consolidated Human Activity Database and the latest data available regarding penetration of PM to indoor environments. The results of this modeling approach are currently undergoing peer review and are therefore considered a draft and subject to change.

Nationwide exposure estimates from HAPEM4 are provided in Table 2-30. The draft National-Scale Assessment 1996 national average estimate of DPM exposure attributable to on-road and nonroad sources is 1.4 μg/m^3. On-road sources are estimated to account for 0.5 μg/m^3 and nonroad sources 0.9 μg/m^3. The HAPEM-MS3 1996 exposure value of 0.8 μg/m^3 and the most recent draft National-Scale Assessment value of 0.5 μg/m^3 differ slightly as a result of the different modeling approaches. Both the HAPEM-MS3 and HAPEM4 exposure results support the risk perspective provided in Chapter 8, Section 8.3.

2.4.3.2.2. *Personal exposures: microenvironments/hotspots.* Personal monitoring for DPM exposure has focused on occupationally exposed groups, including railroad workers, mine workers, mechanics, and truck drivers. Although some studies have measured personal exposures to ambient PM, none have conducted detailed chemical analysis to quantify the portion of PM attributable to DE (e.g., using extended species CMB, discussed above). EC concentrations have been reported for some microenvironments and are discussed in this section. Microenvironmental exposures of significant concern include in-vehicle exposures such as school buses and passenger cars as well as near highways and in urban canyons. Because DPM from mobile sources is emitted into the breathing zone of humans, this source has a greater potential for human exposure (per kg of emissions) compared to combustion particulates emitted from point sources.

Recent EC measurements reported for enclosed vehicles driving on Sacramento roadways ranged from below detection limits up to 10 μg/m^3 and from 3 μg/m^3 to 40 μg/m^3 on Los Angeles roadways. Elevated levels of $PM_{2.5}$ and EC were observed when the vehicle being followed was powered by a HD diesel truck or bus (Cal EPA, 1998b). EC is also present in the exhaust of gasoline vehicles, so these measurements are likely to include some EC from gasoline vehicles. The SHEDS (Stochastic Human Exposure and Dose Simulation) model for PM predicts that although the typical person spends only about 5% of his or her time in a vehicle, this microenvironment can contribute on average 20% and as much as 40% of a person's total PM exposure (Burke et al., 2000).

The California Air Resources Board also collected EC near the Long Beach Freeway for 4 days in May 1993 and 3 days in December 1993 (Cal EPA, 1998a). Using emission estimates from their EMFAC7G model and EC and OC composition profiles for diesel and gasoline exhaust, tire wear, and road dust, CARB estimated the contribution of the freeway to DPM concentrations. For the 2 days of sampling in December 1993, DE from vehicles on the nearby freeway was estimated to contribute from 0.7 μg/m^3 to 4.0 μg/m^3 excess DPM above background concentrations, with a maximum of 7.5 μg/m^3.

In 1986, EC concentrations were measured in Glendora, CA, during a carbonaceous aerosol intercomparison study (Cadle and Mulawa, 1990; Hansen and Novakov, 1990). One technique used during the study reported EC concentrations in 1-minute intervals, reflecting the impact from diesel vehicles 50 m from the study site. The diesel vehicles were estimated to contribute up to 5 μg/m^3 EC above the background concentration.

In a study designed to investigate relationships between DE exposure and respiratory health of children in the Netherlands, EC measurements were collected in 23 schools located from 47 m to 377 m from a freeway and in 8 schools located at a distance greater than 400 m from a freeway (Brunekreef, 1999). EC concentrations in schools near freeways ranged from 1.1 $\mu g/m^3$ to 6.3 $\mu g/m^3$, with a mean of 3.4 $\mu g/m^3$, and EC concentrations in schools more than 400 m from freeways ranged from 0.8 $\mu g/m^3$ to 2.1 $\mu g/m^3$, with a mean of 1.4 $\mu g/m^3$. Brunekreef et al. (2000), using a reflectance method to report "soot" or carbonaceous particulate concentrations as a surrogate for EC, found a statistically significant increase in carbonaceous particle concentrations inside and outside of the schools with increasing truck traffic (predominantly diesel), with decreasing distance between the school and the highway, and with an increase in the percent of time the school was downwind of the highway. In additional studies in elderly subjects in Helsinki and Amsterdam, Janssen et al. (2000) reported that outdoor measurements of EC were highly correlated with indoor and personal exposure measurements of EC, supporting the position that short-term increases in outdoor EC concentrations are reflected in increased personal exposures even for those who spend much of their time indoors.

Although there is little quantitative information regarding personal exposure to DPM, certain exposure situations are expected to result in higher than average exposures. Those in the more highly exposed categories would generally include people living in urban areas in which diesel delivery trucks, buses, and garbage trucks frequent the roadways, but also included would be people living near freeways, bus stations, construction sites, train stations, marinas frequented by diesel-powered vessels, and distribution hubs using diesel truck transport. One study using the 1-hydroxypyrene biomarker of DE exposure reported exposure among most (76%) of the 26 adolescents sampled in Harlem (Northridge et al., 1999). In a follow-on study, Kinney et al. (2000) reported EC concentrations from personal monitors worn by study staff on sidewalks at four Harlem intersections that ranged from 1.5 $\mu g/m^3$ to 6 $\mu g/m^3$. The EC concentrations were found to be associated with diesel bus and truck counts such that spatial variations in sidewalk concentrations of EC were attributed to local diesel sources in Harlem.

In any situation in which diesel engines operate and a majority of time is spent outdoors, personal exposures to DE are expected to exceed average exposures. Because a large but currently undefined portion of DPM is emitted during acceleration, those living and working in the vicinity of sources operating in this transient mode could experience highly elevated levels of DPM. DPM enriched in soluble organic material (as opposed to EC) is emitted from LD vehicles, some nonroad equipment, on-road diesel engines during cold-start and motoring conditions, and poorly maintained vehicles. The potential health effects of acute exposures to elevated DPM levels as well as health effects resulting from chronic exposures are discussed in subsequent chapters in this document.

2.4.3.2.3. ***The California Population Indoor Exposure Model.*** CPIEM, developed under contract to the CARB, estimates Californians' exposure to DPM using distributions of input data and a Monte Carlo approach (Cal EPA, 1998a). This model uses population-weighted outdoor DPM concentrations in a mass balance model to estimate DPM concentrations in four indoor environments: residences, office buildings, schools, and stores/retail buildings. The model takes into account air exchange rates, penetration factors, and a net loss factor for deposition/removal. In four additional environments (industrial plants, restaurants/lounges, other indoor places, and enclosed vehicles), assumptions were made about the similarity of each of these spaces to environments for which DPM exposures had been calculated. Industrial plants and enclosed vehicles were assumed to have DPM exposures similar to those in the outdoor environment; restaurants/lounges were assumed to have DPM concentrations similar to stores; and other indoor places were assumed to have DPM concentrations similar to offices. The estimated DPM concentrations in the indoor and outdoor environments range from 1.6 $\mu g/m^3$ to 3.0 $\mu g/m^3$ (Table 2-32).

Table 2-32. Modeled and estimated concentrations of DPM in microenvironments for California for all sources

Microenvironment	Estimated mean DPM (stdev), $\mu g/m^3$
Residences	1.9 (0.9)
Offices	1.6 (0.7)
Schools	1.9 (0.8)
Stores/public/retail bldgs	2.1 (0.9)
Outdoor places	3.0 (1.1)
Industrial plants[a]	3.0 (1.1)
Restaurants/lounges[a]	2.1 (0.9)
Other indoor places[a]	1.6 (0.7)
Enclosed vehicles[a]	3.0 (1.1)

[a]Concentrations assumed based on similarity with modeled environments.
Source: California EPA, 1998a.

The DPM concentrations reported in Table 2-32 were used as input to CPIEM, and time-activity patterns for children and adults were used to estimate total indoor and total air exposures to DPM. Overall, total indoor exposures were estimated to be 2.0 ± 0.7 µg/m^3, and total air exposures (indoor and outdoor exposures) were 2.1 ± 0.7 µg/m^3 (Table 2-33). The South Coast Air Basin and the San Francisco Bay Area were also modeled using CPIEM, where total air exposures to DPM were estimated to be 2.5 ± 0.9 µg/m^3 and 1.7 ± 0.9 µg/m^3, respectively.

Table 2-33. Estimated indoor air and total air exposures to DPM in California in 1990

Exposed population	Total indoor exposure (stdev), µg/m^3	Total air exposure, (stdev), µg/m^3
All Californians	2.0 (0.7)	2.1 (0.8)
South Coast Air Basin	2.4 (0.9)	2.5 (0.9)
San Francisco Bay Area	1.7 (0.9)	1.7 (0.9)

Source: California EPA, 1998a.

Exposure estimates were also made by Cal EPA (1998a) for 1995, 2000, and 2010 using a ratiometric approach to 1990 exposures. Total air exposures reported for 1995 and projected for 2000 and 2010 were 1.5 µg/m^3, 1.3 µg/m^3, and 1.2 µg/m^3, respectively.

2.5. SUMMARY AND DISCUSSION

This chapter summarizes information regarding the history of the use of diesel engines, technological developments and their impact on emissions over time, Federal standards on DE, the chemical and physical character of DE, atmospheric transformations of DE, and ambient DE concentrations and exposures. The aspects of each of these topics that are most relevant to the discussion of health effects in later chapters of this document are summarized here. Because the majority of information regarding the chemical composition and historical changes in DE pertains to on-road diesel engines, these data are discussed in greater detail than diesel emissions from nonroad equipment. Where possible, nonroad emissions were discussed in Chapter 2 and are briefly summarized here.

2.5.1. History of Diesel Engine Use, Standards, and Technology

The use of diesel engines in the trucking industry began in the 1940s, and diesel engines slowly displaced gasoline engines among HD trucks, accounting for 36% of new HD truck sales in 1960, 85% of sales in 1970, and almost 100% of sales in 1997. It is estimated that in 2000, HD diesel vehicles will travel more than 224 billion miles (U.S. EPA, 2000b). In 1997, on-highway HD diesel engines contributed 66% of the $PM_{2.5}$ emitted by on-highway vehicles.

To understand changes in emissions over time, it is important to note the difference between model year emission trends and calendar year emission trends. Emission trends by model year refer to the year in which an engine was made; the emission rate is specific to the technology and regulations in effect for that year. Emissions in a specific calendar year refer to aggregate emissions due to the mix of model year engines on the road. Because of the time required for fleet turnover, emission rates for the on-road fleet in any calendar year are not as low as the most recent model year emission rate. In 1997, 40% of the HD vehicles on the road were at least 10 years old and traveled approximately 17% of total HD vehicle miles.

EPA set a smoke standard for on-road HD diesel engines beginning with the 1970 model year. In the ensuing years, standards for PM from diesel engines for on-road applications decreased from 0.6 g/bhp-hr in 1988 to 0.1 g/bhp-hr for trucks in 1994-1995 and 0.05 g/bhp-hr for buses in 1996-1997. Calendar year emission contributions of PM from diesel engines to national PM_{10} inventories reflect decreases expected to result from Federal regulations, because the emission factor models (MOBILE5 and PART5) used to provide emission estimates for mobile sources largely use engine test data required for certification. The U.S. EPA Trends Report estimates that PM_{10} emissions attributable to on-road diesel vehicles decreased 27% between 1980 and 1998. DPM emission factors (g/mi by model year) measured from in-use vehicles decreased on average by a factor of six from the mid-1970s to the mid-1990s.

It is important to note that in spite of the decreasing trend in DPM emission factors by model year, a wide range in emission factors from in-use testing is reported, even for newer model year HD vehicles (from less than 0.1 g/mi to more than 1 g/mi for model year 1996 vehicles). The high variability in DPM emissions within one model year has been attributed to deterioration[3] and differences in measurement methods and test conditions at the various testing facilities. Studies in which consistent testing methods were used suggest that deterioration (even for newer model year engines) causes some of the variability in emission factors, whereas other

[3]Deterioration includes increases in emission rates (g/bhp hr) due to normal wear as well as manufacturing defects and malfunctions such as retarded timing, fuel injector malfunction, smoke limiting mechanism problems, clogged air filter, wrong or worn turbocharger, clogged intercooler, engine mechanical failure, excess oil consumption, and electronics that have been tampered with or have failed.

studies clearly demonstrate the important influence of test conditions and driving protocols (e.g., aggressive driving) on DPM emission factors.

Even though significant reductions in DPM from diesel vehicle emissions for on-road applications have been realized, diesel engines (nonroad and on-road combined) are still significant contributors to 1998 inventories of particulate matter, contributing approximately 23% of $PM_{2.5}$ emissions (not including the contribution from natural and miscellaneous sources).

Technology innovations that impact diesel engine emissions have occurred in the years since 1960, in particular the advent of turbocharging with charge air cooling and direct-injection engines. The use of these new technologies tends to lower emissions from on-road diesel engines; until the late 1970s, however, engines were optimized for performance rather than emissions, so the effect on emissions prior to this time was small. The limited amount of data available indicates that on-road engines in the 1950 to 1975 timeframe had DPM emissions similar to, and in some cases higher than, those of the mid-1970 engines that were not yet controlled for particulates.

Few data are available to assess the changes in emission rates from locomotive, marine, or other nonroad diesel engine sources over time. It is expected that because the typical lifespan of a locomotive engine is at least 40 years and PM regulations for these engines do not take effect until 2000, PM emission rates by model year from locomotives are not likely to have changed substantially since the introduction of the diesel engine into the railroad industry in the early 1950s.

Particulate matter regulations for nonroad diesel equipment are not as stringent as PM regulations for on-road diesel engines. Although PM emissions have declined for on-road trucks, it is estimated that PM_{10} emissions from nonroad diesel engines increased 17% between 1980 and 1998. DPM emissions from nonroad diesel engines are expected to continue to increase from current levels in the absence of new regulations. No information is available regarding changes in the chemical composition of nonroad engine emissions over time.

2.5.2. Physical and Chemical Composition of Diesel Exhaust

Complete and incomplete combustion of fuel in the diesel engine results in the formation of a complex mixture of hundreds of organic and inorganic compounds in the gas and particle phases. Among the gaseous components of DE, the aldehydes are particularly important because of their health effects and because they are an important fraction of the gaseous emissions. Formaldehyde makes up a majority of the aldehyde emissions (65%-80%) from diesel engines, with the next most abundant aldehydes being acetaldehyde and acrolein. Other gaseous components of DE that are notable for their health effects include benzene, 1,3-butadiene, PAH, and nitro-PAH. Dioxin compounds have also been detected in trace quantities in DE and currently account for 1.2% of the national inventory. Dioxin compounds are known to accumulate in certain foods, such as beef, poultry, and dairy products. It is unknown whether deposition of DE emissions has an impact on food chains in local areas.

DPM contains EC, OC, and small amounts of sulfate, nitrate, metals, trace elements, water, and unidentified compounds. DPM is typically composed of more than 50% to approximately 75% EC depending on the age of the engine, deterioration, HD versus LD, fuel characteristics, and driving conditions. The OC portion of DPM originates from unburned fuel, engine lubrication oil, and low levels of partial combustion and pyrolysis products and typically ranges from approximately 19% to 43%, although the range can be broader depending on many of the same factors that influence the EC content of DPM. Polyaromatic hydrocarbons generally constitute less than 1% of the DPM mass. Metal compounds and other elements in the fuel and engine lubrication oil are exhausted as ash and typically make up 1%-5% of the DPM mass. Elements and metals detected in DE include barium, calcium, chlorine, chromium, copper, iron, lead, manganese, mercury, nickel, phosphorus, sodium, silicon, and zinc. The composition of DPM contrasts strongly with the typical chemical composition of ambient $DPM_{2.5}$ that is dominated by sulfate for aerosols measured in the eastern United States and by nitrate, ammonium, and OC in the western United States.

Approximately 1% to 20% of the mass of DPM in DE is in the ultrafine size range (nuclei-mode), with the majority of particles ranging in size from 0.005 to 0.05 microns and having a mean diameter of about 0.02 microns. These particles account for 50%-90% of the number of particles. These ultrafine particles are largely composed of sulfate and/or sulfate with condensed OC.

Evidence regarding an increase in the number of ultrafine particles from new HD engines is inconclusive. The dilution conditions used to measure the size distribution of DE have a large impact on the number of ultrafine particles quantified. To understand the size distribution of DPM to which people are exposed will require measurements under conditions that more closely resemble ambient conditions.

Approximately 80%-95% of the mass of particles in DE is in the size range from 0.05-1.0 microns, with a mean particle diameter of about 0.2 microns, and therefore in the fine PM size range. Diesel particles in the 0.05-1.0 micron range are aggregates of primary spherical particles consisting of an EC core, adsorbed organic compounds, sulfate, nitrate, and trace elements. These particles have a very large surface area per gram of mass, which makes them an excellent carrier for adsorbed inorganic and organic compounds and, due to their small size, they can effectively reach the lower portions of the respiratory tract. The EC core has a high specific surface area of approximately 30-90 m^2/g.

Because of the potential toxicological significance of the organic components associated with DPM, it is important to understand, to the extent possible, the historical changes in the amount and composition of the DPM-associated organic fraction. The organic component of DPM has typically been characterized by extraction with organic solvents, although other techniques such as thermogravimetric methods have also been used. Results from studies using similar extraction methods were compared to characterize historical changes in the SOF emission rates, the percentage of DPM comprised by SOF, and the composition of SOF. Data from both engine and chassis dynamometer tests suggest that SOF emission rates have decreased by model year from 1975 to 1995. When expressed as a percentage of total DPM, the contribution of SOF to total DPM demonstrates a wide range of variability that may be attributed to different test cycles, different engine types, and different deterioration rates among the vehicles tested. Currently, LD diesel engines emit DPM with a higher fraction of SOF than do HD engines.

Chassis dynamometer tests demonstrate an overall decrease in the mass percentage contribution of SOF to DPM, ranging from 10% to 60% in the 1980s and ~5% to 20% in the 1990s. In contrast, engine dynamometer tests demonstrate that typically 10%-50% of DPM mass is soluble organic matter for engines in model years 1980-1995. The higher SOF fraction of DPM from 1990s model year engine dynamometer tests is attributed primarily to the differences in the engine and chassis dynamometer driving cycles. The engine dynamometer testing includes high- speed and low-load or low-speed lugging test modes in the engine Federal Test Procedure that produce DPM with a high SOF fraction.

The chassis dynamometer data are considered to reflect real-world trends in emissions from heavy HD vehicles by model year because vehicles from different model years, with different mileage and different levels of deterioration, are represented. Thus, it is expected that the percentage of SOF from new (1990 or later) model year heavy HD diesel vehicles is lower than that from older vehicles. This expectation is supported by data demonstrating an overall increase in the fraction of EC in the carbonaceous component of DPM. The important observation from the engine test data is that some driving modes occurring in real-world applications even with new (post-1990) engines may produce DPM with a high SOF component (up to 50%).

PAH and nitro-PAH are present in DPM from both new and older engine exhaust. There is no information to suggest that the overall PAH composition profile for DPM has changed. There are too few data to speculate on the changes in emissions of total PAH, nitro-PAH, or PAH and nitro-PAH components such as BaP and 1-NP. The data suggest that differences in a vehicle's engine type and make, general engine condition, fuel composition, and test conditions can influence the emissions levels of PAH. Some studies suggest that fuel composition is the most important determinant of PAH emissions. There is limited evidence that gas-phase PAH emission rates increase with higher fuel PAH content and that some particle-phase PAH emission rates increase with higher fuel PAH content. These data suggest that during the period from 1960 to 1986, when the aromatic content of fuel increased, PAH emissions may have increased until the aromatic content of diesel fuel was capped in 1993. The aromatic content of nonroad diesel fuel is not federally regulated and is typically greater than 30%. PAH emissions from nonroad equipment would also be expected to vary with the PAH content of the fuel.

Currently, information regarding emission rates, chemical composition, and relative contribution of DPM from high-emitting HD diesel vehicles is not available and may significantly change the understanding of DPM composition to which people are exposed. Some studies have reported a substantial number of smoking diesel trucks in the in-use fleet. Although the correlation between smoke and particulate concentration varies with the driving cycle and measurement method, the results of smoke opacity tests suggest that high-emitting HD diesel vehicles may be important contributors to ambient DE and DPM concentrations.

The chemical composition of DPM to which people are currently exposed is determined by a combination of older and newer technology on-road and nonroad engines. Consequently, the decrease in the SOF of DPM by model year does not directly translate into a proportional decrease in DPM-associated organic material to which people are currently exposed. In addition, the impact from high-emitting and/or smoking diesel engines is not quantified at this time. Because of these uncertainties, the changes in DPM composition over time cannot presently be quantified. The data clearly indicate that toxicologically significant organic components of DE (e.g., PAHs, PAH derivatives, nitro-PAHs) were present in DPM and DE in the 1970s and are still present in DPM and DE as a whole.

Although a significant fraction of ambient DPM (over 50% is possible) is also emitted by nonroad equipment, there are no data available to characterize changes in the chemical composition of DPM from nonroad equipment over time.

Some analysts project that diesel engines will increase substantially in the LD fleet in coming years. Although LD engines currently emit DPM with higher SOF than HD engines of the same model year, recently promulgated Tier 2 standards will require control measures in the 2004-2007 timeframe that will reduce PM emissions from these vehicles. These control measures provide some assurance that even if LD diesel use increases, DPM emitted from these vehicles will likely have a smaller SOF component than such engines currently emit.

2.5.3. Atmospheric Transformation of Diesel Exhaust

An understanding of the physical as well as chemical transformations of DE in the atmosphere is necessary to fully understand the impact of this complex chemical mixture on human health. In the past two decades, data acquired from laboratory and ambient experiments have provided information regarding the atmospheric loss processes and transformation of DE, but knowledge concerning the products of these chemical transformations is still limited. A recent study has suggested that DPM exposed to ambient levels of ozone is sufficiently altered to increase the rat lung inflammatory effect compared with DPM not exposed to ozone.

Studies investigating the chemical and physical changes of DE emissions suggest that there is little or no hygroscopic growth of primary diesel particles. This observation suggests that the small size of DPM particles might be maintained upon inhalation, particularly near the emission source, allowing these particles to reach the lower portions of the respiratory tract. Increased solubility can increase the removal efficiency of secondary diesel particles compared with their precursor compounds. Secondary aerosols from DE may also exhibit different biological reactivities from the primary particles. For example, there is evidence for nitration of some PAH compounds resulting in the formation of nitroarenes that are often more mutagenic than their precursors.

2.5.4. Ambient Concentrations and Exposure to Diesel Exhaust

Because of changes in engine technology and DPM emissions over time, ambient concentrations reported from studies before 1990 are compared here to those reported after 1990. There are no studies in which direct comparisons can be made because of different analytical and modeling tools used to assess DPM ambient levels.

DPM concentrations reported from CMB and dispersion modeling studies in the 1980s suggest that in urban and suburban areas (Phoenix, AZ, and Southern California), annual average DPM concentrations ranged from 2 to 13 $\mu g/m^3$, with possible maximum daily values in Phoenix of 22 $\mu g/m^3$. In these studies, the average contribution of DPM in urban areas to total ambient PM ranged from 7% in Pasadena, CA, to 36% in Los Angeles.

In the 1990 timeframe, annual or seasonal average DPM concentrations reported in CMB studies and from EC measurements for urban and suburban areas range from 1.2 to 4.5 $\mu g/m^3$. The contribution of DPM to ambient PM at these sites averaged 10%-15% on a seasonal or annual basis, with contributions up to 38% on individual days (Brighton, CO). Dispersion modeling on individual days in Southern California in the 1990s predicts DPM concentrations ranging from 1.9 to 4.4 $\mu g/m^3$ (8%-12% of ambient PM). On individual days at a major bus stop in New York City, DPM concentrations were reported to reach 46.7 $\mu g/m^3$ and averaged 53% of ambient PM, highlighting the important influence of diesel bus traffic in an urban street canyon.

In nonurban and rural areas in the 1980s, DPM concentrations reported range from 1.4 to 5 $\mu g/m^3$ and on average comprised 5%-12% of the ambient aerosol. In the 1990s, nonurban air basins in California were reported to have DPM concentrations ranging from 0.2-2.6 $\mu g/m^3$.

Although estimates from emissions models suggest that DPM emissions from on-road sources decreased during the 1990s, the atmospheric data available do not provide a clear indication of trends in DPM concentrations but are likely to be more a reflection of the choice in sampling sites, source apportionment methods, and modeling techniques. In general, from the limited number of studies available it appears that DPM concentrations averaged over at least a season in the 1990s typically ranged from 1-4 $\mu g/m^3$. These data can be used in model-monitor comparisons and to provide an indication of long-term average exposures in some urban areas. Additional work is needed to assess ambient DPM and DE concentrations in several urban environments, to assess microenvironments, and to evaluate the relative impact of nonroad and on-road sources on concentrations.

A comprehensive exposure assessment cannot currently be conducted because of the lack of data. Information regarding DPM in occupational environments suggests that exposure ranges up to approximately 1,280 $\mu g/m^3$ for miners, with lower exposure measured for railroad workers (39-191 $\mu g/m^3$), firefighters (4-748 $\mu g/m^3$), public transit personnel who work with diesel equipment (7-98 $\mu g/m^3$), mechanics and dockworkers (5-65 $\mu g/m^3$), truck drivers (2-7 $\mu g/m^3$), and bus drivers (1-3 $\mu g/m^3$). Work area concentrations at fixed sites are often higher than measured exposures, especially for mining operations or other enclosed spaces. For several occupations involving DE exposure, an increased risk of lung cancer has been reported by epidemiologic studies (discussed in Chapter 7). An estimate of the 70-year lifetime environmental exposure equivalent to these occupational exposures provides one means of comparing the potential overlap between occupational exposures and exposures modeled for the general public. The estimated 70-year lifetime exposures equivalent to those for the occupational groups discussed above range from 0.4-2 $\mu g/m^3$ on the low end to 2-269 $\mu g/m^3$ on the high end.

The EPA has performed a national-scale exposure assessment for DPM from on-road sources. Current national exposure modeling using the HAPEM-MS3 model suggests that in 1996, annual average DPM exposure from on-road DE sources in urban areas was 0.8 $\mu g/m^3$, whereas in rural areas, exposures were 0.4 $\mu g/m^3$. Among 10 urban areas in which DPM exposures were modeled, 1996 annual average exposure from on-road DE sources ranged from 0.6 $\mu g/m^3$ to 1.2 $\mu g/m^3$. Outdoor workers and children who spent a large amount of time outdoors were estimated to have elevated DPM exposures in 1990, ranging up to 4.0 $\mu g/m^3$ from on-road sources only. Based on the national inventory, nonroad emission sources could contribute at least twofold more DPM than that emitted by on-road sources. Results of the draft National-Scale Assessment for 1996 indicate that national average exposure to DPM, including nonroad sources, is 1.4 $\mu g/m^3$, with 0.9 $\mu g/m^3$ of that average attributed to emissions from nonroad sources.

Low-end exposures for many of the occupational groups overlap 1990 and 1996 exposures from on-road sources modeled for the general population (0.8 μg/m^3) and for the more highly exposed groups. This potential overlap, or small difference between occupational and ambient exposures, presents a concern that health effects observed in occupational groups may also be evidenced in the general population. The potential magnitude of this risk is discussed in Chapter 8.

In different exposure environments, the types of diesel vehicles, their mode of operation, maintenance, atmospheric transformation, and many additional factors influence the chemical nature and quantity of DPM to which people are exposed. The potential health consequences of both short- and long-term exposures to DE are discussed in the following chapters of this document.

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3. DOSIMETRY OF DIESEL PARTICULATE MATTER

3.1. INTRODUCTION

Animals and humans receive different internal doses when breathing the same external concentrations of airborne materials such as diesel particulate matter (DPM) (Brain and Mensah, 1983; Schlesinger, 1985). The dose received in different species differs from the aspects of the total amount deposited within the respiratory tract, the relative distribution of the dose to specific regions in the respiratory tract, and the residence time of these materials within the respiratory tract, i.e., clearance. Using an external concentration breathed by laboratory animals as a basis for any guidance for human exposure to DPM would then be an inadequate approximation of the total and regional dose that humans may receive.

The reason for the existence of this chapter and for consideration about interspecies dosimetry is the lack of human health effect data on DPM and the concomitant need to be able to evaluate existing animal data from the aspect of an equivalent human dose. The objective of this chapter is to evaluate and address this issue of interspecies dosimetric differences through:

- A general overview of what is known about how particles like DPM are deposited, transported to, and cleared from the respiratory tract. Information on both laboratory animals (mainly rodents) and humans will be considered and interspecies similarities and differences highlighted.
- An overview of what is known about the bioavailability of the organic compounds adsorbed onto DPM from information in humans, animals, and in vitro studies, and from model predictions.
- An evaluation of the suitability of available dosimetric models and procedures for DPM to estimate interspecies extrapolations whereby an exposure scenario, conditions, and outcome in laboratory animals are adjusted to an equivalent outcome in humans via calculation of an internal dose.

The focus in this chapter will be on the particulate fraction of diesel emissions, i.e, DPM. Although diesel engine exhaust consists of a complex mixture of typical combustion gases, vapors, low-molecular-weight hydrocarbons, and particles, it is the particle phase that is considered to be of major health concern. The major constituents of diesel engine exhaust (DE) and their atmospheric reaction products are described in Chapter 2.

As will be deduced in Chapter 5, pulmonary toxicity and carcinogenicity are the major focal points of diesel toxicity and of DPM deposition. Therefore, dosimetric considerations are limited to the lung although DPM deposition would occur throughout the respiratory tract, from the nares to the alveoli. Aspects of respiratory tract dosimetry to be considered in this chapter include the characteristics of DPM, deposition of DPM throughout the respiratory tract, the conducting airways and alveolar regions, normal DPM clearance mechanisms and rates of clearance in both these regions, clearance rates during lung overload (in rats), elution of organics from DPM, transport of DPM to extra-alveolar sites, and the interrelationships of these factors.

The overall goal in this chapter follows from the objective—to judge the feasibility and suitability of procedures allowing for derivation of an internal dose estimate of DPM for humans, i.e., of a human equivalent concentration to exposure concentrations and conditions used in animal studies. This goal is of significance especially in the quantitative dose-response analysis of DPM effects in laboratory animals proposed in Chapter 6.

3.2. CHARACTERISTICS OF INHALED DIESEL PARTICULATE MATTER

The formation, transport, and characteristics of DPM are among the subjects considered in detail in Chapter 2. DPM consists of aggregates of spherical carbonaceous particles (typically about 0.2 µm mass median aerodynamic diameter [MMAD] or, more appropriately, mass median thermodynamic diameter [MMTD]) to which significant amounts of higher-molecular-weight organic compounds are adsorbed. DPM has an extremely large surface area that allows for the adsorption of organic compounds (see Chapter 2, Section 2.2.2). The organic carbon portion of DPM can range from at least 19% to 43% from highway diesel engines; no data are available to characterize the organic content of DPM from nonroad engines. The toxicologically relevant organic chemicals include high-molecular-weight hydrocarbons such as the polycyclic aromatic hydrocarbons (PAHs) and their derivatives (Chapter 2, Section 2.2.8).

3.3. REGIONAL DEPOSITION OF INHALED DIESEL PARTICULATE MATTER

This section discusses the major factors controlling the disposition of inhaled particles. Note that disposition is defined as encompassing the processes of deposition, absorption, distribution, metabolism, and elimination. The regional deposition of particulate matter in the respiratory tract is dependent on the interaction of a number of factors, including respiratory tract anatomy (airway dimensions and branching configurations), ventilatory characteristics (breathing mode and rate, ventilatory volumes and capacities), physical processes (diffusion, sedimentation, impaction, and interception), and the physicochemical characteristics (particle size, shape, density, and electrostatic attraction) of the inhaled particles. Regional deposition of particulate material is usually expressed as deposition fraction of the total particles or mass inhaled and may be represented by the ratio of the particles or mass deposited in a specific region to the number or mass of particles inspired. The factors affecting deposition in these various regions and their importance in understanding the fate of inhaled DPM are discussed in the following sections.

It is beyond the scope of this document to present a comprehensive account of the complexities of respiratory mechanics, physiology, and toxicology, and only a brief review will be presented here. The reader is referred to publications that provide a more in-depth treatment of these topics (Weibel, 1963; Brain and Mensah, 1983; Raabe et al., 1988; Stöber et al., 1993; U.S. EPA, 1996).

The respiratory tract in both humans and experimental mammals can be divided into three general regions on the basis of structure, size, and function: the extrathoracic (ET), the tracheobronchial (TB), and the alveolar (A). In humans, inhalation can occur through the nose or mouth or both (oronasal breathing). Animal models used in respiratory toxicology studies, particularly the rat, however, are obligate nose breathers.

3.3.1. Deposition Mechanisms

This section provides an overview of the basic mechanisms by which inhaled particles deposit within the respiratory tract. Details concerning the aerosol physics that explain both how and why particle deposition occurs as well as data on total human respiratory tract deposition are presented in detail in the earlier PM Criteria Document (U.S. EPA, 1996) and will only be briefly summarized here. For more extensive discussions of deposition processes, refer to reviews by Morrow (1966), Raabe (1982), U.S. EPA (1982), Phalen and Oldham (1983), Lippmann and Schlesinger (1984), Raabe et al. (1988), and Stöber et al. (1993).

As pictorially represented in Figure 3-1, particles may deposit by five major mechanisms (inertial impaction, gravitational settling, Brownian diffusion, electrostatic attraction, and interception). The relative contribution of each deposition mechanism to the fraction of inhaled particles deposited varies for each region of the respiratory tract.

It is important to appreciate that these processes are not necessarily independent but may, in some instances, interact with one another such that total deposition in the respiratory tract may be less than the calculated probabilities for deposition by the individual processes (Raabe, 1982). Depending on the particle size and mass, varying degrees of deposition may occur in the ET (or nasopharyngeal), TB, and A regions of the respiratory tract.

Upon inhalation of particulate matter such as that found in DE, particle deposition will occur throughout the respiratory tract. Because of high airflow velocities and abrupt directional changes in the ET and TB regions, inertial impaction is a primary deposition mechanism, especially for particles $\geq$2.5 µm d_{ae} (aerodynamic equivalent diameter). Although inertial impaction is a prominent process for deposition of larger particles in the tracheobronchial region, it is of considerably less significance as a determinant of regional deposition patterns for

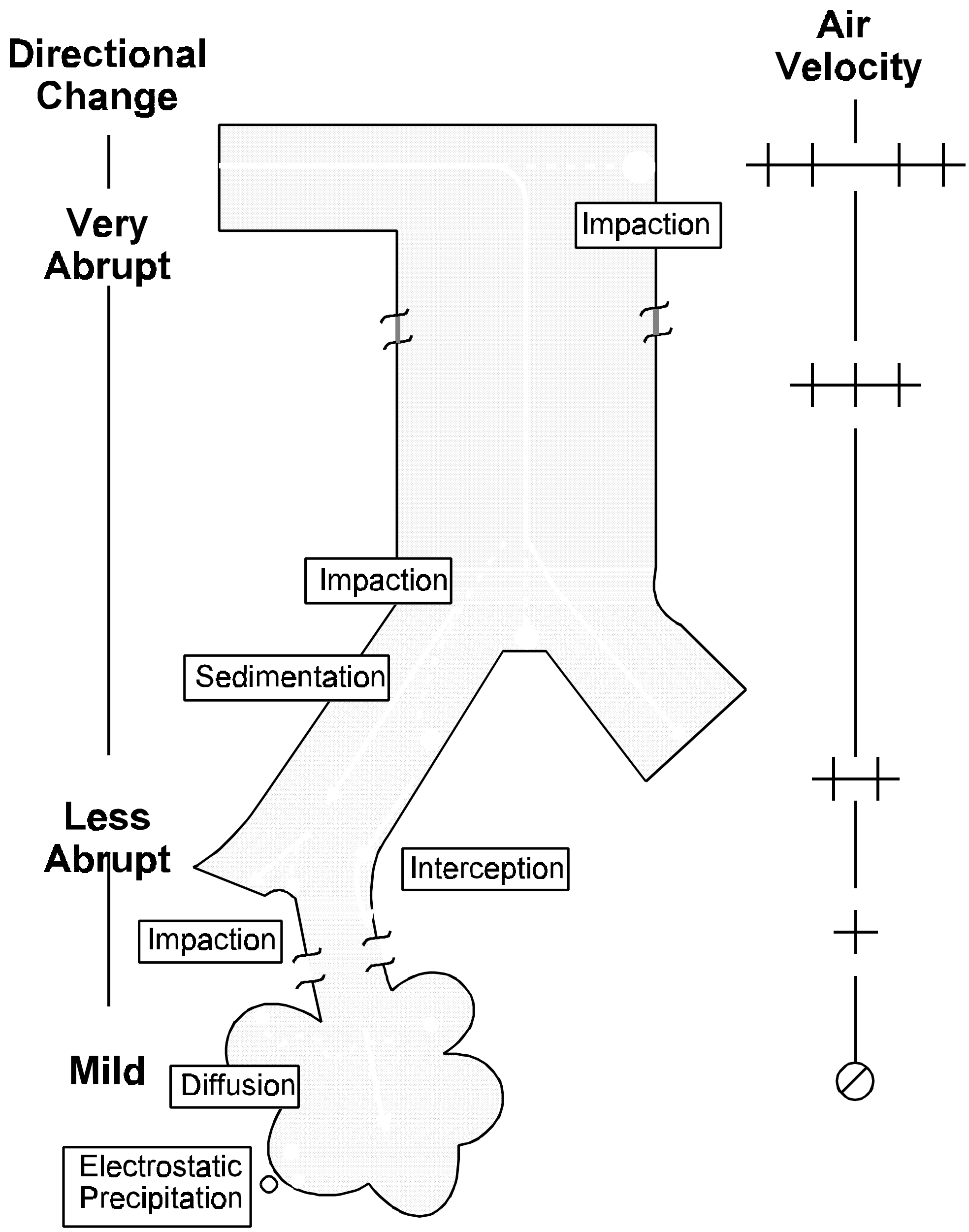

Figure 3-1. Schematic representation of major mechanisms, including diffusion, involved in particle deposition. Airflow is signified by the arrows and particle trajectories by the dashed line.

DPM, which have a $d_{ae} \leq 0.2$ µm and may be considered a rather polydisperse distribution with sigma g values of 2.4 and greater.

All aerosol particles are continuously influenced by gravity, but particles with a $d_{ae} > 0.5$ µm are affected to the greatest extent. A spherical compact particle will acquire a terminal settling velocity when a balance is achieved between the acceleration of gravity acting on the particle and the viscous resistance of the air; it is this velocity that brings the particle into contact with airway surfaces. Both sedimentation and inertial impaction cause the deposition of many particles within the same size range. These deposition processes act together in the ET and TB regions, with inertial impaction dominating in the upper airways and sedimentation becoming increasingly dominant in the lower conducting airways, especially for the largest particles that can penetrate into the smaller bronchial airways.

As particle diameters become <1 µm, the particles are increasingly subjected to diffusive deposition because of random bombardment by air molecules, which results in contact with airway surfaces. A d_{ae} of 0.5 µm is often considered a boundary between diffusion and aerodynamic (sedimentation and impaction) mechanisms of deposition. Thus, instead of having a d_{ae}, diffusive particles of different shapes can be related to the diffusivity of a thermodynamic equivalent size based on spherical particles (Heyder et al., 1986). Diffusive deposition of particles is favored in the A region of the respiratory tract as particles of this size are likely to penetrate past the ET and TB regions.

Electrostatic precipitation is deposition related to particle charge. The electrical charge on some particles may result in an enhanced deposition over what would be expected from size alone. This is due to image charges induced on the surface of the airway by these particles, or to space-charge effects whereby repulsion of particles containing like charges results in increased migration toward the airway wall. The effect of charge on deposition is inversely proportional to particle size and airflow rate. A recent study employing hollow airway casts of the human tracheobronchial tree that assessed deposition of ultrafine (0.02 µm) and fine (0.125 µm) particles found that deposition of singly charged particles was 5-6 times that of particles having no charge, and 2-3 times that of particles at Boltzmann equilibrium (Cohen et al., 1998). This suggests that within the TB region of humans, electrostatic precipitation may be a significant deposition mechanism for ultrafine and some fine particles, the latter of which are inclusive of DPM. Thus, although electrostatic precipitation is generally a minor contributor to overall particle deposition, it may be important for DPM.

Interception is deposition by physical contact with airway surfaces and is most important for fiber deposition (U.S. EPA, 1996).

Figure 3-2 shows the regional (ET, TB, A) deposition in the human respiratory tract as influenced by particle size. Keeping in mind that DPM is a polydisperse distribution with 0.2 µm

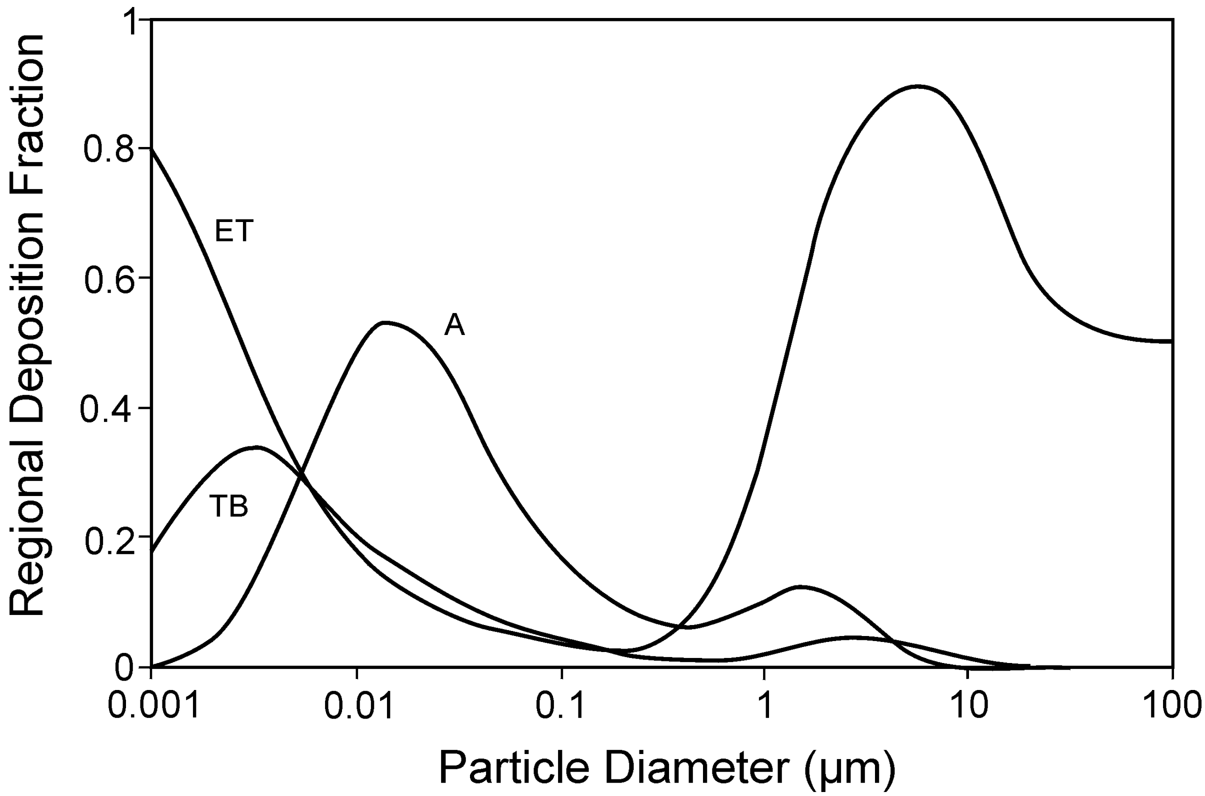

Figure 3-2. Generalized regional deposition fractions of various sized particles in the human respiratory tract. (Adapted from the International Commission on Radiological Protection (ICRP) Publication 66 (1994) model. For unit density, spherical particles inhaled through the nose by an adult male with a tidal volume of 1250 mL, respiratory frequency of 20 min^{-1}, and functional residual capacity (FRC) of 3300 mL.) ET, extrathoracic; TB, tracheobronchial; A, alveolar.

being only the median diameter, it can be seen that principal fraction particles sized from < 0.2 down to around 0.002 µm would, as predicted based on their size and the expected mechanism of diffusion, deposit in the alveolar region. Particles below this size range (and above around 4 µm) tend to deposit in the ET region. Specific modeling results for deposition of DPM particles inclusive of their distribution (i.e., σ_g) are presented in Section 3.6.

3.3.1.1. *Biological Factors Modifying Deposition*

The available experimental deposition data in humans are commonly derived using healthy adult Caucasian males. Various factors can act to alter deposition patterns from those obtained in this group. The effects of different biological factors, including gender, age, and respiratory tract disease, on particle deposition have been reviewed previously (U.S. EPA, 1996, Section 10.4.1.6). In general, there appears to be an inverse relationship between airway resistance and total deposition.

Differences in patterns of deposition between humans and animals have been summarized (U.S. EPA, 1996; Schlesinger, 1985) and show clearly that when exposed to the same aerosol or gas, humans and animals receive doses that may differ in both total and regional (i.e., ET, TB, or A) deposition from a number of variables including particle size, especially for larger sized particles, i.e. $d_{ae} \geq 1$ µm. Such interspecies differences are important because the adverse toxic effect is likely more related to the quantitative pattern of deposition within the respiratory tract than to the exposure concentration; this pattern determines not only the initial respiratory tract tissue dose but also the specific pathways by which the inhaled material is cleared and redistributed (Schlesinger, 1985). Such differences in initial deposition must be considered when relating biological responses obtained in laboratory animal studies to effects in humans.

The deposition patterns of inhaled diesel particles in the respiratory tract of humans and mammalian species has been reviewed (Health Effects Institute, 1995). Schlesinger (1985) showed that physiological differences in the breathing mode for humans (nasal or oronasal breathers) and laboratory rats (obligatory nose breathers), combined with different airway geometries, resulted in significant differences in lower respiratory tract deposition patterns for larger sized particles (>1 µm d_{ae}) in that a much lower fraction of inhaled larger particles is deposited in the alveolar region of the rat compared with humans. However, alveolar deposition of the much smaller DPM (around 0.2 µm d_{ae}) was not affected as much by the differences among species, as was demonstrated in model calculations by Xu and Yu (1987). These investigators modeled the deposition efficiency of inhaled DPM in rats, hamsters, and humans on the basis of calculations of the models of Schum and Yeh (1980) and Weibel (1963). These simulations (Figure 3-3) indicate relative deposition patterns in the lower respiratory tract (trachea = generation 1; alveoli = generation 23) and are similar among hamsters, rats, and humans. Variations in alveolar deposition of DPM over one breathing cycle in these different species were predicted to be within 30% of one another (Xu and Yu, 1987). Xu and Yu (1987) note that this similarity is concordant with the premise that deposition of the submicron diesel particles is dominated by diffusion rather than sedimentation or impaction. Although these data assumed nose-breathing by humans, the results would not be very different for mouth-breathing because of the low filtering capacity of the nose for particles in the 0.1 to 0.5 µm range (see Figure 3-2).

The preceding discussion addresses deposition patterns and deposition efficiencies of DPM in the respiratory tract of various species including humans. The alveolar region was focused upon primarily because, as shown in Chapter 5, this region is where adverse effects from long-term DPM exposure are typically observed. For dosimetric calculations and modeling, however, it would be of much greater importance to consider the actual deposited dose. Table 3-1 presents the analysis of Xu and Yu (1987) on prediction of the deposited doses of DPM

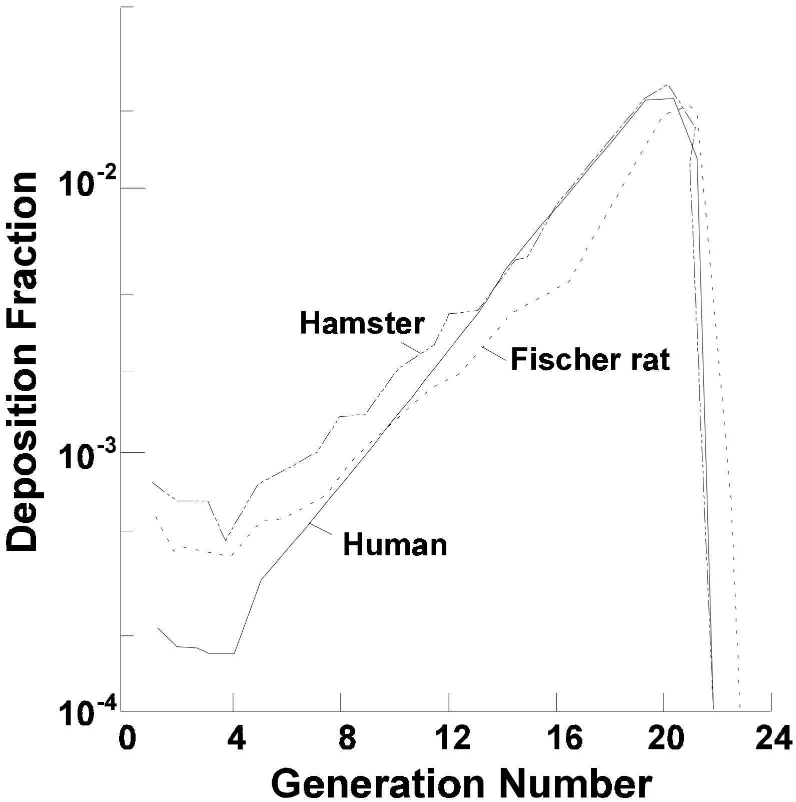

Figure 3-3. Modeled deposition distribution patterns of inhaled DE particles in the airways of different species. Generation 1-18 are TB; >18 are A.

inhaled in 1 min in the lungs of humans, rats, and hamsters on three different bases: the total lung volume (M), the surface area of all lung airways (M_1), or the surface area of the epithelium of the alveolar region only (M_2). According to this analysis, the deposited dose is lower in humans than in the two rodent species regardless of how the deposited dose is expressed. These results are most certainly due predominately to the greater respiratory exchange rate in rodents and smaller size of the rodent lung. Table 3-1 also indicates that the differences (between humans to animals) are less on a surface area basis (≈3-fold) than on a lung volume basis (≈14-fold). This is due to larger alveolar diameters and concomitant lower surface area per unit of lung volume in humans. Such differences in the deposited dose in relevant target areas such as the alveolar region are important and have to be considered when extrapolating the results from DPM exposure studies in animals to humans. As will be discussed elsewhere in this document, procedures for dose extrapolation from animals to humans includes considering the process of clearance, with clearance measurements being in relation to surface area rather than to volume. Thus predicted doses of particulates would be based on surface areas, such as M_1 andM_2 in Table 3-1, rather than on volume, M.

Table 3-1. Predicted doses of inhaled DPM per minute based on total lung volume (M), total airway surface area (M_1), or surface area in alveolar region (M_2)

Species	M (10^{-3} µg/min/cm^3)	M_1 (10^{-6} µg/min/cm^2)	M_2 (10^{-6} µg/min/cm^2)
Hamster	3.548	3.088	2.382
Fischer rat	3.434	3.463	2.608
Human	0.249	1.237	0.775

$$M = \frac{\text{mass DPM deposited in lung per minute}}{\text{total lung volume}}$$

$$M_1 = \frac{\text{mass DPM deposited in lung per minute}}{\text{total airway surface area}}$$

$$M_2 = \frac{\text{mass DPM deposited on the unciliated airways per minute}}{\text{surface area of the unciliated airways}}$$

Based on the following conditions: (1) mass median aerodynamic diameter (MMAD) = 0.2 µm; geometric standard deviation (σ_g) = 1.9; packing density (ϕ) = 0.3; and particle mass density (ρ) = 1.5 g/cm^2; (2) particle concentration = 1 mg/m^3; and (3) nose-breathing. For humans, total lung volume = 3200 cm^2, total airway surface area = 633,000 cm^2, surface area of the unciliated airways = 627,000 cm^2. Corresponding values for Fisher rats are 418cm^2, 412cm^2, and 409cm^2; for hamsters, 282cm^2, 262cm^2, and 261cm^2. Tidal volumes (in cm^2) and respiratory frequency (per min) used for humans were 500 and 14; for Fisher rats, 1.6 and 98; for hamsters, 67 and 1.0.

Source: Xu and Yu, 1987.

Particle deposition will initiate particle redistribution processes (e.g., clearance mechanisms, phagocytosis) that transfer the particles to various subcompartments, including the alveolar macrophage pool, pulmonary interstitium, and lymph nodes. Over time, therefore, only small amounts of the original particle intake would be associated with the alveolar surface areas.

3.3.2. Particle Clearance and Translocation Mechanisms

This section provides an overview of the mechanisms and pathways by which particles are cleared from the respiratory tract. The mechanisms of particle clearance as well as clearance routes from the various regions of the respiratory tract have been considered in the PM Criteria Document (U.S. EPA, 1996) and reviewed by Schlesinger et al. (1997).

Particles that deposit upon airway surfaces may be cleared from the respiratory tract completely, or be translocated to other sites within this system, by various regionally distinct processes. These clearance mechanisms can be categorized as either absorptive (i.e., dissolution) or nonabsorptive (i.e., transport of intact particles) and may occur simultaneously or with temporal variations. Particle solubility in terms of clearance refers to solubility within the respiratory tract fluids and cells. Thus, a poorly soluble particle is one whose rate of clearance by dissolution is insignificant compared to its rate of clearance as an intact particle (as is the case with DPM). The same clearance mechanisms act on different particles to different degrees, with their ultimate fate being a function of deposition site, physicochemical properties (including any toxicity), and sometimes deposited mass or number concentration. However, the duration of clearance for poorly soluble particles such as DPM as it exists between species, months for rats vs. years or even decades for humans, can make dissolution of DPM a significant contributor for humans (Kreyling, 1992).

Figure 3-4 outlines many of the known and suspected clearance pathways for poorly soluble particles, such as DPM, that deposit in the alveolar region. Included are the representations of the translocation pathways from the alveolar epithelium through the insterstitium and on through the lymph nodes; this latter path will be referred to frequently later in this chapter.

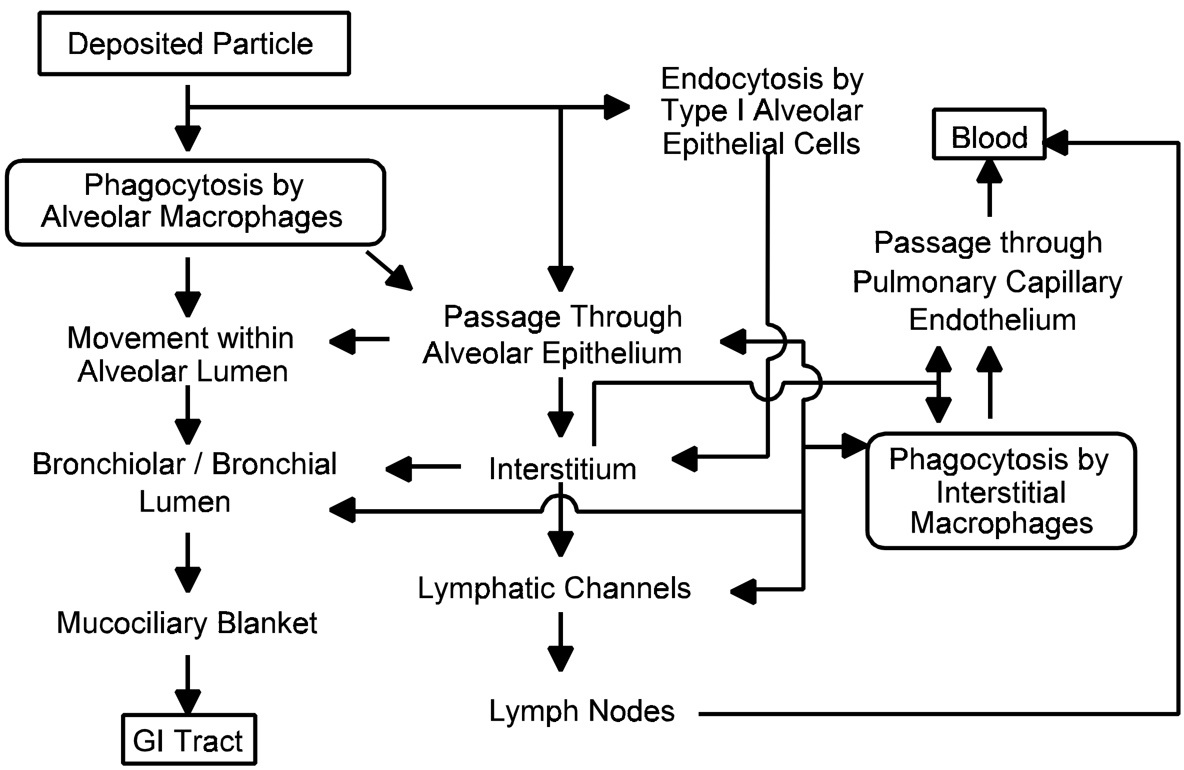

Figure 3-4. Diagram of known and suspected clearance pathways for poorly soluble particles depositing in the alveolar region. (Modified from Schlesinger, 1995).

3.3.2.1. *Extrathoracic Region*

The clearance of poorly soluble particles deposited in the nasal passages occurs via mucociliary transport, and the general flow of mucus is backwards, i.e., towards the nasopharynx. Mucus flow in the most anterior portion of the nasal passages is forward, clearing deposited particles to the vestibular region where removal is by sneezing, wiping, or blowing.

Soluble material deposited on the nasal epithelium is accessible to underlying cells via diffusion through the mucus. Dissolved substances may be subsequently translocated into the bloodstream. The nasal passages have a rich vasculature, and uptake into the blood from this region may occur rapidly.

Clearance of poorly soluble particles deposited in the oral passages is by expectoration or by swallowing into the gastrointestinal tract.

3.3.2.2. *Tracheobronchial Region*

The dynamic relationship between deposition and clearance is responsible for determining lung burden at any point in time. Clearance of poorly soluble particles from the TB region is mediated primarily by mucociliary transport, a more rapid process than those operating in alveolar regions. Mucociliary transport (often referred to as the mucociliary escalator) is accomplished by the rhythmic beating of cilia that line the respiratory tract from the trachea through the terminal bronchioles. This movement propels the mucous layer containing deposited particles (or particles within alveolar macrophages [AMs]) toward the larynx. Clearance rate by this system is determined primarily by the flow velocity of the mucus, which is greater in the proximal airways and decreases distally. These rates also exhibit interspecies and individual variability. Considerable species-dependent variability in tracheobronchial clearance has been reported, with dogs generally having faster clearance rates than guinea pigs, rats, or rabbits (Felicetti et al., 1981). The half-time ($t_{1/2}$) values for tracheobronchial clearance of relatively insoluble particles are usually on the order of hours, as compared to alveolar clearance, which is on the order of hundreds of days in humans and dogs. The clearance of particulate matter from the tracheobronchial region is generally recognized as being biphasic or multiphasic (Raabe, 1982). Some studies have shown that particles are cleared from large, intermediate, and small airways with $t_{1/2}$ of 0.5, 2.5, and 5 h, respectively. However, reports have indicated that clearance from airways is biphasic and that the long-term component for humans may take much longer for a significant fraction of particles deposited in this region, and may not be complete within 24 h as generally believed (Stahlhofen et al., 1990; ICRP, 1994).

Although most of the particulate matter will be cleared from the tracheobronchial region towards the larynx and ultimately swallowed, the contribution of this fraction relative to carcinogenic potential is unclear. With the exception of conditions of impaired bronchial clearance, the desorption $t_{1/2}$ for particle-associated organics is generally longer than the tracheobronchial clearance times, thereby making uncertain the importance of this fraction relative to toxicity in the respiratory tract (Pepelko, 1987). However, Gerde et al. (1991a) showed that for low-dose exposures, particle-associated PAHs were released rapidly at the site of deposition indicating that they would be available for involvement in postulated carcinogenic processes. The relationship between the early clearance of poorly soluble particles of 4 µm aerodynamic diameter from the tracheobronchial regions and their longer-term clearance from the alveolar region is illustrated in Figure 3-5, clearly showing the rapid depuration from the TB region compared with the A region. This relationship, although demonstrated with 4 µm particles, is probably relevant and applicable to DPM-sized particles (i.e., 0.2 µm) as clearance mechanisms are believed not to be particularly particle-sized dependent (Morrow et al., 1967a,b; Snipes et al., 1983).

Cuddihy and Yeh (1986) reviewed respiratory tract clearance of particles inhaled by humans. Depending on the type of particle (ferric oxide, Teflon discs, or albumin microspheres), the technique employed, and the anatomic region (midtrachea, trachea, or main bronchi), particle

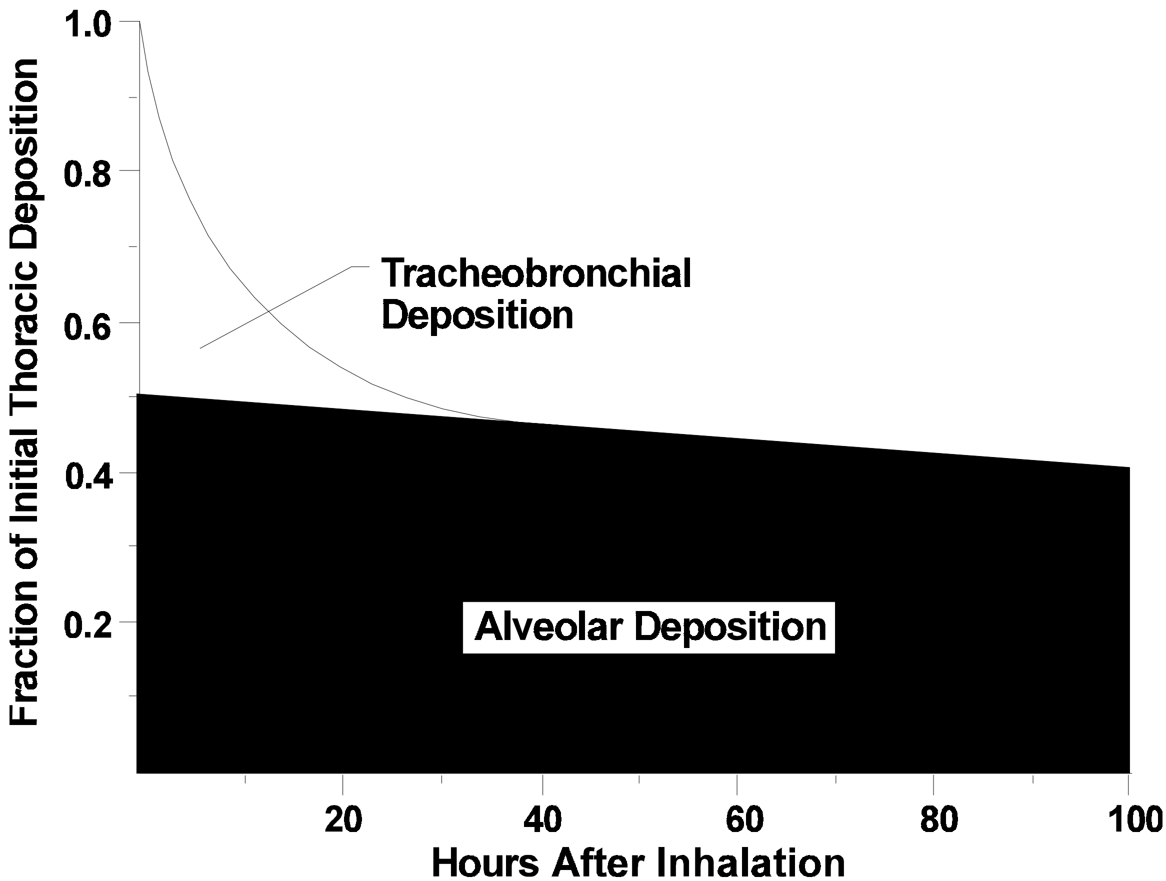

Figure 3-5. Modeled clearance of poorly soluble 4-µm particles deposited in tracheobronchial and alveolar regions in humans.

velocity (moved by mucociliary transport) ranged from 2.4 to 21.5 mm/min. The highest velocities were recorded for midtracheal transport, and the lowest were for main bronchi.

Cuddihy and Yeh (1986) described salient points to be considered when estimating particle clearance velocities from tracheobronchial regions: these include respiratory tract airway dimensions, calculated inhaled particle deposition fractions for individual airways, and thoracic (A + TB) clearance measurements. Predicted clearance velocities for the trachea and main bronchi were found to be similar to those experimentally determined for inhaled radiolabeled particles, but not those for intratracheally instilled particles. The velocities observed for inhalation studies were generally lower than those of instillation studies. Figure 3-6 illustrates a comparison of the short-term clearance of inhaled particles by human subjects and the model predictions for this clearance. However, tracheobronchial clearance via the mucociliary escalator is of limited importance for long-term clearance.

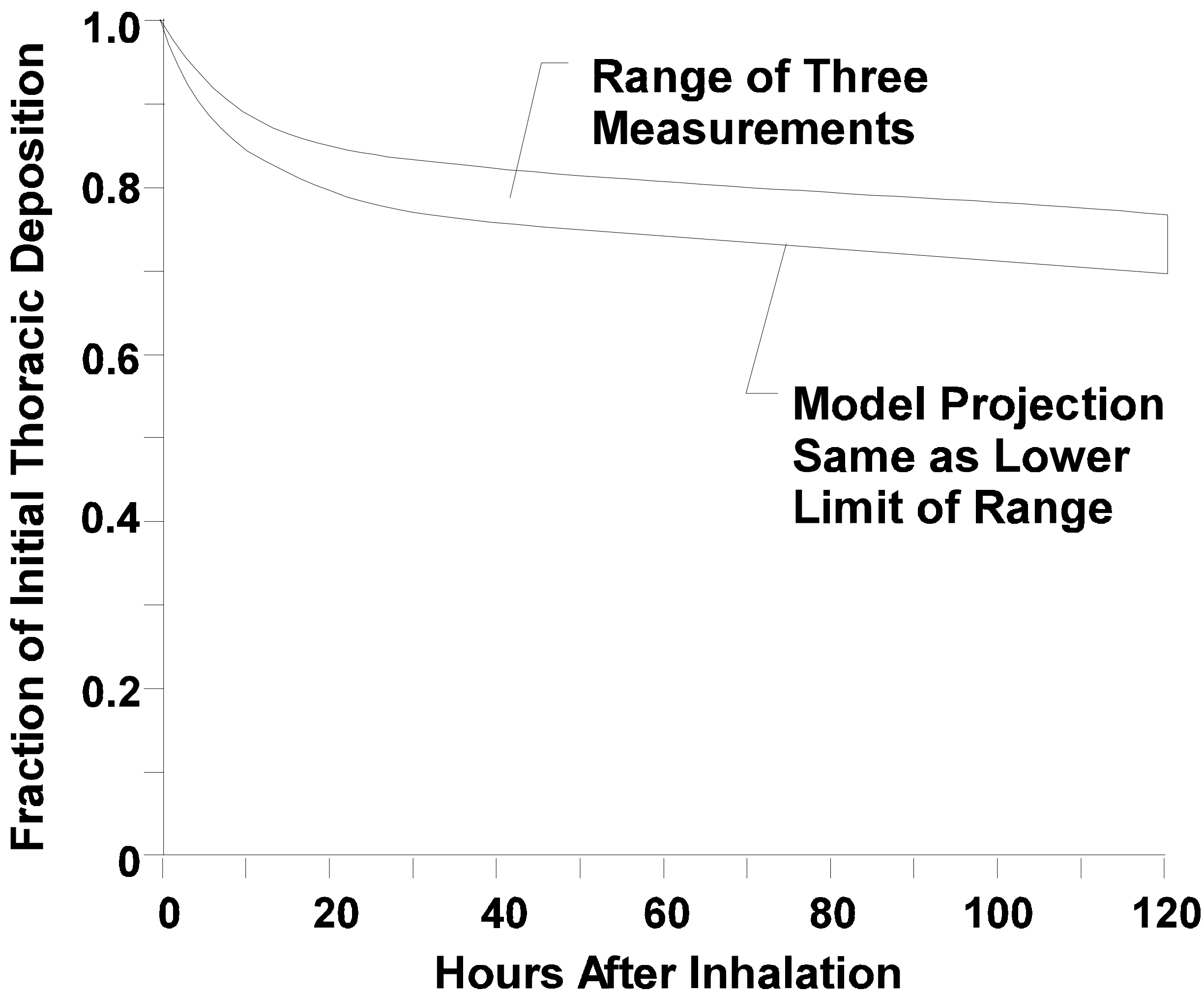

Figure 3-6. Short-term thoracic clearance of inhaled particles as determined by model prediction and experimental measurement.

Source: Cuddihy and Yeh, 1986 (from Stahlhofen et al., 1980).

Exposure of F344 rats to whole exhaust containing DPM at concentrations of 0.35, 3.5, or 7.1 mg/m^3 for up to 24 mo did not significantly alter tracheal mucociliary clearance as assessed by clearance of ^{99m}Tc-macroaggregated albumin instilled into the trachea (Wolff et al., 1987). The authors stated that measuring retention would yield estimates of clearance efficiency comparable to measuring the velocity for transport of the markers in the trachea. The results of this study were in agreement with similar findings of unaltered tracheal mucociliary clearance in rats exposed to DPM (0.21, 1.0, or 4.4 mg/m^3) for up to 4 mo (Wolff and Gray, 1980). However, the 1980 study by Wolff and Gray, as well as an earlier study by Battigelli et al. (1966), showed that acute exposure to high concentrations of DE soot (1.0 and 4.4 mg/m^3 in the study by Wolff and Gray [1980] and 8 to 17 mg/m^3 in the study by Battigelli et al. [1966]) produced transient reductions in tracheal mucociliary clearance. Battigelli et al. (1966) also noted that the compromised tracheal clearance was not observed following cessation of exhaust exposure.

That tracheal clearance does not appear to be significantly impaired or is impaired only transiently following exposure to high concentrations of DPM is consistent with the absence of pathological effects in the tracheobronchial region of the respiratory tract in experimental animals exposed to DPM. The apparent retention of a fraction of the deposited dose in the airways could be cause for some concern regarding possible effects in this region, especially in light of the results from simulation studies by Gerde et al. (1991b) suggesting that release of PAHs from particles may occur within minutes and therefore at the site of initial deposition. However, the absence of effects in the TB areas in long-term DPM studies and experimental evidence that particle-associated PAHs are released at the site of particle deposition together suggest that these PAHs and other organics may be of lesser importance in tumorigenic responses of rats than originally suspected. On the other hand, the data of Nikula et al. (1997a,b) could be interpreted to suggest that a larger fraction of particles are translocated to the interstitium of the respiratory tract in primates that are heavily exposed (and therefore presumably in humans) than in rats that are heavily exposed, including the interstitium of the respiratory bronchioles, an anatomical site absent in rats (Section 3.6). Moreover, eluted PAHs in the TB region are retained longer than those in the alveoli (Gerde et al., 1999), allowing time for activation. Also, the results of Kreyling (1992) indicate that appreciable dissolution of even poorly soluble particles may occur as a consequence of long absolute duration of clearance, such as years or decades, in humans. Thus PAHs may have a role in human response to DE that cannot be evaluated with the rat model.

Also, impairment of mucociliary clearance function as a result of exposure to occupational or environmental respiratory tract toxicants or to cigarette smoke may significantly enhance the retention of particles in the TB region. For example, Vastag et al. (1986) demonstrated that not only smokers with clinical symptoms of bronchitis but also symptom-free smokers have significantly reduced mucociliary clearance rates. Although impaired tracheobronchial clearance could conceivably have an impact on the effects of deposited DPM in the conducting airways, it does not appear to be relevant to the epigenetic mechanism likely responsible for DE-induced rat pulmonary tumors as the tumors observed in these studies were all or nearly all of A vice TB origin.

Poorly soluble particles such as DPM that are deposited within the TB region are cleared predominantly by mucociliary transport towards the oropharynx, followed by swallowing. Poorly soluble particles may also be cleared by traversing the epithelium by endocytotic processes, and enter the peribronchial region. Clearance may occur following phagocytosis by airway macrophages, located on or beneath the mucous lining throughout the bronchial tree, or via macrophages that enter the airway lumen from the bronchial or bronchiolar mucosa (Robertson, 1980).

3.3.2.3. *A Region*

A number of investigators have reported on the alveolar clearance kinetics of human subjects. Bohning et al. (1980) examined alveolar clearance in eight humans who had inhaled <0.4 mg of ^{85}Sr-labeled polystyrene particles (3.6 ± 1.6 µm diam.). A double-exponential model best described the clearance of the particles and provided $t_{1/2}$ values of 29 ± 19 days and 298 ± 114 days for short-term and long-term phases, respectively. It was noted that of the particles deposited in the alveolar region, 75% ± 13% were cleared via the long-term phase. Alveolar retention $t_{1/2}$ values of 330 and 420 days were reported for humans who had inhaled aluminosilicate particles of MMAD 1.9 and 6.1 µm (Bailey et al., 1982). In a comprehensive study Bailey et al. (1985) followed the long-term retention of inhaled particles in a human respiratory tract. The retention of 1 and 4 µm fused aluminosilicate particles labeled with strontium-85 and yttrium-88, respectively, was followed in male volunteers for about 533 days. Approximately 7% of the initial lung deposit of 1 µm particles and 40% of the 4 µm particles were associated with a rapid clearance phase corresponding to the calculated tracheobronchial deposits. Retention of the remaining material followed a two-component exponential function, with phases having half-times of the order of tens of days and several hundred days, respectively.

Quantitative data on clearance rates in humans having large lung burdens of particulate matter are lacking. Bohning et al. (1982) and Cohen et al. (1979), however, did provide evidence for slower clearance in smokers, and Freedman and Robinson (1988) reported slower clearance rates in coal miners who had mild pneumoconiosis with presumably high lung burdens of coal dust. Although information on particle burden and particle overload relationships in humans is much more limited than in experimental animal models, inhibition of clearance does seem to occur. Stöber et al. (1967) estimated a clearance $t_{1/2}$ of 4.9 years in coal miners with nil or slight silicosis, based on postmortem lung burdens. The lung burdens and estimated exposure histories ranged from 2 to 50 mg/g of lung or more, well above the value at which clearance impairment is observed in the rat. Furthermore, impaired clearance resulting from smoking or exposure to other respiratory toxicants may increase the possibility of an enhanced particle accumulation effect resulting from exposure to other particle sources such as DPM.

Normal alveolar clearance rates in laboratory animals exposed to DPM have been reported by a number of investigators (Table 3-2). Because the rat is, historically, the species for which experimentally induced lung cancer data are available and for which most clearance data exist, it is the species most often used for assessing human risk, and reviews of alveolar clearance studies have been generally limited to this species.

Chan et al. (1981) subjected 24 male F344 rats to nose-only inhalation of diluted DE generated from a diesel engine (6 mg/m^3) labeled with ^{131}Ba or ^{14}C for 40 to 45 min and assessed total lung deposition, retention, and elimination. Based on radiolabel inventory, the deposition efficiency in the respiratory tract was 15% to 17%. Measurement of ^{131}Ba label in the feces during the first 4 days following exposure indicated that 40% of the deposited DPM was eliminated via mucociliary clearance. Clearance of the particles from the lower respiratory tract followed a two-phase elimination process consisting of a rapid ($t_{1/2}$ of 1 day) elimination by mucociliary transport and a slower ($t_{1/2}$ of 62 days) macrophage-mediated alveolar clearance. This study provided data for normal alveolar clearance rates of DPM not affected by prolonged exposure or particle overloading.

Several studies have investigated the effects of exposure concentration on the alveolar clearance of DPM by laboratory animals. Wolff et al. (1986, 1987) provided clearance data ($t_{1/2}$) and lung burden values for F344 rats exposed to DE for 7 h/day, 5 days/week for 24 mo. Exposure concentrations of 0.35, 3.5, and 7.1 mg of DPM/m^3 were employed in this whole body-inhalation exposure experiment. Intermediate (hours-days) clearance of $^{67}Ga_2O_3$ particles (30 min, nose-only inhalation) was assessed after 6, 12, 18, and 24 mo of exposure at all of the DPM concentrations. A two-component function described the clearance of the administered radiolabel:

$$F_{(t)} = A\exp(-0.693\ t/\tau_1) + B\exp(-0.693\ t/\tau_2), \qquad (3\text{-}1)$$

where $F_{(t)}$ was the percentage retained throughout the respiratory tract, *A* and *B* were the magnitudes of the two components (component *A* included nasal, lung, and gastrointestinal clearance, while component *B* represented intermediate lung clearance) and τ_1 and τ_2 were the

Table 3-2. Alveolar clearance in laboratory animals exposed to DPM in whole exhaust

Species/sex	Exposure technique	Exposure duration	Particles mg/m^3	Observed effects	Reference
Rats, F-344, M	Nose only; Radiolabeled DPM	40-45 min	6	Four days after exposure, 40% of DPM eliminated by mucociliary clearance. Clearance from lower RT was in 2 phases. Rapid mucociliary ($t_{1/2}$ = 1 day); slower macrophage-mediated ($t_{1/2}$ = 62 days).	Chan et al. (1981)
Rats, F-344	Whole body; assessed effect on clearance of $^{67}Ga_2O_3$ particles	7 h/day 5 days/week 24 mo	0.35 3.5 7.1	τ_1 significantly higher with exposure to 7.1 mg/m^3 for 24 mo; τ_2 significantly longer after exposure to 7.1 mg/m^3 for 6 mo and to 3.5 mg/m^3 for 18 mo.	Wolff et al. (1986, 1987)
Rats	Whole body	19 h/day 5 days/week 2.5 years	4	Estimated alveolar deposition = 60 mg; particle burden caused lung overload. Estimated 6-15 mg particle-bound organics deposited.	Heinrich et al. (1986)
Rats, F-344, MF	Whole body	7 h/day 5 days/week 18 mo	0.15 0.94 4.1	Long-term clearance was 87 ± 28 and 99 ± 8 days for 0.15 and 0.94 mg/m^3 groups, respectively; $t_{1/2}$ = 165 days for 4.1 mg/m^3 group.	Griffis et al. (1983)
Rats, F-344; Guinea pigs, Hartley	Nose-only; Radiolabeled ^{14}C	45 min 140 min 45 min	7 2 7	Rats demonstrated 3 phases of clearance with $t_{1/2}$ = 1, 6, and 80 days, representing tracheobronchial, respiratory bronchioles, and alveolar clearance, respectively. Guinea pigs demonstrated negligible alveolar clearance from day 10 to 432.	Lee et al. (1983)
Rats, F-344		20 h/day 7 days/week 7-112 days	0.25 6	Monitored rats for a year. Proposed two clearance models. Clearance depends on initial particle burden; $t_{1/2}$ increases with higher exposure. Increases in $t_{1/2}$ indicate increasing impairment of AM mobility and transition into overload condition.	Chan et al. (1984)

RT = respiratory tract.
AM = alveolar macrophage.
τ_1 = clearance from primary, ciliated airways.
τ_2 = clearance from nonciliated passages.

half-times for the *A* and *B* components, respectively. The early clearance half-times (τ_1), were similar for rats in all exposure groups at all time points except in the high-exposure (7.1 mg/m^3) group following 24 mo of exposure, which was faster than the controls. Significantly longer *B* component retention half-times, representing intermediate clearance probably from nonciliated structures such as alveolar ducts and alveoli, were noted after as little as 6 mo exposure to DPM at 7.1 mg/m^3 and 18 mo exposure to 3.5 mg/m^3.

Nose-only exposures to ^{134}Cs fused aluminosilicate particles (FAP) were used to assess long-term (weeks-months) clearance. Following 24-mo exposure to DPM, long-term clearance of ^{134}Cs-FAP was significantly (p<0.01) altered in the 3.5 (cumulative exposure [C × T] of 11,760 mg·h/m^3) and 7.1 mg/m^3, C × T = 23,520 mg·h/m^3) exposure groups ($t_{1/2}$ of 264 and 240 days, respectively) relative to the 0.35 mg/m^3 and control groups ($t_{1/2}$ of 81 and 79 days, respectively). Long-term clearance represents the slow component of particle removal from the alveoli. The decreased clearance correlated with the greater particle burden in the lungs of the 3.5 and 7.1 mg/m^3 exposure groups. Based on these findings, the cumulative exposure of > 11,760 mg·h/m^3 (or 3.5 mg/m^3 for a lifetime exposure) represented a particle overload condition resulting in compromised alveolar clearance mechanisms; the clearance rate at the lowest concentration (0.35 mg/m^3; cumulative exposure of 118 mg·h/m^3) was not different from control rates (Figure 3-7).

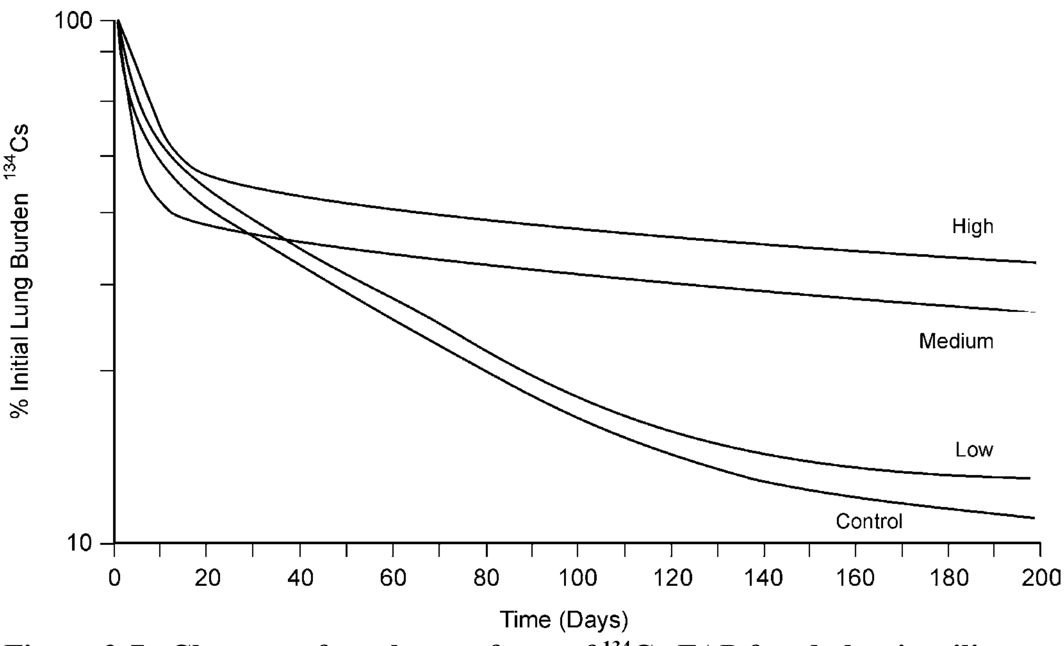

Figure 3-7. Clearance from lungs of rats of ^{134}Cs-FAP fused aluminosilicate tracer particles inhaled after 24 months of DE exposure at concentrations of 0 (control), 0.35 (low), 3.5 (medium), and 7.1 (high) mg DPM/m^3.

Heinrich et al. (1986) exposed rats 19 h/day, 5 days/week for 2.5 years to DPM at a particle concentration of about 4 mg/m^3, equal to a "C × T" of 53,200 $mg \cdot h/m^3$. The deposition in the alveolar region was estimated to equal 60 mg. The lung particle burden was apparently sufficient to result in a "particle overload" condition (Section 3.4). With respect to the organic matter adsorbed onto the particles, the authors estimated that over the 2.5-year period, 6-15 mg of particle-bound organic matter had been deposited and was potentially available for biological effects. This estimation was based on the analysis of the DE used in the experiments, values for rat ventilatory functions, and estimates of deposition and clearance.

Accumulated burden of DPM in the lungs following an 18-mo, 7 h/day, 5 days/week exposure to whole DE was reported by Griffis et al. (1983). Male and female F344 rats exposed to 0.15, 0.94, or 4.1 mg DPM/m^3 were sacrificed at 1 day and 1, 5, 15, 33, and 52 weeks after exposure, and DPM was extracted from lung tissue dissolved in tetramethylammonium hydroxide. Following centrifugation and washing of the supernatant, DPM content of the tissue was quantitated using spectrophotometric techniques. The analytical procedure was verified by comparing results to recovery studies using known amounts of DPM with lungs of unexposed rats. Lung burdens were 0.035, 0.220, and 1.890 mg/g lung tissue, respectively, in rats exposed to diluted whole exhaust at 0.15, 0.94, and 4.1 mg DPM/m^3. Long-term retention for the 0.15 and 0.94 mg/m^3 groups had estimated half-times of 87 ± 28 and 99 ± 8 days, respectively. The retention $t_{1/2}$ for the 4.1-mg/m^3 exposure group was 165 ± 8 days, which was significantly ($p<0.0001$) greater than those of the lower exposure groups. The 18-mo exposures to 0.15 or 0.96 mg/m^3 levels of DPM [C × T] equivalent of 378 and 2,368 $mg \cdot h/m^3$, respectively) did not affect clearance rates, whereas the exposure to the 4.1 mg/m^3 concentration C × T = 10,332 $mg \cdot h/m^3$) resulted in impaired clearance.

Lee et al. (1983) described the clearance of DPM (7 mg/m^3 for 45 min or 2 mg/m^3 for 140 min) by F344 rats (24 per group) and Hartley guinea pigs exposed by nose-only inhalation to diluted whole exhaust with no apparent particle overload in the lungs as being in three distinct phases. The exposure protocols provided comparable total doses based on a ^{14}C radiolabel. $^{14}CO_2$ resulting from combustion of ^{14}C-labeled diesel fuel was removed by a diffusion scrubber to avoid erroneous assessment of ^{14}C intake by the animals. Retention of the radiolabeled particles was determined up to 335 days after exposure and resulted in a three-phase clearance with retention $t_{1/2}$ values of 1, 6, and 80 days. The three clearance phases are taken to represent removal of tracheobronchial deposits by the mucociliary escalator, removal of particles deposited in the respiratory bronchioles, and alveolar clearance, respectively. Species variability in clearance of DPM was also demonstrated because the Hartley guinea pigs exhibited negligible alveolar clearance from day 10 to day 432 following a 45-min exposure to a DPM concentration of 7 mg/m^3. Initial deposition efficiency (20% ± 2%) and short-term clearance were, however, similar to those for rats.

Lung clearance in male F344 rats preexposed to diluted whole DE containing DPM at 0.25 or 6 mg/m^3 20 h/day, 7 days/week for periods lasting from 7 to 112 days was studied by Chan et al. (1984). Following this preexposure protocol, rats were subjected to 45-min nose-only exposure to ^{14}C-DE, and alveolar clearance of radiolabel was monitored for up to 1 year. Two models were proposed: a normal biphasic clearance model and a modified lung retention model that included a slow-clearing residual component to account for sequestered aggregates of macrophages. The first model described a first-order clearance for two compartments: $R(t) = Ae^{-u1t} + Be^{-u2t}$. This yielded clearance $t_{1/2}$ values of 166 and 562 days for rats preexposed to 6.0 mg/m^3 for 7 and 62 days, respectively. These values were significantly (p<0.05) greater than the retention $t_{1/2}$ of 77 ± 17 days for control rats. The same retention values for rats of the 0.25 mg/m^3 groups were 90 ± 14 and 92 ± 15 days, respectively, for 52- and 112-day exposures and were not significantly different from controls. The two-compartment model represents overall clearance of the tracer particles, even if some of the particles were sequestered in particle-laden macrophages with substantially slower clearance rates. For the second model, which excluded transport of the residual fractions in sequestered macrophage aggregates, slower clearance was observed in the group with a lung burden of 6.5 mg (exposed to 6.0 mg/m^3 for 62 days), and no clearance was observed in the 11.8 mg group (exposed to 6.0 mg/m^3 for 112 days). Clearance was shown to be dependent on the initial burden of particles, and therefore the clearance $t_{1/2}$ would increase in higher exposure scenarios. This study emphasizes the importance of particle overloading of the lung and the ramifications on clearance of particles; the significant increases in half-times indicate an increasing impairment of the alveolar macrophage mobility and subsequent transition into an overload condition as is discussed further in Section 3.4.

Long-term alveolar clearance rates of particles in various laboratory animals and humans have been reviewed by Pepelko (1987). Although retention $t_{1/2}$ varies both among and within species and is also dependent on the physicochemical properties of the inhaled particles, the retention $t_{1/2}$ for humans is much longer (>8 mo) than the average retention $t_{1/2}$ of 60 days for rats.

Clearance from the A region occurs via a number of mechanisms and pathways, but the relative importance of each is not always certain and may vary between species. Particle removal by macrophages comprises the main nonabsorptive clearance process in this region. Alveolar macrophages reside on the epithelium, where they phagocytize and transport deposited material, which they contact by random motion or via directed migration under the influence of local chemotactic factors (Warheit et al., 1988).

Particle-laden macrophages may be cleared from the A region along a number of pathways (U.S. EPA, 1996). Uningested particles or macrophages in the interstitium may traverse the alveolar-capillary endothelium, directly entering the blood (Raabe, 1982; Holt, 1981); endocytosis by endothelial cells followed by exocytosis into the vessel lumen seems, however, to be restricted to particles <0.1 µm diameter, and may increase with increasing lung burden (Lee et al., 1985; Oberdörster, 1988). Once in the systemic circulation, transmigrated macrophages, as well as uningested particles, can travel to extrapulmonary organs.

Alveolar macrophages constitute an important first-line cellular defense mechanism against inhaled particles that deposit in the alveolar region of the lung. It is well established that a host of diverse materials, including DPM, are phagocytized by AMs shortly after deposition (White and Garg, 1981; Lehnert and Morrow, 1985) and that such cell-contained particles are generally rapidly sequestered from both the extracellular fluid lining in the alveolar region and the potentially sensitive alveolar epithelial cells. In addition to this role in compartmentalizing particles from other lung constituents, AMs are prominently involved in mediating the clearance of relatively insoluble particles from the air spaces (Lehnert and Morrow, 1985). Although the details of the actual process have not been delineated, AMs with their particle burdens gain access and become coupled to the mucociliary escalator and are subsequently transported from the lung via the conducting airways. Although circumstantial, numerous lines of evidence indicate that such AM-mediated particle clearance is the predominant mechanism by which relatively insoluble particles are removed from the alveolar region of the lungs (Gibb and Morrow, 1962; Ferin, 1982; Harmsen et al., 1985; Lehnert and Morrow, 1985; Powdrill et al., 1989).

The removal characteristics for particles deposited in the alveolar region of the lung have been descriptively represented by numerous investigators as a multicompartment or multicomponent process in which each component follows simple first-order kinetics (Snipes and Clem, 1981; Snipes et al., 1988; Lee et al., 1983). Although the various compartments can be described mathematically, the actual physiological mechanisms determining these differing clearance rates have not been well characterized.

Lehnert et al. (1988, 1989) performed studies using laboratory rats to examine particle-AM relationships over the course of alveolar clearance of low to high lung burdens of noncytotoxic microspheres (2.13 µm diam.) to obtain information on potential AM-related mechanisms that form the underlying bases for kinetic patterns of alveolar clearance as a function of particle lung burdens. The intratracheally instilled lung burdens varied from 1.6×10^7 particles (about 85 µg) for the low lung burden to 2.0×10^8 particles (about 1.06 mg) for the mid-dose and 6.8×10^8 particles (about 3.6 mg) for the highest lung burden. The lungs were lavaged at various times postexposure and the numbers of spheres in each macrophage counted. Although such experiments provide information regarding the response of the lung to particulate matter, intratracheal instillation is not likely to result in the same depositional characteristics as inhalation of particles. Therefore, it is unlikely that the response of alveolar macrophages to these different depositional characteristics will be quantitatively similar.

The $t_{1/2}$ values of both the early and later components of clearance were virtually identical following deposition of the low and medium lung burdens. For the highest lung burden, significant prolongations were found in both the early, more rapid, as well as the slower component of alveolar clearance. The percentages of the particle burden associated with the earlier and later components, however, were similar to those of the lesser lung burdens. On the basis of the data, the authors concluded that translocation of AMs from alveolar spaces by way of the conducting airways is fundamentally influenced by the particle burden of the cells so translocated. In the case of particle overload that occurred at the highest lung burden, the translocation of AMs with the heaviest cellular burdens of particles (i.e., greater than about 100 microspheres per AM) was definitely compromised.

On the other hand, analysis of the disappearance of AMs with various numbers of particles indicates that the particles may not exclusively reflect the translocation of AMs from the lung. The observations are also consistent with a gradual redistribution of retained particles among the AMs in the lung concurrent with the removal of particle-containing AMs via the conducting airways. Experimental support suggestive of potential processes for such particle redistribution comes from a variety of investigations involving AMs and other endocytic cells (Heppleston and Young, 1973; Evans et al., 1986; Aronson, 1963; Sandusky et al., 1977; Heppleston, 1961; Riley and Dean, 1978).

3.3.3. Translocations of Particles to Extra-Alveolar Macrophage Compartment Sites

Although the phagocytosis of particles by cells free within the lung and the mucociliary clearance of the cells with their particulate matter burdens represent the most prominent mechanisms that govern the fate of particles deposited in the alveolar region, other mechanisms exist that can affect both the retention characteristics of relatively insoluble particles in the lung and the lung clearance pathways for the particles. One mechanism is endocytosis of particles by alveolar lining (Type I) cells (Sorokin and Brain, 1975; Adamson and Bowden, 1978, 1981) that normally provide >90% of the cell surface of the alveoli in the lungs of a variety of mammalian species (Crapo et al., 1983). This process may be related to the size of the particles that deposit in the lungs and the numbers of particles that are deposited. Adamson and Bowden (1981) found that with increasing loads of carbon particles (0.03 µm diam.) instilled in the lungs of mice, more free particles were observed in the alveoli within a few days; it should be noted, however, that this phenomenon was demonstrated with very high doses given as a bolus such that the mechanism and relevance of this phenomenon at lower concentrations may be different or even unrelated to what may happen at much lower concentrations. The relative abundance of particles endocytosed by Type I cells also increased with increasing lung burdens of the particles, but instillation of large particles (1.0 µm) rarely resulted in their undergoing endocytosis. A 4 mg burden of 0.1 µm diameter latex particles is equivalent to 8×10^{12} particles, whereas a 4 mg burden of 1.0 µm particles is composed of 8×10^{9} particles. Regardless, DPM with volume median diameters between 0.05 and 0.3 µm (Frey and Corn, 1967; Kittleson et al., 1978) would be expected to be within the size range for engulfment by Type I cells should suitable encounters occur. Indeed, it has been demonstrated that DPM is endocytosed by Type I cells in vivo (White and Garg, 1981).

Unfortunately, information on the kinetics of particle engulfment (endocytosis) by Type I cells relative to that by AMs is scanty. Even when relatively low burdens of particulate matter are deposited in the lungs, some fraction of the particles usually appears in the regional lymph nodes (Ferin and Feldstein, 1978; Lehnert, 1989). As will be discussed, endocytosis of particles by Type I cells is an initial, early step in the passage of particles to the lymph nodes. Assuming particle phagocytosis is not sufficiently rapid or perfectly efficient, increasing numbers of particles would be expected to gain entry into the Type I epithelial cell compartment during chronic aerosol exposures. Additionally, if particles are released on a continual basis by AMs that initially sequestered them after lung deposition, some fraction of the “free” particles so released could also undergo passage from the alveolar space into Type I cells.

The endocytosis of particles by Type I cells represents only the initial stage of a process that can lead to the accumulation of particles in the lung’s interstitial compartment and the subsequent translocation of particles to the regional lymph nodes. As suggested by the results of Adamson and Bowden (1981), a vesicular transport mechanism in the Type I cell can transfer particles administered at high concentrations by instillation from the air surface of the alveolar epithelium into the lung’s interstitium, where particles may be phagocytized by interstitial macrophages or remain in a “free” state for a poorly defined period that may be dependent on the physicochemical characteristics of the particle. The lung’s interstitial compartment accordingly represents an anatomical site for the retention of particles in the lung, although the kinetics on movement into and out of this site remain obscure for both humans and test species. Whether or not AMs, and perhaps polymorphonuclear neutrophils (PMNs) that have gained access to the alveolar space compartment and phagocytize particles there, also contribute to the particle translocation process into the lung’s interstitium also remains a controversial issue.

Translocation of particulate matter to the various interstitial spaces within the lung is a prominent phenomenon occurring at least at high (occupational) exposures that has been examined extensively for both DPM and coal dust in a species comparison between rats and primates (Nikula et al., 1997a,b). Detailed pulmonary morphometry conducted on F344 rats and cynomolgus monkeys that had been exposed for 24 months to occupational levels of DPM (1.95

mg/m^3; see Lewis et al., 1989) showed major differences in the pulmonary sites of particulate deposition. In rats, about 73% of DPM was present in the alveolar ducts/alveoli and 27% in interstitial compartments; for monkeys the corresponding figures were markedly different at 43% and 57%. The corresponding pulmonary histopathology confirmed that both species were affected, although rats are more sensitive, as incidence and severity scores for alveolar effects ranged from 15 of 15 with severity scores from 1-4 (minimal to moderate), whereas for monkeys the corresponding values were only 4 of 15 at a range of 0-2 (not observed to minimal). Similarly, both species exhibited histopathology at the interstitial sites of deposition but with effects in monkeys being slightly more severe (1 of 15 graded as slight, 14 of 15 graded as minimal) than those in rats (14 of 15 graded as slight, 1 of 15 graded as minimal). The basis for this interspecies difference may be due to any number of clear contrasts that exist between rat and primate lungs, including anatomical (primates and humans have respiratory bronchioles whereas rats do not), kinetic (primates and human clearance processes allow more residence time of particles in the lung than do those in rats or rats may have faster interstitial to lymph node clearance rates than do humans and primates), or morphological (primates and humans have more interstitial tissue, more and thicker pleura, and wider interstitial spaces than do rats). Aspects of the study itself that may obscure its interpretation include the relative lifespan the exposure represented between the tested species (lifetime for rat vs. about 10% lifetime of primate), that there was only the single time point at which the relative burdens were determined, and that rat lymph node burdens were not included in the analysis. The analysis of Kuempel (2000) using human occupational data clearly showed that models require an interstitialization process to provide adequate fits to the empirical human (miners') lung deposition data discussed in that study. Hypotheses about possible mechanisms for the interstitialization process are scant, although Harmsen et al. (1985) provided some evidence in dogs that migration of AMs may contribute to the passage of particles to the interstitial compartment and also may be involved in the subsequent translocation of particles to draining lymph nodes. Translocation to the extrapulmonary regional lymph nodes apparently can involve the passage of free particles as well as particle-containing cells via lymphatic channels in the lungs (Harmsen et al., 1985; Ferin and Feldstein, 1978; Lee et al., 1985). Further, it has been noted that particles accumulate both more rapidly and more abundantly in lymph nodes that receive lymphatic drainage from the lung (Ferin and Feldstein, 1978; Lee et al., 1985). It should be stressed that further investigation is required to confirm the character and even existence of the interstitialization process in the lungs of humans with exposures to particles at lower environmental concentrations, or to submicrometer particles such as DPM, or to examine the kinetics and time course of the interstitialization process.

3.3.3.1. *Clearance Kinetics*

The clearance kinetics of PM have been reviewed in the PM CD (U.S. EPA, 1996) and by Schlesinger et al. (1997), the results of which indicate that clearance kinetics may be profoundly influenced by several factors. The influence of time, for example, is definitively showed by the work of Bailey et al. (1985; discussed above), who showed that the rate of clearance from the pulmonary region to the GI tract decreased nearly fourfold from initial values to those noted at 200 days and beyond after particle inhalation.

3.3.3.2. *Interspecies Patterns of Clearance*

The inability to study the retention of certain materials in humans for direct risk assessment requires the use of laboratory animals. Adequate toxicological assessment necessitates that interspecies comparisons consider aspects of dosimetry including knowledge of clearance rates and routes. The basic mechanisms and overall patterns of clearance from the respiratory tract are similar in humans and most other mammals. Regional clearance rates, however, can show substantial variation between species, even for similar particles deposited under comparable exposure conditions (U.S. EPA, 1996; Schlesinger et al., 1997; Snipes et al., 1989).

In general, there are species-dependent rate constants for various clearance pathways. Differences in regional and total clearance rates between some species are a reflection of differences in mechanical clearance processes. For consideration in assessing particle dosimetry, the end result of interspecies differences in clearance is that the retained doses in the lower respiratory tract can differ between species, which may result in differences in response to similar particulate exposures.

3.3.3.3. *Clearance Modifying Factors and Susceptible Populations*

A number of host and environmental factors may modify clearance kinetics and may consequently make individuals exhibiting or afflicted with these factors particularly susceptible to the effects resulting from exposure to DPM. These include age, gender, physical activity, respiratory tract disease, and inhalation of irritants (U.S. EPA, 1996, Section 10.4.2.5). Respiratory tract clearance appears to be prolonged in a number of pathophysiological conditions in humans, including chronic sinusitis, chronic bronchitis, asthma, chronic obstructive lung disease, and various acute respiratory infections.

3.3.3.4. *Respiratory Tract Disease*

Earlier studies reviewed in the PM CD (U.S. EPA, 1996) noted that various respiratory tract diseases are associated with alterations in overall clearance and clearance rates. Prolonged nasal mucociliary clearance in humans is associated with chronic sinusitis or rhinitis, and cystic fibrosis. Bronchial mucus transport may be impaired in people with bronchial carcinoma, chronic bronchitis, asthma, and various acute infections. In certain of these cases, coughing may enhance mucus clearance, but it generally is effective only if excess secretions are present.

The rates of A region particle clearance are reduced in humans with chronic obstructive lung disease and in laboratory animals with viral infections, whereas the viability and functional activity of macrophages are impaired in human asthmatics and in animals with viral-induced lung infections (U.S. EPA, 1996). However, any modification of functional properties of macrophages appears to be injury specific, reflecting the nature and anatomic pattern of disease.

3.4. PARTICLE "OVERLOAD"

3.4.1. Introduction

Some experimental studies using laboratory rodents employed high exposure concentrations of relatively nontoxic, poorly soluble particles. These particle loads interfered with normal clearance mechanisms, producing clearance rates different from those that would occur at lower exposure levels. Prolonged exposure to high particle concentrations is associated with what is termed particle overload. This is defined as the overwhelming of macrophage-mediated clearance by the deposition of particles at a rate exceeding the capacity of that clearance pathway. Aspects and occurrence of this phenomenon have already been alluded to in earlier portions of this chapter on alveolar clearance (Section 3.3.2.3). The relevance of this phenomenon for human risk assessment has long been the object of scientific inquiry. A monograph on this matter and many others relevant to DPM has appeared (ILSI, 2000), and the results, opinions, and judgments put forth therein are used extensively in this chapter and in this assessment.

Wolff et al. (1987) used ^{134}Cs-labeled fused aluminosilicate particles to measure alveolar clearance in rats following 24-mo exposure to low, medium, and high concentrations of DE (targeted concentrations of DPM of 0.35, 3.5 and 7.1 mg/m^3). The short-term component of the multicomponent clearance curves was similar for all groups, but long-term clearance was retarded in the medium- and high-exposure groups (Figure 3-7). The half times of the long-term clearance curves were 79, 81, 264, and 240 days, respectively, for the control, low-, medium-, and high-exposure groups. Clearance was overloaded at the high and medium but not at the low exposure level. Lung burdens of DPM were measured after 6, 12, 18, and 24 mo of exposure. The results (Figure 3-8) indicate that the lung burden of deposited particles was appreciably increased or "overloaded" compared with the low level of exposure in the two highest exposures post 6 months. Figure 3-8 also compares these observational results of lung burden with simulated results where no overload would occur (McClellan, 2000). Comparison

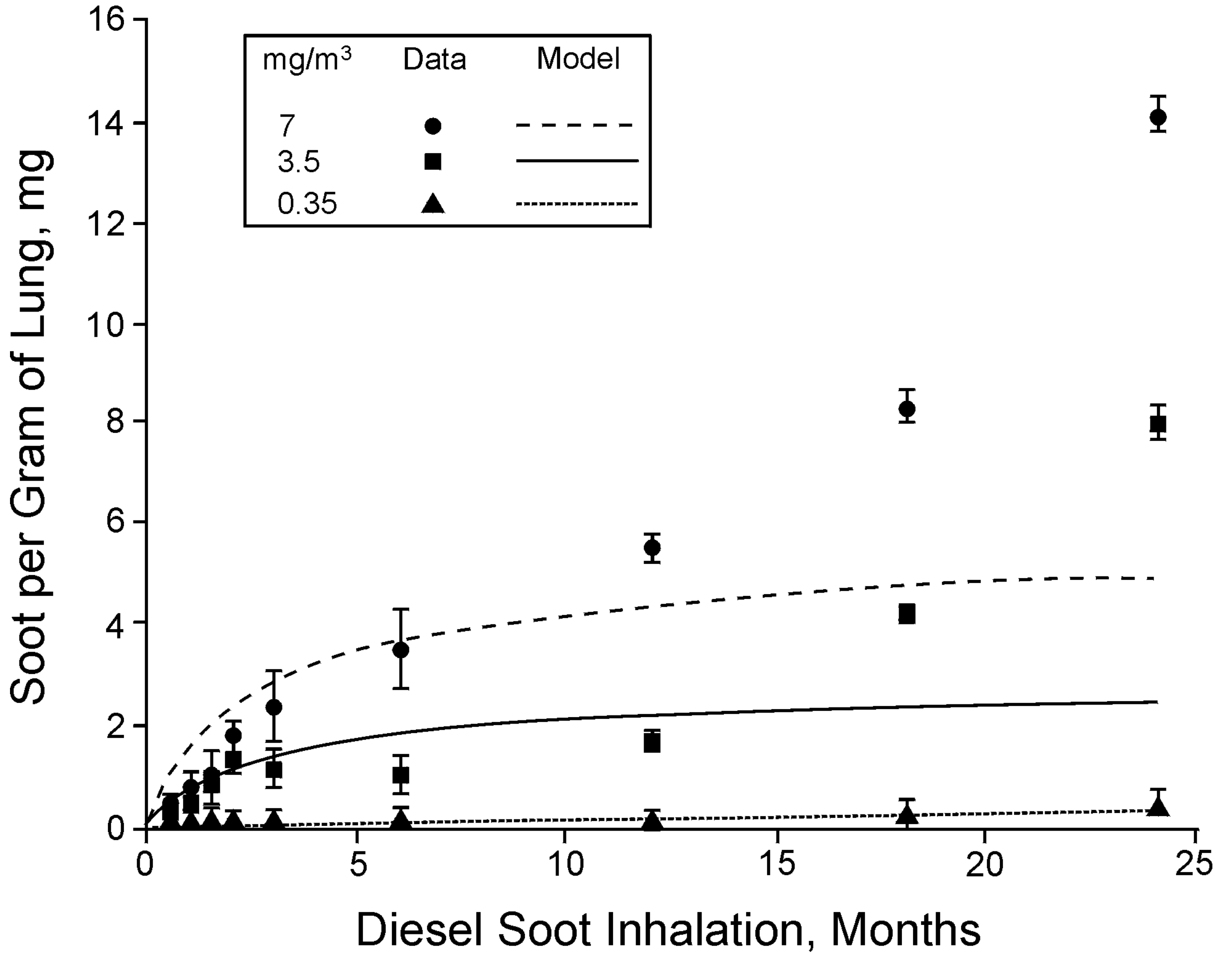

Figure 3-8. Lung burdens (in mg DPM soot/g lung) in rats chronically exposed to DE at 0.35 (low) (●), 3.5 (medium) (▲), and 7.1 (high) mg / m³ (■). The solid figures represent actual data with means and standard errors from animals sacrificed at 6, 12, and 18 months after initiation of exposures. Lines are simulated model results from these same exposure levels, assuming no effect of exposure concentration on deposition or clearance of particles (from Wolff et al., 1987; McClellan, 2000).

of the observed and simulated results clearly shows that the two highest exposure levels resulted in lung burdens that were ever-increasing and not at all concordant with the simulated results, whereas the burdens at the low-exposure level were closely approximated by the simulation. Thus, at the two highest exposure levels, deposition processes were outpacing clearance mechanisms. Results from the low-exposure level indicate that clearance processes were not inhibited, the lung burden remaining the same throughout all time periods examined.

Morrow (1988) has proposed that the condition of particle overloading in the lungs is caused by a loss in the mobility of particle-engorged AMs and that such an impediment is related to the cumulative volumetric load of particles in the AMs. Morrow (1988) has further estimated that the clearance function of an AM may be completely impaired when the particle burden in the AM is of a volumetric size equivalent to about 60% of the normal volume of the AM. Morrow's hypothesis was the initial basis for the physiology-oriented multicompartmental kinetic (POCK) model derived by Stöber et al. (1989) for estimating alveolar clearance and retention of relatively insoluble, respirable particles in rats.

A revised version of this model refines the characterization of the macrophage pool by including both the mobile and immobilized macrophages (Stöber et al., 1994). Application of the revised version of the model to experimental data suggested that lung overload does not cause a dramatic increase in the total burden of the macrophage pool but results in a great increase in the particle burden of the interstitial space, a compartment that is not available for macrophage-mediated clearance. The revised version of the POCK model is discussed in greater detail in the context of other dosimetry models below.

Oberdörster and co-workers (1992) assessed the alveolar clearance of smaller (3.3 µm diam.) and larger (10.3 µm diam.) polystyrene particles, the latter of which are volumetrically equivalent to about 60% of the average normal volume of a rat AM, after intratracheal instillation into the lungs of rats. Even though both sizes of particles were found to be phagocytized by AMs within a day after deposition, and the smaller particles were cleared at a normal rate, only minimal lung clearance of the larger particles was observed over an approximately 200-day postinstillation period, thus supporting the volumetric AM overload hypothesis.

It has been hypothesized that when the retained lung burden approaches 1 mg particles/g lung tissue, overloading will begin in the rat (Morrow, 1988); at 10 mg particles/g lung tissue macrophage-mediated clearance of particles would effectively cease. Overloading appears to be a nonspecific effect noted in experimental studies, generally in rats, using many different kinds of poorly soluble particles (including TiO_2, volcanic ash, DPM, carbon black, and fly ash) and results in A region clearance slowing or stasis, with an associated inflammation and aggregation of macrophages in the lungs and increased translocation of particles into the interstitium (Muhle et al., 1990a,b; Lehnert, 1990; Morrow, 1994). Following overloading, the subsequent retardation of lung clearance, accumulation of particles, chronic inflammation, and the interaction of inflammatory mediators with cell proliferative processes and DNA may lead to the development of fibrosis, epithelial cell mutations, and fibrosis in rats (Mauderly, 1996). The phenomenon of overload has been discussed in greater detail in the previous PM CD (U.S. EPA, 1996).

3.4.2. Relevance to Humans

The relevance of “lung overload” to humans, and even to species other than laboratory species (rats and mice and hamsters; Muhle et al., 1990a,b), is not clear. Although likely to be of little relevance for most “real world” ambient exposures of humans, this phenomenon is of concern in interpreting some long-term experimental exposure data and perhaps for human occupational exposure. In addition, relevance to humans is clouded by the fact that macrophage-mediated clearance is slower and perhaps less important in humans than in rats (Morrow, 1994).

Particle overload appears to be an important factor in the pulmonary carcinogenicity observed in rats exposed to DPM. A study by Griffis et al. (1983) demonstrated that exposure (7 h/day, 5 days/week) of rats to diluted whole DE containing DPM at concentrations of 0.15, 0.94, or 4.1 mg/m^3 for 18 mo resulted in lung burdens of 0.035, 0.220, and 1.89 mg/g of lung tissue, respectively. The alveolar clearance of those rats with the highest lung burden (1.89 mg/g of lung) was impaired, as determined by a significantly greater (p<0.0001) retention $t_{1/2}$ for DPM. Impaired clearance was reflected in the greater lung burden/exposure concentration ratio at the highest exposure level. Similarly, in the study by Chan et al. (1984), rats exposed for 20 h/day, 7 days/week to diluted whole DE containing DPM (6 mg/m^3) for 112 days had an extraordinarily high lung particle burden of 11.8 mg, with no alveolar particle clearance being detected over 1 year.

Muhle et al. (1990a,b) indicated that overloading of rat lungs occurred when lung particle burdens reached 0.5 to 1.5 mg/g of lung tissue and that clearance mechanisms were totally compromised at lung particle burdens $\geq$10 mg/g for particles with a specific density close to 1, observations that are concordant with those of Morrow (1988).

Pritchard (1989), utilizing data from a number of DE exposure studies, examined alveolar clearance in rats as a function of cumulative exposure. The resulting analysis noted a significant increase in retention $t_{1/2}$ values at exposures above 10 mg/m^3·h/day and also showed that normal lung clearance mechanisms appeared to be compromised as the lung DPM burden approached 0.5 mg/g of lung.

Animal studies have revealed that impairment of alveolar clearance can occur following chronic exposure to DPM (Griffis et al., 1983; Wolff et al., 1987; Vostal et al., 1982; Lee et al., 1983) or a variety of other diverse poorly soluble particles of low toxicity (Lee et al., 1986, 1988; Ferin and Feldstein, 1978; Muhle et al., 1990). Because high lung burdens of relatively insoluble, biochemically inert particles result in diminution of normal lung clearance kinetics or in what is now called particle overloading, this effect appears to be more related to the mass and/or volume of particles in the lung than to the nature of the particles per se. Particle overload relates only to poorly soluble particles of low toxicity. It must be noted, however, that some types of particles may be cytotoxic and impair clearance at lower lung burdens (e.g., crystalline silica may impair clearance at much lower lung burdens than DPM). Regardless, as pointed out by Morrow (1988), particle overloading in the lung modifies the dosimetry for particles in the lung and thereby can alter toxicologic responses.

Although quantitative data are limited regarding lung overload associated with impaired alveolar clearance in humans, impairment of clearance mechanisms appears to occur, and at a lung burden generally in the range reported to impair clearance in rats, i.e., approximately 1 mg/g lung tissue. Stöber et al. (1967), in their study of coal miners, reported lung particle burdens of 2 to 50 mg/g lung tissue, for which estimated clearance $t_{1/2}$ values were very long (4.9 years). Freedman and Robinson (1988) also reported slower alveolar clearance rates in coal miners, some of whom had a mild degree of pneumoconiosis. It must be noted, however, as has been reported even in some studies with rats exposed lifetime to overload conditions (50 mg/m^3 TiO_2; Lee et al., 1986) that no lung cancer was reported among those miners with apparent particle overload.

Consideration of the above information further clarifies the human relevance of noncancer effects that may be elicited from overload-type conditions in rats studies. Under conditions that would be most likely to elicit overload conditions in humans, such as the excessive dust burdens in the lungs of miners, cancer is not observed although noncancer responses such as fibrosis and macrophage responses are documented (Freedman and Robinson, 1988; Haschek and Witschi, 1991; Oberdörster, 1994). In deliberation on the matter of whether the rat lung nonneoplastic responses to poorly soluble particles (such as DPM) are predictive of a similar hazard in humans, an expert panel (ILSI, 2000) opined that such responses would indeed be a useful predictor for similar responses in humans.

3.4.3. Potential Mechanisms for an AM Sequestration Compartment for Particles During Particle Overload

Several factors may be involved in the particle-load-dependent retardations in the rate of particle removal from the lung and the corresponding functional appearance of an abnormally slow clearing or particle sequestration compartment. As previously mentioned, one potential site for particle sequestration is the containment of particles in the Type I cells. Information on the retention kinetics for particles in the Type I cells is not currently available. Also, no morphometric analyses have been performed to date to estimate what fraction of a retained lung burden may be contained in the Type I cell population of the lung during lung overloading.

Another anatomical region in the lung that may be a slow clearing site is the interstitial compartment (Kuempel, 2000). Little is known about the kinetics of removal of free particles or particle-containing macrophages from the interstitial spaces, or what fraction of a retained burden of particles is contained in the lung's interstitium during particle overload. The gradual accumulation of particles in the regional lymph nodes and the appearance of particles and cells with associated particles in lymphatic channels and in the peribronchial and perivascular lymphoid tissue (Lee et al., 1985; White and Garg, 1981) suggest that the mobilization of particles from interstitial sites via local lymphatics is a continual process.

Indeed, it is clear from histologic observations of the lungs of rodents chronically exposed to DPM that Type I cells, the interstitium, the lymphatic channels, and pulmonary lymphoid tissues could collectively comprise subcompartments of a more generalized slow clearing compartment.

Although these sites must be considered potential contributors to the increased retention of particles during particle overload, a disturbance in particle-associated AM-mediated clearance is undoubtedly the predominant cause, inasmuch as, at least in rodents, the AMs are the primary reservoirs of deposited particles. The factors responsible for a failure of AMs to translocate from the alveolar space compartment in lungs with high particulate matter burdens remain uncertain, although a hypothesis concerning the process involving volumetric AM burden has been offered (Morrow, 1988).

Other processes also may be involved in preventing particle-laden AMs from leaving the alveolar compartment under conditions of particle overload in the lung. Clusters or aggregates of particle-laden AMs in the alveoli are typically found in the lungs of laboratory animals that have received large lung burdens of a variety of types of particles (Lee et al., 1985), including DPM (White and Garg, 1981; McClellan et al., 1982). The aggregation of AMs may explain, in part, the reduced clearance of particle-laden AM during particle overload. The definitive mechanism(s) responsible for this clustering of AMs has not been elucidated to date. Whatever the underlying mechanism(s) for the AM aggregation response, it is noteworthy that AMs lavaged from the lungs of DE-exposed animals continue to demonstrate a propensity to aggregate (Strom, 1984). This observation could result either from the surface characteristics of AMs being fundamentally altered or from macrophage activation by phagocytized particles that then release chemotactic factors (Bellmann et al., 1990) in a manner that promotes their adherence to one another in the alveolar region. AM aggregation may not simply be directly caused by their abundant accumulation as a result of immobilization by large particle loads. Furthermore, even though overloaded macrophages may redistribute particle burden to other AMs, clearance may remain inhibited (Lehnert, 1988). This may, in part, be because attractants from the overloaded AMs cause aggregation of those that are not carrying a particle burden.

3.5. BIOAVAILABILITY OF ORGANIC CONSTITUENTS PRESENT ON DIESEL EXHAUST PARTICLES

Because it has been shown that DPM extract is not only mutagenic but also contains known carcinogens, the organic fraction was originally considered to be the primary source of carcinogenicity in animal studies. Since then, evidence has been presented that carbon black, lacking an organic component, is capable of inducing lung cancer at exposure concentrations sufficient to induce lung particle overload. This suggested that the relatively insoluble carbon core of the particle may be of greater importance for the pathogenic and carcinogenic processes observed in the rat inhalation studies conducted at high exposure concentrations. (See Chapter 7 for a discussion of this issue.) However, lung cancer reported in epidemiologic studies was associated with diesel exposure levels far below those inducing particle overload in lifetime studies in rats. It is therefore suggested that compounds in the organic fraction of DPM may have some role in the etiology of human lung cancers. This leads to an interest in characterizing the bioavailability of organics.

The bioavailability of toxic organic compounds adsorbed to DPM can be influenced by a variety of factors. Although the agent may be active while present on the particle, most particles are taken up by AMs, a cell type not generally considered to be a target site. In order to reach the target site, elution from the particle surface is necessary followed by diffusion and uptake by the target cell. Metabolism to an active form by either the phagocytes or the target cells is also required for activity of many of the compounds present.

This section describes only the various manner and mechanisms by which organics adsorbed onto DPM may become bioavailable. In vivo and in vitro results involving various biological extraction media as well as modeled scenarios of bioavailability are presented. Actual estimates of the amount of organics from DPM to which respiratory tract tissues may be exposed are discussed and presented in Section 3.6.2.7.

3.5.1. In Vivo Studies

3.5.1.1. *Laboratory Investigations*

Several studies reported on the retention of particle-adsorbed organics following administration to various rodent species. In studies reported by Sun et al. (1982, 1984) and Bond et al. (1986), labeled organics were deposited on DPM following heating to vaporize away the organics originally present. Sun et al. (1982) compared the disposition of either pure or diesel particle-adsorbed benzo[*a*]pyrene (B[*a*]P) following nose-only inhalation by F344 rats. About 50% of particle-adsorbed B[*a*]P was cleared with a half-time of 1 h, predominantly by mucociliary clearance. The long-term retention of particle-adsorbed ^{3}H-B[*a*]P at 18 days was approximately 230-fold greater than that for pure ^{3}H-B[*a*]P (Sun et al., 1982). At the end of exposure, about 15% of the ^{3}H label was found in blood, liver, and kidney. Similar results were reported in a companion study by Bond et al. (1986), and by Sun et al. (1984) with another PAH, 1-nitropyrene, except the retention half-time was 36 days.

Ball and King (1985) studied the disposition and metabolism of intratracheally instilled ^{14}C-labeled 1-NP (>99.9% purity) coated onto DPM. About 50% of the ^{14}C was excreted within the first 24 h; 20% to 30% of this appeared in the urine, and 40% to 60% was excreted in the feces. Traces of radiolabel were detected in the trachea and esophagus. Five percent to 12% of the radiolabel in the lung co-purified with the protein fraction, indicating some protein binding. The corresponding DNA fraction contained no ^{14}C above background levels.

Bevan and Ruggio (1991) assessed the bioavailability of B[*a*]P adsorbed to DPM from a 5.7-L Oldsmobile diesel engine. In this study, exhaust particles containing 1.03 µg B[*a*]P/g particles were supplemented with exogenous ^{3}H-B[*a*]P to provide 2.62 µg B[*a*]P/g of exhaust particles. In vitro analysis indicated that the supplemented B[*a*]P eluted from the particles at the same rate as the original B[*a*]P. Twenty-four hours after intratracheal instillation in Sprague-Dawley rats, 68.5% of the radiolabel remained in the lungs. This is approximately a 3.5-fold greater proportion than that reported by Sun et al. (1984), possibly because smaller amounts of B[*a*]P adsorbed on the particles resulted in stronger binding or possibly because of differences between inhalation exposure and intratracheal exposure. At 3 days following administration, more than 50% of the radioactivity remained in the lungs, nearly 30% had been excreted into the feces, and the remainder was distributed throughout the body. Experiments using rats with cannulated bile ducts showed that approximately 10% of the administered radioactivity appeared in the bile over a 10-h period and that less than 5% of the radioactivity entered the feces via mucociliary transport. Results of these studies showed that when organics are adsorbed to DPM the retention of organics in the lungs is increased considerably. Because retention time is very short following exposure to pure compounds not bound to particles, it can be concluded that the increased retention time is primarily the result of continued binding to DPM. The detection of labeled compounds in blood, systemic organs, urine, and bile as well as the trachea, however, provides evidence that at least some of the organics are eluted from the particles following deposition in the lungs and would not be available as a carcinogenic dose to the lung. As discussed above, the results of Gerde (1999a,b) indicate that most of the organics eluted from particles deposited in the alveolar region, especially PAHs, are predicted to rapidly enter the bloodstream and thus not to contribute to potential induction of lung cancer.

3.5.1.2. *Studies in Occupationally Exposed Humans*

DNA adducts in the lungs of experimental animals exposed to DE have been measured in a number of animal experiments (World Health Organization, 1996). Such studies, however, provide limited information regarding bioavailability of organics, as positive results may well have been related to factors associated with lung particle overload, a circumstance reported by Bond et al. (1990), who found carbon black, a substance virtually devoid of organics, to induce DNA adducts in rats at lung overload doses. These authors showed that levels of DNA adducts present in pulmonary type II cells from the lungs of rats (n=15) exposed to equivalent conditions of either carbon black or DE (each at 6.2 mg/m^3) were nearly the same and 4- to 5-fold more than air-exposed controls. This similarity was noted despite a difference of nearly three orders of magnitude in solvent-extractable organic content between DE (30%) and carbon black (0.04%). None of the DE or carbon black adducts comigrated with B[*a*]P diol epoxide.

On the other hand, DNA adduct formation and/or mutations in blood cells following exposure to DPM, especially at levels insufficient to induce lung overload, can be presumed to be the result of organics diffusing into the blood. Hemminki et al. (1994) reported increased levels of DNA adducts in lymphocytes of bus maintenance and truck terminal workers. Österholm et al. (1995) studied mutations at the hprt-locus of T-lymphocytes in bus maintenance workers. Although they were unable to identify clear-cut exposure-related differences in types of mutations, adduct formation was significantly increased in the exposed workers. Nielsen et al. (1996) reported significantly increased levels of lymphocyte DNA adducts, hydroxyvaline adducts in hemoglobin, and 1-hydroxypyrene in urine of garage workers exposed to DE.

3.5.2. In Vitro Studies

3.5.2.1. *Extraction of Diesel Particle-Associated Organics by Biological Fluids*

In vitro extraction of mutagenic organics by biological fluids can be estimated by measurement of mutagenic activity in the particular fluid. Using this approach, Brooks et al. (1981) reported extraction efficiencies of only 3% to 10% that of dichloromethane following DPM incubation in lavage fluid, serum, saline, albumin, or dipalmitoyl lecithin. Moreover, extraction efficiency did not increase with incubation time up to 120 h. Similar findings were reported by King et al. (1981), who also reported that lung lavage fluid and lung cytosol fluid extracts of DPM were not mutagenic. Serum extracts of DPM did exhibit some mutagenic activity, but considerably less than that of organic solvent extracts. Furthermore, the mutagenic activity of the solvent extract was significantly reduced when combined with serum or lung cytosol fluid, suggesting protein binding or biotransformation of the mutagenic components. Siak et al. (1980) assessed the mutagenicity of material extracted from DPM by bovine serum albumin in solution, simulated lung surfactant, fetal calf serum (FCS), and physiological saline. Only FCS was found to extract some mutagenic activity from the DPM. Keane et al. (1991), however, reported positive effects for mutagenicity in salmonella and sister chromatid exchange in V79 cells exclusively in the supernatant fraction of DPM dispersed in aqueous mixtures of dipalmitoyl phosphatidyl choline, a major component of pulmonary surfactant, indicating that pulmonary surfactant components can extract active components of DPM and result in bioavailability.

The ability of biological fluids to extract organics in vitro and their effectiveness in vivo remains equivocal because of the character of the particular fluid. For example, extracellular lung fluid is a complex mixture of constituents that undoubtedly have a broad range of hydrophobicity (George and Hook, 1984; Wright and Clements, 1987), which is fundamentally different from serum in terms of chemical composition (Gurley et al., 1988). Moreover, assessments of the ability of lavage fluids, which actually represent substantially diluted extracellular lung fluid, to extract mutagenic activity from DPM clearly do not reflect the in vivo condition. Finally, except under very high exposure concentrations, few particles escape phagocytosis and possible intracellular extraction. In this respect, Hiura et al. (1999) have shown that whole exhaust containing DPM, but not carbon black or diesel particles devoid of organics, induces apoptosis, apparently through generation of oxygen radicals. This study implicates organic compounds present on DPM. It also indicates the bioavailability of organics for generation of radicals from reaction with particle-associated organics or following elution from DPM.

3.5.2.2. *Extraction of DPM-Associated Organics by Lung Cells and Cellular Components*

A more likely means by which organics may be extracted from DPM and metabolized in the lung is either through particle dissolution or extraction of organics from the particle surface within the phagolysosomes of AMs and other lung cells. This mechanism presupposes that the particles are internalized. Specific details about the physicochemical conditions of the intraphagolysosomal environment, where particle dissolution in AMs presumably occurs in vivo, have not been well characterized. It is known that phagolysosomes constitute an acidic (pH 4 to 5) compartment in macrophages (Nilsen et al., 1988; Ohkuma and Poole, 1978). The relatively low pH in the phagolysosomes has been associated with the dissolution of some types of inorganic particles (some metals) by macrophages (Marafante et al., 1987; Lundborg et al., 1984), but few studies provide quantitative information concerning how organics from DPM may be extracted in the phagolysosomes (Bond et al., 1983). Whatever the mechanism, assuming elution occurs, the end result is a prolonged exposure of the respiratory epithelium to DPM organics, which include low concentrations of carcinogenic agents such as PAH.

Early studies by King et al. (1981) found that when pulmonary alveolar macrophages were incubated with DPM, amounts of organic compounds and mutagenic activity decreased measurably from the amount originally associated with the particles, suggesting that organics were removed from the phagocytized particles. Leung et al. (1988) studied the ability of rat lung and liver microsomes to facilitate transfer and metabolism of B[*a*]P from diesel particles. ^{14}C-B[*a*]P coated diesel particles, previously extracted to remove the original organics, were incubated directly with liver or lung microsomes. About 3% of the particle-adsorbed B[*a*]P was transferred to the lung microsomes within 2 h. Of this amount about 1.5% was metabolized, for a total of about 0.05% of the B[*a*]P originally adsorbed to the DPM. Although transformation is slow, the long retention of particles, including DPM, in humans may cause the fraction eluted and metabolized to be considerably higher than this figure.

In analyzing phagolysosomal dissolution of various ions from particles in the lungs of Syrian golden hamsters, however, Godleski et al. (1988) demonstrated that solubilization did not necessarily result in clearance of the ions (and therefore general bioavailability) in that binding of the solubilized components to cellular and extracellular structures occurred. It is reasonable to assume that phagocytized DPM particles may be subject to similar processes and that these processes would be important in determining the rate of bioavailability of the particle-bound constituents of DPM.

Alveolar macrophages or macrophage cell lines that were exposed to high concentrations of DPM in vitro were observed to undergo apoptosis, which was attributed to the generation of reactive oxygen radicals (ROR) (Hiura et al. 1999). Further experimentation showed that DPM with the organic constituents extracted was no longer able to induce apoptosis or generate ROR. The organic extracts alone, however, were able to induce apoptosis as well as the formation of stress-activated protein kinases that play definitive roles in cellular apoptotic pathways. The injurious effects of nonextracted DPM or of DPM extracts were observed to be reversible by the antioxidant radical scavenger N-acetyl cysteine. These data suggest strongly that, at least at high concentrations of DPM, the organic constituents contained on DPM play a central role in cellular toxicity and that this toxicity may be attributable to the generation of ROR.

3.5.3. Modeling Studies

Gerde et al. (1991a,b) described a model simulating the effect of particle aggregation and PAH content on the rate of PAH release in the lung. According to this model, particle aggregation will occur with high exposure concentrations, resulting in a slow release of PAHs and prolonged exposure to surrounding tissues. However, large aggregates of particles are unlikely to form at doses typical of human exposures. Inhaled particles, at low concentrations, are more likely to deposit and react with surrounding lung medium without interference from other particles. The model predicts that under low-dose exposure conditions, more typical in humans, particle-associated organics will be released more rapidly from the particles because they are not aggregated. Output from this model suggests strongly that sustained exposure of target tissues to PAHs will result from repeated exposures, not from increased retention due to association of PAHs with carrier particles. This distinction is important because at low doses PAH exposure and lung tumor formation would be predicted to occur at sites of deposition rather than retention, as occurs with high doses.

The site of release of PAHs influences effective dose to the lungs because, as noted previously, at least some free organic compounds deposited in the lungs are rapidly absorbed into the bloodstream. Gerde et al. (1991b) predicted PAHs would be retained in the alveoli less than 1 min, whereas they may be retained in the conducting airways for hours. These predictions were based on an average diffusion distance to capillaries of only about 0.5 µm in the alveoli, as compared to possibly greater than 50 µm in the conducting airways such as the bronchi. An experimental study by Gerde et al. (1999) provided support for this prediction. Beagle dogs were exposed to ^{3}H-B[*a*]P adsorbed on the carbonaceous core of DPM at a concentration of 15 µg B[*a*]P/gm particles. A rapidly eluting fraction from DPM deposited in the alveoli was adsorbed into the bloodstream and metabolized in the liver, whereas the rapidly eluting fraction from DPM deposited in the conducting airways was to a large extent retained and metabolized in situ in the airway epithelium. Thus, organics eluting from DPM depositing in the conducting airways (i.e., the TB region) would have a basis for a longer residence time in the tissues (and for consequent biological activity) than would organics eluting from DPM depositing in the pulmonary parenchyma. And, given the same overall deposited dose of DPM to the total pulmonary system, a deposited dose with a higher proportion in the TB region would incur a higher probability of tissue interactions with any eluted organics. This may be the case when comparing regional doses of DPM to humans as compared to rats for two reasons. First, one deposition model (Freijer et al., 1999) projects that for air concentrations of DPM at either 0.1 or 1.0 mg/m^3, a higher proportion of the total DPM dose to the pulmonary system would be deposited in the TB area for humans at 31% (TB/Total; 0.098 / 0.318) than for rats at only 16% (0.04 / 0.205). Second, comparative morphometry data of DPM from chronically exposed rats and primates showed higher levels of DPM adjacent to conducting airways in primates (i.e., the interstitium of the respiratory bronchioles) than were present in parallel regions in the rat (interstitium of the alveolar ducts) (Nikula et al., 1997a,b). The focal nature of this deposition could give rise to localized high concentrations of any organics eluted.

3.5.4. Summary and Bioavailability

At present, the available data are insufficient to accurately model the effective dose of organics in the respiratory tract of humans or animals exposed to DPM. As mentioned above, though, the following Section (3.6.2.7) does present estimates of the actual amount of organics, including carcinogenic PAH such as B[*a*]P, that are deposited in the lung and could become bioavailable.

Overall, the results of studies presented in Section 3.6 provide evidence that at least some of the organic matter adsorbed to DPM deposited in the respiratory tract is eluted. The percentage taken up and metabolized to an active form by target cells is, however, uncertain. Organics eluted from particles deposited in alveoli are likely to rapidly enter the bloodstream via translocation across endothelial cells, where they may undergo metabolism by enzymes such as cytochromes P-450 that are capable of producing reactive species. Organics eluted from particles deposited in the conducting airways (the bronchioles, bronchi, and trachea) may also undergo metabolism in other cell types such as the Clara cells with constituent or inducible cytochrome P-450 species. Risk of harmful effects for particles deposited in the conducting airways is predicted to be greater because solubilized organic compounds will be retained in the thicker tissue longer, allowing for metabolism by epithelial cells lining the airways. Furthermore, since some deposition in conducting airways occurs primarily at bifurcations, localized higher concentrations may occur.

3.6. MODELING THE DEPOSITION AND CLEARANCE OF PARTICLES IN THE RESPIRATORY TRACT

3.6.1. Introduction

The biological effects of inhaled particles are a function of their disposition, i.e., their deposition and clearance. This, in turn, depends on their patterns of deposition (i.e., the sites within which particles initially come into contact with airway epithelial surfaces and the amount removed from the inhaled air at these sites) and clearance (i.e., the rates and routes by which deposited materials are removed from the respiratory tract). Removal of deposited materials involves the competing processes of macrophage-mediated clearance and dissolution-absorption. Over the years, mathematical models for predicting deposition, clearance and, ultimately, retention of particles in the respiratory tract have been developed. Such models help interpret experimental data and can be used to make predictions of deposition for cases where data are not available. A review of various mathematical particle deposition models was given by Morrow and Yu (1993) and in U.S. EPA (1996).

Currently available data for long-term inhalation exposures to poorly soluble particles (e.g., TiO_2, carbon black, and DPM) show that pulmonary retention and clearance of these particles are not adequately described by simple first-order kinetics and a single compartment representing the alveolar macrophage particle burden. Several investigators have developed models for deposition, transport, and clearance of poorly soluble particulate matter in the lungs. All of these models identify various compartments and associated transport rates, but empirically derived data are not available to substantiate many of the assumptions made in these models.

3.6.2. Dosimetry Models for DPM

3.6.2.1. *Introduction*

The extrapolation of toxicological results from laboratory animals to humans, the goal of this chapter, requires the use of dosimetry models for both species that include, first, the deposition of DPM in various regions of the respiratory tract, and second, the transport and clearance of the particles, including adsorbed constituents, from their deposited sites. Therefore the ideal model structure would incorporate both deposition and clearance in animals and humans.

Deposition of particles in the respiratory tract, as described above, can be by impaction, sedimentation, interception, and diffusion, with the contribution from each mechanism a function of particle size, lung structure, and size and breathing parameters. Because of the size of diesel particles, under normal breathing conditions most of this deposition takes place by diffusion, and the fraction of the inhaled mass that is deposited in the thoracic region (i.e., TB plus A regions) is substantially similar for rats and humans.

Among deposition models that include aspects of lung structure and breathing dynamics, the most widely used have been typical-path or single-path models (Yu, 1978; Yu and Diu, 1983). The single-path models are based on an idealized symmetric geometry of the lung, assuming regular dichotomous branching of the airways and alveolar ducts (Weibel, 1963). They lead to modeling the deposition in an average regional sense for a given lung depth. Although the lower airways of the lung may be reasonably characterized by such a symmetric representation, there are major asymmetries in the upper airways of the tracheobronchial tree that in turn lead to different apportionment of airflow and particulate burden to the different lung lobes. The rat lung structure is highly asymmetric because of its monopodial nature, leading to significant errors in a single-path description. This is rectified in the multiple-path model of the lung, which incorporates asymmetry and heterogeneity in lung branching structure and calculates deposition at the individual airway level. This model has been developed for the rat lung (Anjilvel and Asgharian, 1995; Freijer et al., 1999) and, in a limited fashion because of insufficient morphometric data, for the human lung (Subramaniam et al., 1998; Yeh and Schum, 1980). Such models are particularly relevant for fine and ultrafine particles such as occur in DPM. However, models for clearance have not yet been implemented in conjunction with the use of the multiple-path model.

Clearance of particles in the respiratory tract takes place (1) by mechanical processes: mucociliary transport in the ciliated conducting airways and macrophage phagocytosis and migration in the nonciliated airways, and (2) by dissolution. The removal of material such as the carbonaceous core of DPM is largely by mechanical clearance, whereas the clearance of the organics adsorbed onto the carbon core is principally by dissolution.

Several models currently exist that integrate both deposition and clearance, some specific for humans and others specific for laboratory animals. They differ significantly in the level of physiological detail that is captured in the model and in the uncertainties associated with the values of the parameters used. All of these models identify various compartments and associated transport rates, but empirically derived data are not available to validate many of the assumptions made in the models. A review of the principal human and animal deposition/clearance models, including candidate models for use in animal-to-human extrapolation in this assessment, are considered below.

3.6.2.2. *Human Models*

The International Commission on Radiological Protection (ICRP) recommends specific mathematical dosimetry models as a means to calculate the mass deposition and retention by different parts of the human respiratory tract and, if needed, tissues beyond the respiratory tract. The latest ICRP-recommended model, ICRP66 (1994), considers the human respiratory tract as four general anatomical regions: the ET region, which is divided into two subregions; the TB region, which is also subdivided into two regions; and the gas-exchange tissues, which are further defined as the alveolar-interstitial (AI) region but are exactly comparable to the pulmonary or A region. The fourth region is the lymph nodes. The deposition component of the model for the ET, TB, and A regions is semi-empirical based on equations derived from fitting experimental deposition data. The dimensional model used for the TB and A regions was adopted from several sources (Weibel, 1963; Yeh and Schum, 1980; and Phalen et al., 1985); the physical aspects of the individual airway generations for these regions were all averaged after each source was adjusted to a standard functional residual capacity. The equations for estimating deposition in these areas was empirical, obtained from fitting data obtained from partial human lung casts or from theoretical calculation for these regions. Deposition in the four regions is given as a function of particle size with two different types of particle size parameters: activity median thermodynamic diameter (AMTD) for deposition of particles ranging in size from 0.0005 to 1.0 µm and the activity median aerodynamic diameter (AMAD) for deposition of particles from 0.1 to 100µm. Reference values of regional deposition are provided and guidance is given for extrapolating to specific individuals and populations under different levels of activity. This model also includes consideration of particle inhalability, a measure of the degree to which particles can enter the respiratory tract and be available for deposition. After deposition occurs in a given region, two different intrinsic clearance processes act competitively on the deposited particles: particle transport, including mucociliary clearance from the respiratory tract and physical clearance of particles to the regional lymph nodes; and absorption, including movement of material to blood and both dissolution-absorption and transport of ultrafine particles. Rates of particle clearance derived from studies with human subjects are assumed to be the same for all types of particles. The ICRP model provides average concentration or average number values on a regional basis, i.e., mass or number deposited or retained in the ET, TB, or A regions. Additionally, while the ICRP66 model was developed primarily for use with airborne radioactive particles and gases in humans, its use for describing the dosimetry of inhaled mass of nonradioactive substances in humans is also appropriate.

The National Council on Radiation Protection (NCRP) has issued a human respiratory tract dosimetry model that was developed concurrently with the ICRP model (NCRP, 1997; Phalen et al.,1991). It addresses (1) inhalability of particles, (2) new subregions of the respiratory tract, (3) dissolution-absorption as an important aspect of the model, and (4) body size (and age). The proposed NCRP model defines the respiratory tract in terms of a naso-oro-pharyngo-laryngeal (NOPL) region, a TB region, a pulmonary (P) region, and the lung-associated lymph nodes (LN). Like the ICRP model, the deposition component of the model for the ET region is semi-empirical, based on equations derived from fitting experimental deposition data. The dimensional model used for the TB and A regions was that of Yeh and Schum (1980). The data from this model were used to estimate physical processes along a typical lung path (vice multiple-path; see MPPDep model description below) on a generation-by-generation basis. The rates of dissolution-absorption of particles and their constituents are derived from clearance data from humans and laboratory animals. The effect of body growth on particle deposition is also considered in the model, although particle clearance rates are assumed to be independent of age. The NCRP model currently available considers deposition only within these regions of the respiratory tract. As with the ICRP model, the NCRP model can be used for evaluating inhalation exposures to all types of particles. Comparison of regional deposition patterns estimated by the ICRP66 and the current NCRP models have been reported (Yeh et al., 1996). One principal difference between the models is the enhanced deposition of ultrafines in the tracheobronchial region predicted by the NCRP model compared with the ICRP model. This effect of enhanced deposition is claimed to be due to the entrance configuration of an airway bifurcation.

The model of Freijer et al. (1999) is a multiple-path particle deposition model (MPPDep) for the human respiratory tract that differs fundamentally from the above two models as described in the Introduction. Calculations from the model may be based on either single-path or multiple-path methods for tracking air flow and calculating aerosol deposition in the lung. The single-path method calculates deposition for a typical path, whereas the multiple-path method is capable of incorporating the asymmetry in lung structure and providing lobar-specific and airway-specific information. Two options are provided for idealizing the geometry of the human lung; one uses a symmetric geometry for the whole lung and the second option captures the asymmetry in the lobar structure, but treats the geometry within each lung lobe in a symmetric fashion. Both models are constructed using morphometric data compiled by Yeh and Schum (1980). Within each airway, deposition is calculated using theoretically derived efficiencies for deposition by diffusion (most relevant to DPM), sedimentation, and impaction within the airway or airway bifurcation. Filtration of particulate aerosols by the head is determined using empirical efficiency functions. The model calculates deposition of monodisperse and polydisperse aerosols in the respiratory tract of both humans (and rats) for particles ranging from ultrafine (0.01 microns) to coarse (20 microns) sizes. Various breathing patterns may be simulated: endotratracheal, nasal, oral, and combined nasal and oral (oronasal). The exposure scenario may be constant or variable. For the variable scenario, the user may specify different breathing patterns either on an hourly basis during the day or activity patterns for variable time durations. Adjustment for inhalability of the particle is also included as an option. The software in this model provides results for the deposition fraction and mass deposited in the various regions of the respiratory tract in graphical and text formats.

The combined model of Yu et al. (1991) has a human component that will be discussed below.

3.6.2.3. *Animal Models*

Strom et al. (1988) developed a multicompartmental model for particle retention that partitioned the alveolar region into two compartments on the basis of the physiology of clearance. The alveolar region has a separate compartment for sequestered macrophages, corresponding to phagocytic macrophages that are heavily laden with particles and clustered, and consequently have significantly lowered mobility. The model has the following compartments: (1) tracheobronchial tree, (2) free particulate on the alveolar surface, (3) mobile phagocytic alveolar macrophages, (4) sequestered particle-laden alveolar macrophages, (5) regional lymph nodes, and (6) gastrointestinal tract. The model is based on mass-dependent clearance (the rate coefficients reflect this relationship), which dictates sequestration of particles and their eventual transfer to the lymph nodes. The transport rates between various compartments were obtained by fitting the calculated results to lung and lymph node burden experimental data for both exposure and postexposure periods. Because the number of fitted parameters was large, the model is not likely to provide unique solutions that would simulate experimental data from various sources and for different exposure scenarios. For the same reason, it is not readily possible to use this model for extrapolating to humans.

Stöber and co-workers have worked extensively in developing models for estimating retention and clearance of relatively insoluble respirable particles (as DPM) in the lung. Their most recent work (1994), a revised version of the POCK model, is a rigorous attempt to incorporate most of the physiologically known aspects of alveolar clearance and retention of inhaled relatively insoluble particles. Their multicompartmental kinetics model has five subcompartments. The transfer of particles between any of the compartments within the alveolar region is macrophage mediated. There are two compartments that receive particles cleared from the alveolar regions: the TB tract and the lymphatic system. The macrophage pool includes both mobile and particle-laden immobilized macrophages. The model assumes a constant maximum volume capacity of the macrophages for particle uptake and a material-dependent critical macrophage load that results in total loss of macrophage mobility. Sequestration of those macrophages heavily loaded with a particle burden close to a volume load capacity is treated in a sophisticated manner by approximating the particle load distribution in the macrophages. The macrophage pool is compartmentalized in terms of numbers of macrophages that are subject to discrete particle load intervals. Upon macrophage death, the phagocytized particle is released back to the alveolar surface; thus phagocytic particle collection competes to some extent with this release back to the alveolar surface. This recycled particle load is also divided into particle clusters of size intervals defining a cluster size distribution on the alveolar surface. The model yields a time-dependent frequency distribution of loaded macrophages that is sensitive to both exposure and recovery periods in inhalation studies.

The POCK model also emphasizes the importance of interstitial burden in the particle overload phenomenon and indicates that particle overload (Section 3.4) is a function of a massive increase in particle burden of the interstitial space rather than total burden of the macrophage pool. The relevance of the increased particle burden in the interstitial space lies with the fact that this compartmental burden is not available for macrophage-mediated clearance and, therefore, persists even after cessation of exposure.

Although the POCK model is the most sophisticated in the physiological complexity it introduces, it suffers from a major disadvantage. Experimental retention studies provide data only on total alveolar and lymph node mass burdens of the particles as a function of time. The relative fraction of the deposition between the alveolar subcompartments in the Stöber model therefore cannot be obtained experimentally; the model thus uses a large number of parameters that are simultaneously fit to experimental data. Although the model predictions are tenable, experimental data are not currently available to substantiate the proposed compartmental burdens or the transfer rates associated with these compartments. Thus, overparameterization in the model leads to the possibility that the model may not provide a unique solution that may be used for a variety of exposure scenarios, and for the same reason, cannot be used for extrapolation to humans. Stöber et al. have not developed an equivalent model for humans; therefore the use of their model in our risk assessment for diesel is not attempted.

3.6.2.4. *Combined Models (for interspecies extrapolation)*

Currently available data for long-term inhalation exposures to poorly soluble particles (e.g., TiO_2, carbon black, and DPM) show that pulmonary retention and clearance of these particles are not adequately described by simple first-order kinetics and a single compartment representing the alveolar macrophage particle burden. A two-compartment lung model that could be applied to both humans and animals was developed by Smith (1985) and includes alveolar and interstitial compartments. For uptake and clearance of particles by alveolar surface macrophages and interstitial encapsulation of particles (i.e., quartz dust), available experimental data show that the rate-controlling functions followed Michaelis-Menton type kinetics, whereas other processes affecting particle transfer are assumed to be linear. The model was used in an attempt to estimate interstitial dust and fibrosis levels among a group of 171 silicon carbide workers; the levels were then compared with evidence of fibrosis from chest radiographs. A significant correlation was found between estimated fibrosis and profusion of opacities on the radiographs. This model provides as many as seven different rate constants derived by various estimations and under various conditions from both animal and human sources. The model was intended for estimation of generalized dust described only as respirable without any other regard to sizing for establishing the various particle-related rate constants. As most of the described functions could not be validated with experimental data, the applicability of this model, especially for particulates in the size range of DPM, was unclear.

Yu et al. (1991; also reported as Yu and Yoon, 1990) have developed a three-compartment lung model that consists of tracheobronchial (T), alveolar (A), and lymph node (L) compartments (Appendix A, Figure A-1) and, in addition, considered filtration by a nasopharyngeal or head (H) compartment. The tracheobronchial compartment is important for short-term considerations, whereas long-term clearance takes place via the alveolar compartment. In contrast to the Stöber and Strom approaches, the macrophage compartment in the Yu model contains all of the phagocytized particles; that is, there is no separate (and hypothetical) sequestered macrophage subcompartment. Absorption by the blood (B) and gastrointestinal (G) compartments was also considered. Although the treatment of alveolar clearance is physiologically less sophisticated than that of the Stöber et al. model, the Yu model provides a more comprehensive treatment of clearance by including systemic compartments and the head, and including the clearance of the organic components of DPM in addition to the relatively insoluble carbon core.

In order to progress beyond the classical human ICRP66 retention model, Yu has addressed the impairment of long-term clearance (the overload effect) by using a set of variable transport rates for clearance from the alveolar region as a function of the mass of DPM in the alveolar compartment. A functional relationship for this was derived mathematically (Yu et al., 1989) based upon Morrow's hypothesis for the macrophage overload effect discussed earlier in the section on pulmonary overload. The extent of the impairment depends on the initial particle burden, with greater particulate concentration leading to slower clearance.

Within this model, DPM is treated as being composed of three material components: a relatively insoluble carbonaceous core, slowly cleared organics (10% particle mass), and fast-cleared organics (10% particle mass). Such a partitioning of organics was based on observations that the retention of particle-associated organics in lungs shows a biphasic decay curve (Sun et al., 1984; Bond et al., 1986). For any compartment, each of these components has a different transport rate. The total alveolar clearance rate of each material component is the sum of clearance rates of that material from the alveolar to the tracheobronchial, lymph, and blood compartments. In the Strom and Stöber models discussed above, the clearance kinetics of DPM were assumed to be entirely dictated by those of the relatively insoluble carbonaceous core. For those organic compounds that become dissociated from the carbon core, clearance rates are likely to be very different, and some of these compounds may be metabolized in the pulmonary tissue or be absorbed by blood.

The transport rates for the three components were derived from experimental data for rats using several approximations. The transport rates for the carbonaceous core and the two organic components were derived by fitting to data from separate experiments. Lung and lymph node burdens from the experiment of Strom et al. (1988) were used to determine the transport rate of the carbonaceous core. The Yu model incorporates the impairment of clearance by including a mass dependency in the transport rate. This mass dependency is easily extracted because the animals in the experiment were sacrificed over varying periods following the end of exposure.

It was assumed that the transport rates from the alveolar and lymph compartments to the blood were equal and independent of the particulate mass in the alveolar region. The clearance rates of particle-associated organics for rats were derived from the retention data of Sun et al. (1984) for B[a]P and the data of Bond et al. (1986) for nitropyrene adsorbed on diesel particles.

In their model Yu et al. (1991) make two important assumptions to carry out the extrapolation in consideration of inadequate human data. First, the transport rates of organics in the DPM do not change across species. This is based upon lung clearance data of inhaled lipophilic compounds (Schanker et al., 1986), where the clearance was seen to be dependent on the lipid/water partition coefficient. In contrast, the transport rate of the carbonaceous core is considered to be significantly species dependent (Bailey et al., 1982). DPM clearance rate is determined by two terms in the model (see Equation A-82 in Appendix A). The first, corresponding to macrophage-mediated clearance, is a function of the lung burden and is assumed to vary significantly across species. The second term, a constant, corresponding to clearance by dissolution, is assumed to be species independent. The mass-dependent term for humans is assumed to vary in the same proportion as in rats under the same unit surface particulate dose. The extrapolation is then achieved by using the data of Bailey et al. (1982) for the low lung burden limit of the clearance rate. This value of 0.0017/day was lower (i.e., slower) than the rat value by a factor of 7.6. This is elaborated further in Appendix A. Other transport rates that have lung burden dependence are extrapolated in the same manner.

It should be noted that the Bailey et al. (1982) experiment in humans used fused monodisperse aluminosilicate particles of 1.9 and 6.1 µm aerodynamic diameters. Yu and co-workers have used the longer of the half-times observed in this experiment to obtain an alveolar human clearance rate (λ), of 0.00169/day. In using such data for DPM 0.2 µm in diameter, they have assumed the clearance of relatively insoluble particles to be independent of size over the range in diameter from 6.1 down to 0.2 µm. This assumption is consistent with observations and views currently in the literature indicating that clearance mechanisms are not particularly particle-size dependent (Morrow et al., 1967a,b; Snipes et al., 1983). That the linear dimensions of an alveolar macrophage, considered to be the principal means of clearance in the A region, are significantly larger, roughly 10 µm (Yu et al., 1996), and could therefore accommodate engulfment of a range of particle sizes also makes this assumption reasonable. Snipes (1979), however, has reported in rats a λ (converted here from half-time values) of 0.0022/day for 1 and 2 µm particles but a higher value of 0.0039/day for 0.4 µm particles indicating that clearance rates may indeed depend on size. In the absence of reliable data for 0.2 µm particles, the slower clearance rate pertaining to this larger particle size, i.e., 0.00169/day, is being used. Such a choice may underestimate the actual DPM clearance rate in humans. The resulting model output (i.e., lung DPM burden) from this slower rate would predict more DPM in the alveolar space than may actually be present at any given time. Therefore, use of this slower λ may be considered to be more protective of human health. Long-term clearance rates for particle sizes more comparable to DPM are available, e.g., iron oxide and polystyrene spheres (Waite and Ramsden, 1971; Jammet et al., 1978), but these data show a large range in the values obtained for half-lives or are based upon a very small number of trials, and therefore compare unfavorably with the quality of data from the Bailey experiment.

The deposition fractions of particulate matter in the pulmonary and tracheobronchial regions of the human lung remain relatively unchanged over the particle size range between 0.2 and 1.0 µm, on the basis of analysis done with the ICRP model (ICRP66, 1994). As the clearance of relatively insoluble particles is also likely to remain the same over this range, the dosimetry results in this report for the carbonaceous core component of DPM could also be extended to other particles in this size range within the $PM_{2.5.}$ For respirable particles with diameters larger than this range, e.g., between 1.0 and 3.5 µm, the extent of the fraction deposited in the pulmonary region is unclear. Results from the ICRP66 (1994) model predict little change in human deposition for this diameter range, whereas the earlier model of Yu and Diu (1983) predicts a significant increase as reported in ICRP66 (1994). It is therefore unclear if either model would be applicable for particles in this larger-sized range without changing the value for the deposition fractions. As will be presented and discussed below, regional deposition fractions of DPM-sized particles from the MPPDep, the ICRP66 (1994) and draft NCRP models compare favorably with the human alveolar deposition in humans specific for DPM, which has been estimated with the Yu model to be 7% to 13% (Yu and Xu, 1986).

Although there was good agreement between experimental and modeled results, this agreement follows a circular logic (as adequately pointed out by Yu and Yoon [1990]) because the same experimental data that figured into the derivation of transport rates were used in the model. Nevertheless, even though this agreement is not a validation, it provides an important consistency check on the model. Further experimental data and policy definitions on what constitutes validation would be necessary for a more formal validation.

The model showed that at low lung burdens, alveolar clearance is dominated by mucociliary transport to the tracheobronchial region, and at high lung burdens, clearance is dominated by transport to the lymphatic system. The head and tracheobronchial compartments showed quick clearance of DPM by mucociliary transport and dissolution. Lung burdens of both the carbonaceous core and organics were found to be greater in humans than in rats for similar periods of exposure.

The Yu and Yoon (1990) version of the model provides a parametric study of the dosimetry model, examining variation over a range of exposure concentrations, breathing scenarios, and ventilation parameters; particle mass median aerodynamic diameters; and geometric standard deviations of the aerosol size distribution. It examines how lung burden varies with age for exposure over a lifespan, provides dosimetry extrapolations to children, and examines changes in lung burden with lung volume. The results showed that children would exhibit more diminished alveolar clearance of DPM at high lung burden than adults when exposed to equal concentrations of DPM. These features make the model easy to use in risk assessment studies. The reader is referred to Appendix A for further details on the model and for analyses of the sensitivity of the model to change in parameter values.

The Yu model presents some uncertainties in addition to those discussed earlier in the context of particle size dependence of clearance rate. The reports of Yu and Yoon (1990) as well as Yu et al. (1991) underwent extensive peer review; we list below the most important among the model uncertainties discussed by the review panel. The experimental data used by the Yu model for adsorbed organics used passively adsorbed radiolabeled compounds as surrogates for combustion-derived organics. These compounds may adhere differently to the carbon core than do those formed during combustion. Yu has estimated that slowly cleared organics represent 10% of the total particle mass; the actual figure could be substantially less; the reviewers estimate that the amount of tightly bound organics is probably only 0.1% to 0.25% of the particle mass.

The model was based upon the experimental data of Strom et al. (1988), where Fischer-344 rats were exposed to DPM at a concentration of 6.0 mg/m^3 for 20 h/day and 7 days/week for periods ranging from 3 to 84 days. Such exposures lead to particle overload effects in rats, whereas human exposure patterns are usually to much lower levels at which overload will not occur. Parameters obtained by fitting to data under the conditions of the experimental scenario for rats may not be optimal for the human exposure and concentration of interest.

The extrapolation of retained dose from rats to humans assumed that the macrophage-mediated mechanical clearance of the DPM varies with the specific particulate dose to the alveolar surface in the same proportion in humans and in rats, whereas clearance rates by dissolution were assumed to be invariant across species. These assumptions have not been validated.

It should also be noted that the Yu et al. (1991) model does not possess a formal interstitial compartment although the lymph nodes, which would be the repository of particles from the interstitium, are represented. The work of Nikula et al. (1997a,b) and of Kuempel (2000) provide compelling information on the significance of an extensive interstitilization process in primates and in humans. Kuempel (2000) developed a lung dosimetry model to describe the kinetics of particle clearance and retention in coal miners' lungs. Models with overloading of lung clearance, as observed in rodent studies, were found to be inadequate to describe the end-of-life lung dust burdens in those miners. The model that provided the best fit to the human data included a sequestration process representing the transfer of particles to the interstitium. These findings are consistent with a study showing reduced lung clearance of particles in retired coal miners (Freedman and Robinson, 1988) and with studies showing increased retention of particles in the lung interstitium of humans and nonhuman primates compared to rodents exposed to coal dust and/or DE (Nikula et al., 1997a,b). These findings are also consistent with the established observation that humans and primates clear particles slowly from the alveolar interstitium compared with rates in rodent species such as rats and mice (Hsieh and Yu, 1998). Because several aspects of the Yu model have not been validated on human data and because it does not include a formal interstitial compartment, it is acknowledged that this model may therefore have some uncertainty concerning the lung burdens in humans exposed to occupational levels of dust. However, it is also not known whether the model based on coal miner data (Kuempel, 2000) would also describe the clearance and retention processes in the lungs of humans with exposures to particles at lower environmental concentrations, or to submicrometer particles such as DE particulate. Further investigation of these issues is needed.

3.6.2.5. ***Use of the Yu et al. (1991) Model for Interspecies Extrapolation***

In addressing the objectives of this chapter, i.e., consideration of what is known and applicable to DPM concerning particle disposition and the bioavailability of adsorbed organics on DPM, it is apparent that the database is considerable for both the processes involved in particle dosimetry and for DPM. This information makes the goal of predicting a human internal dose from animal data through a model utilizing this database both feasible and appropriate.

In their charge to EPA through "Science and Judgment in Risk Assessment" (NRC, 1995), the National Research Council opines that EPA should have principles for judging when and how to depart from default options. The extensive data presented in this chapter their scientific validity, and the limitations of the current default procedures provide a basis for departing from the default options currently identified by the Agency for extrapolating from animals to humans. The default option of assuming external concentrations of DPM in animal studies as being representative of a human concentration (and an equivalent internal dose) is clearly not adequate given the differences in the basic processes of deposition and clearance between animals and humans documented by these data. Use of an alternate default option, the Agency's dosimetric adjustment procedures for inhaled particles in animal-to-human scenarios (described in U.S. EPA, 1994), is also inadequate as only deposition is predicted and then only down to an MMAD of 0.5 µm, whereas the MMAD of DPM is typically 0.2 µm or smaller. Models have been described in this section that consider both deposition and retention specifically for DPM in both laboratory animals and in humans. These points provide justification for moving away from default options and utilizing the best scientific information available (i.e., that integrated into deposition/clearance models) in performing the animal-to-human extrapolation.

Evaluation of the various models discussed in this chapter should be considered from the aspect of both the rat and the human. For rats it is fairly clear that the rat portion of the model of Yu et al. (1991) is the most appropriate because it is based on data, especially extensive information on lung burdens, from actual DPM exposures. The model provides for both deposition and integrated clearance for DPM as well as for two classes of adsorbed organics. The transport rates in the Yu model are derived directly from experiments with DPM exposed rats.

For humans, however, several models are available and discussed above, none of which is based on DPM-specific data. Deposition, but not clearance, modules are available for all models, and Table 3-3 is an attempt to compare deposition projections of the various models to the extent possible for particles in the range of characteristics of size, distribution, and density of DPM. Intake parameters such as breathing rates and minute volumes were also matched among the various models. As alluded to above and shown in Table 3-3, DPM deposition is predicted to

Table 3-3. Model comparison for deposition of DPM under equivalent conditions

Compartment	Yu[a]	ICRP66[b]	MPPDep1.11[c]	NCRP[d]
A (model designation)	13% (A)	14.1% (AI)	16.6% (P)	17.3% (P)
ET (model designation)	8% (H)	6% ($ET_1 + ET_2$)	8.7% (H)	6.6% (NOPL)
TB (model designation)	8% (TB)	4% (BB + bb)	7.2% (TB)	6.2% (TB)
Total	29%	24.1%	32.5%	30.1%

[a]Yu and Xu, 1987 (estimated from Figures 1 and 3).
[b]Jarvis et al., 1996.
[c] Freijer et al., 1999 (The Yeh-Schum 5-lobe and URT volume of 50 mL options were used.)
[d]NCRP, 1997.
Note: Particle characteristics were set at 0.2 MMAD, 2.4 sigma g, 1.5 shape factor (equivalent to 0.3 packing factor), density 1.5 and a concentration of 5 $\mu g/m^3$. Lung parameters were set at 15 breaths per minute, a tidal volume of 0.926 L/hr, and a functional residual capacity (FRC) of 3300 mL.

occur in all regions of the respiratory tract but, because diffusion would be the most likely mechanism of deposition, is most prominent in the alveolar region. When run under equivalent conditions, all models show that higher deposition in the alveolar region is higher, generally by a factor of about 2, than the other regions of the respiratory tract. The percentages projected by the different models to be deposited in the alveolar regions were all similar to one another with a range of only 13% for the Yu model to 17.3 % for the NCRP model. The total deposition of DPM-like particles predicted by the models was also very similar at around 30%. Only the ICRP model differed appreciably from the others in total deposition by a factor of about 1.3 less at 22.9%. Due to its verity and completeness in representation of the lung, the MPPDep model could be considered the most theoretically advanced of these deposition models and, presumably, the most accurate. It can be seen that, at least at the concentration tested, the Yu results and those of the MPPDep model could be judged very similar if not the same in the ET and TB regions, albeit with the MPPDep predicting slightly more deposition in the A region. Based on this limited analysis, total and regional DPM deposition in the human respiratory tract predicted by the Yu model appear similar to other available human models.

Further model comparison may be undertaken for those human models that have clearance as well as deposition modules available; from Table 3-3, these include the Yu et al. (1991) and ICRP66 models. Therefore, the human lung burden outputs of these two models were compared under equivalent physiological parameters, particle characteristics, and duration (70 years) and concentrations of exposure (Figure 3-9).

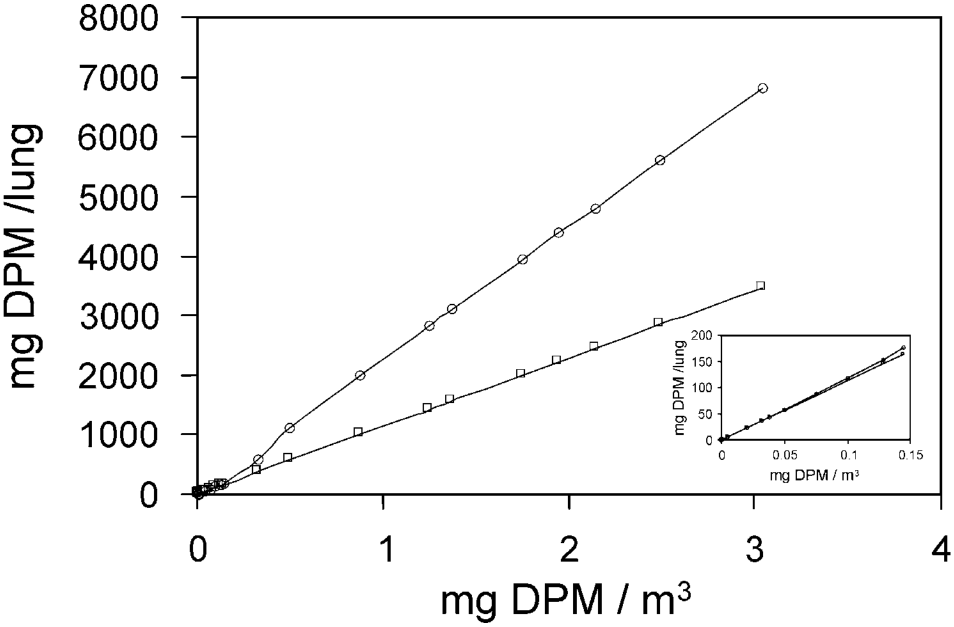

Figure 3-9. Modeled estimates of lung burden in humans after a simulated lifetime exposure to DPM using the Yu et al. (1991;[o]) and ICRP66 (□) models. Simulations include both deposition and clearance. Simulations were run for 70 years using a respiratory frequency of 15 min^{-1} and a tidal volume of 0.926 L/breath for a total daily air intake of 20 m^3/day for the various concentrations shown. Particle characteristics in the ICRP66 model, including MMAD, σ_g, density, and packing/shape factor were all matched to those used in the Yu model.

At DPM concentrations up to about 0.2 mg/m^3, the outputs (lung burden) from these two models are essentially identical (see insert) indicating little if any difference between them in this concentration range. This observation is consonant with the minor differences noted in deposition (Table 3-3).

Above 0.2 mg/m^3 DPM, both models continue to demonstrate a monotonic increase in lung burden with increasing concentration. However, the output of the Yu et al. (1991) model begins to diverge markedly from the burdens predicted by the ICRP model such that the Yu model predicts a greater burden for a given concentration of DPM than does the ICRP66 model. This situation would be predicted based on the assumption in the human portion of the Yu model of a concentration-dependent macrophage inhibition and particle overload occurring in humans; such an inhibition would result in impaired clearance processes, thereby allowing for a greater accumulation of material in the lung with increasing concentrations of DPM. This assumption is not made in the ICRP model, and materials are therefore not predicted to accumulate in the lung to the extent predicted by the Yu model.

Based on this limited analysis of models and the predictions from them for both deposition and clearance of DPM in humans, the model of Yu et al. (1991) can be seen to perform similarly to other available state-of-the-art models. The Yu model(s) are chosen for further analysis for the purposes of this document primarily because the animal portion of the model is based on DPM-specific data and the human components of the model have both deposition and clearance capacities that do not appear different from other available human respiratory tract models.

3.6.2.6. *Model Variability*

As demonstrated in Table 3-3 and Figure 3-9, there appears to be little variability among state-of-the-art models available for predicting disposition (both for deposition and for clearance integrated with deposition) of low levels of DPM (i.e., up to about 200 $\mu g/m^3$) in the respiratory tracts of humans.

Intersubject variability and its relationship to model output, however, is acknowledged in the ICRP model for deposition efficiencies (ICRP, 1994). This variability, recognized as substantial by ICRP, is addressed through use of scaling constants derived from estimates of the upper and lower confidence bounds for regional deposition efficiencies, with the scaling constants representing the variability in the population. It should be noted that the same philosophy is inherent in dose-response methodologies such as the RfC, where variability in the population is accommodated by a 10-fold uncertainty factor rather than by scaling constants. Inspection of data in ICRP66 (e.g., Figures D-4 through D-7 in the ICRP reference) on nasal and extrathoracic deposition in adult males shows that these upper and lower boundaries on output due to intersubject variability are considerably less than 10-fold different from one another. Thus, dividing model outputs by a factor of 10 such as is done in RfC derivation may well be inclusive of not only intersubject variability but also of any model-to-model variability as they exist currently.

3.6.2.7. *Model Comparison — Estimations of Deposition of Adsorbed Organics*

The data presented in Table 3-3 may be viewed as single-breath estimates of DPM deposition patterns in the various regions of the human lung under the breathing patterns and conditions described in the table for the different models considered in this report. From these data it is possible to estimate the total mass of DPM deposited in the pulmonary region under a given set of conditions. Furthermore, if the fraction of organics present on DPM and their ability to be desorbed or eluted from the DPM are assumed also to be the same, then these deposition data could be used to estimate the dose of organics to pulmonary tissues. Such a comparison would not only yield an estimate of the amount of organics but also lend a further comparison between the different human models. This exercise was performed for humans breathing 5 µg DPM/m^3 continuously, and the results are presented in Table 3-4 below.

Table 3-4. Comparative model estimates of DPM deposition in human lungs from exposure to 5 µg/m^3 continuously for one year

	A	B	C	D
Human deposition model	Alveolar Dep[a]	µg DPM deposited/year[b]	µg organics deposited/year[c]	µg carcinogenic PAH deposited/year[d]
Yu et al. (1991)	13%	4745	598	1.82
ICRP66	14.1%	5147	649	1.98
MPPDep	16.6%	6059	763	2.33
NCRP	17.3%	6315	796	2.43

[a]Alveolar deposition fractions predicted for DPM (Yu et al., 1991) and for particles with DPM characteristics (from Table 3-3). No clearance is included in this calculation.

[b]A total air intake of 20 m^3/day is assumed. These numbers were obtained by factoring 20 m^3 × 5 µg DPM/m^3 × Alveolar deposition % (column A) × 365 days/year.

[c]In three samples of DPM extract, DPM-associated organics were noted as being 11.1%, 14.7%, and 12.1% wt. organics/wt. DPM (Tong and Karasek, 1984) with the average being 12.6%; column B is factored by this average to generate column C.

[d]Those seven PAHs identified as being carcinogenic either to humans or to animals (U.S. EPA, 1993) were summed from the data of Tong and Karasek (1984), where they are reported as a concentration in extract from DPM-associated organics. In three different samples, the content of these 7 PAHs was noted as 4739, 2054, and 2360 ng/mg of organic extract, with the average being 3051 ng/mg (3.051 µg/mg) organic extract. This average value was factored with Column C (in mg) to generate column D.

Note: Estimates from different human deposition models of the total amount of DPM-associated organics deposited in the pulmonary regions in humans breathing DPM at 5 µg/m^3 continuously for 1 year.

As may be expected, the relatively minor differences (17.3 % / 13% = 1.3) in the deposition of DPM among the different human models leads to similarly minor differences in projections of dose of carcinogenic PAHs to the lung at a relatively low concentration of 5 µg/m^3 DPM. Somewhat unexpected is the small absolute quantity of carcinogenic PAH that may be delivered to the lung tissues under the conditions of exposure to DPM in this exercise. It should be noted that exercises similar to this have been carried out by others, e.g., Valberg and Watson (1999). However, the possibility that high concentrations of DPM may result in localized areas of deposition (such as the conducting airways), the fact that human exposures may be considerably greater than those presupposed in the exercise (e.g., 5 µg/m^3), the nature of the assays (i.e., in vitro in Chapter 4 vs. actual inhalation exposures), and the findings that DNA adducts may result from other known noncarcinogens such as carbon black (Bond et al., 1990) make the interpretation of such exercises problematic and their meaning unclear.

3.7. SUMMARY AND DISCUSSION

The most consistent historical measure of exposure for DE is DPM in units of µg or mg particles/m^3, with the underlying assumption that all components of diesel emissions (e.g., organics in the form of volatilized liquids or gases) are present in proportion to the DPM mass. DPM is used as the basic dosimeter for effects from various scenarios such as chronic and acute exposures as well as for different endpoints such as irritation, fibrosis, or even cancer. There is, however, little evidence currently available to prove or refute DPM as being the most appropriate dosimeter.

DPM dose to the tissue is related to the extent of the deposition and clearance of DPM. DPM may deposit throughout the respiratory tract via sedimentation or diffusion, with the latter being prevalent in the alveolar region. Particles that deposit upon airway surfaces may be cleared from the respiratory tract completely or may be translocated to other sites by regionally distinct processes that can be categorized as either absorptive (i.e., dissolution) or nonabsorptive (i.e., transport of intact particles via mucociliary transport). Other mechanisms that can affect retention of DPM include endocytosis by alveolar lining cells and interstitialization, which lead to the accumulation of DPM in the interstitial compartment of the lung and subsequent translocation of DPM to lymph nodes; interstitialization of poorly soluble particles may be prominent in primates and humans compared with rodents, although different rates for this path could also explain observed results. For poorly soluble particles such as DPM, species-dependent rate constants exist for the various clearance pathways that can be modified by factors such as respiratory tract disease.

In rats, prolonged exposure to high concentrations of particles will result in particle overload, a condition that is defined as the overwhelming of macrophage-mediated clearance by the deposition of particles at a rate exceeding the capacity of that clearance pathway. This condition seems to begin to occur in rats when the pulmonary dust burden exceeds about 1 mg particles/g lung tissue. On the other hand, there is no clear evidence for particle overload in humans. Macrophage-mediated clearance is slower in humans than in rats, and kinetics relating to interstitialization of poorly soluble particulate matter may have a greater consequence in humans than in rats.

The degree of bioavailability of the organic fraction of DPM is still somewhat uncertain. However, reports of DNA alterations in occupationally exposed workers, as well as results of animal studies using radiolabeled organics deposited on DPM, indicate that at least a fraction of the organics present are eluted prior to particle clearance. Carcinogenic organics eluted in regions where diffusion may be a relatively long process, such as in the conducting airways vs the alveolar region, may remain in the lung long enough to be metabolized to an active form or to interact directly with vital cellular components. The current information suggests that DPM-associated organics could be involved in a carcinogenic process, although the quantitative data are far from adequate to make any firm conclusions.

Use of laboratory animal data in an assessment meant to be applied to humans obligates some form of interspecies extrapolation. Review and evaluation of the considerable, specific database in humans and animals on disposition of DPM, its adsorbed organics, and other poorly soluble particles led to the judgment that default options available for interspecies dosimetry adjustment could be set aside for more scientifically valid, DPM-specific processes. Refinement of this process led to the evaluation of several applicable dosimetry models that in turn led to the identification and choice of the Yu et al. (1991) model to conduct interspecies extrapolation. This model has a three-compartment lung consisting of tracheobronchial, alveolar, and lymph node compartments. It treats DPM as being composed of the insoluble carbonaceous core, slowly cleared organics, and fast-cleared organics, and considers in an integrative manner the simultaneous processes of both deposition and clearance through empirical data derived from both laboratory animals and humans. Also, the model has some limited consideration of model variability in its outputs describing dose to the lung. Major assumptions made in this model include that transport rates of organics in DPM do not change across species and that the transport rate of the carbonaceous core is species dependent, with the clearance rate varying with the dose to the alveolar surface in the same proportion in humans as in rats. Limitations of the model include the lack of definitive information on variability and, quite possibly, the lack of a formal interstitial compartment that may be of consequence in humans. The basis of this model is to derive an internal dose from an external DPM concentration by utilizing species-specific physiological and pharmacokinetic parameters and, as such, is considered to have addressed the pharmacokinetic aspects of interspecies dosimetry. This aspect of the model addresses some of the critical data needs for the quantitative analysis of noncancer effects from DPM, the subject of Chapter 6.

As parallels have been drawn between DPM and $PM_{2.5}$ in other chapters, it is perhaps appropriate to compare them also from the aspect of dosimetry. Obvious comparisons include the nature of the particle distribution, defined artificially for $PM_{2.5}$ as compared with the thorough characterization of DPM for both MMAD (which, at around 0.2 µm, is typically more than an order of magnitude less than the $PM_{2.5}$ cutoff and which, more properly, should be termed a mass median thermodynamic diameter, an MMTD) and geometric standard deviation. It is clear that a larger portion of $PM_{2.5}$ particles than DPM would be above the aerodynamic equivalent diameter (d_{ae}) of 0.5 µm, which is often considered as a boundary between diffusion and aerodynamic mechanisms of deposition. This would imply that a somewhat larger portion of DPM may pass on to the lower respiratory tract than would $PM_{2.5}$. Alveolar deposition in humans specific for DPM has been estimated with the Yu model to be 7%-13% (Yu and Xu, 1986), a figure that is consistent with deposition predictions of other human models (see Table 3-3). This fractional deposition may be compared to one calculated for $PM_{2.5}$ and reported in U.S. EPA (1996a); assuming a MMAD of 2.25 µm and a geometric standard deviation of 2.4, a fractional alveolar deposition of 10.2% was reported. This value is within the range and quite comparable to that obtained by Yu and Xu (1986), indicating that little difference may exist in alveolar deposition between DPM and $PM_{2.5}$, at least for this assumed geometric standard deviation.

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4. MUTAGENICITY

The application of mutagenicity data to the question of the potential carcinogenicity of diesel emissions is based on the premise that genetic alterations are found in all cancers and that several of the chemicals found in diesel emissions possess mutagenic activity in a variety of genetic assays. These genetic alterations can be produced by gene mutations, deletions, translocations, aneuploidy, or amplification of genes; hence no single genotoxicity assay should be expected to predict rodent carcinogenicity. Additionally, because of the inherent biological differences of measured endpoints, both within genotoxicity assays and between genotoxicity assays and cancer bioassays, a direct extrapolation should not be expected (see Brusick [1987] for a more detailed discussion). Indeed, most genotoxicity data are generated with in vitro assays that frequently employ concentrations of test agent that may be orders of magnitude greater than encountered in environmental situations. With diesel emissions or other mixtures, additional complications arise because of the complexity of the material being tested.

Since 1978, more than 100 publications have appeared in which genotoxicity assays were used with diesel emissions, the volatile and particulate fractions (including extracts), or individual chemicals found in diesel emissions. The Huisingh et al. (1978) report not only identified mutagenic activity in salmonella in several fractions of diesel particular mater (DPM) extracts, but also indicated that the mutagenic activity, especially quantitatively, was affected by the extraction solvent as well as method and length of storage. Much of the ensuing research employed bioassays (most commonly salmonella TA98 without S9) to evaluate (1) extraction procedures, (2) fuel modifications, (3) bioavailability of chemicals from DPM, and (4) exhaust filters or other modifications and other variables associated with diesel emissions. The interest in the contribution of mutagens to carcinogenicity was high in the early 1980s and the lack of long- term rodent carcinogenicity information on diesel emissions led to the use of semiquantitative mutagenicity (and in vitro cell transformation) data from diesel emissions and epidemiology based cancer potency estimations to derive a comparative potency estimate for diesel emissions first published by Albert et al. (1983) and more fully discussed in Appendix C of this report.

As indicated in Chapter 2, the number of chemicals in diesel emissions is very large. Many of these have been determined to exhibit mutagenic activity in a variety of assay systems (see Table II. in Claxton, 1983). Although a detailed discussion of those data is beyond the scope of this document, some of the mutagenically active compounds found in the gas phase are ethylene, benzene, 1,3-butadiene, acrolein and several PAHs (see Table 2-21). Of the particle-associated chemicals, several PAHs and nitro-PAHs have been the focus of mutagenic investigations both in bacteria and in mammalian cell systems (see Table 2-22). Several review articles, some containing more detailed descriptions of the available studies, are available (Claxton, 1983; Pepelko and Peirano, 1983; International Agency for Research on Cancer, 1989; Shirnamé-Moré, 1995). Discussions of genotoxicity in the proceedings of several symposia on the health effects of diesel emissions (U.S. EPA, 1980; Lewtas, 1982; Ishinishi et al., 1986) are also available.

4.1. GENE MUTATIONS

Huisingh et al. (1978) demonstrated that dichloromethane extracts from DPM were mutagenic in strains TA1537, TA1538, TA98, and TA100 of *S. typhimurium*, both with and without rat liver S9 activation. This report contained data from several fractions as well as DPM from different vehicles and fuels. Similar results with diesel extracts from various engines and fuels have been reported by a number of investigators using the salmonella frameshift-sensitive strains TA1537, TA1538, and TA98 (Siak et al., 1981; Claxton, 1981; Dukovich et al., 1981; Brooks et al., 1984). Similarly, mutagenic activity was observed in salmonella forward mutation assays measuring 8-azaguanine resistance (Claxton and Kohan, 1981) and in *E. coli* mutation assays (Lewtas, 1983).

One approach to identifying significant mutagens in chemically complex environmental samples such as diesel exhaust or ambient particulate extracts is the combination of short-term bioassays with chemical fractionation (Scheutzle and Lewtas, 1986). The analysis is most frequently carried out by sequential extraction with increasingly polar or binary solvents. Fractionation by silica-column chromatography separates compounds by polarity or into acidic, basic, and neutral fractions. The resulting fractions are too complex to characterize by chemical methods, but the bioassay analysis can be used to determine fractions for further analysis. In most applications of this concept, salmonella strain TA98 without the addition of S9 has been used as the indicator for mutagenic activity. Generally, a variety of nitrated polynuclear aromatic compounds have been found that account for a substantial portion of the mutagenicity (Liberti et al., 1984; Schuetzle and Frazer, 1986; Schuetzle and Perez, 1983). However, not all bacterial mutagenicity has been identified in this way, and the identity of the remaining mutagenic compounds remains unknown. The nitrated aromatics thus far identified in diesel engine exhaust (DE) were the subject of review in the IARC monograph on DE (International Agency for Research on Cancer, 1989). In addition to the simple qualitative identification of mutagenic chemicals, several investigators have used numerical data to express mutagenic activity as activity per distance driven or mass of fuel consumed. These types of calculations have been the basis for estimates that the nitroarenes (both mono- and dinitropyrenes) contribute a significant amount of the total mutagenic activity of the whole extract (Nishioka et al., 1982; Salmeen et al., 1982; Nakagawa et al., 1983). In a 1983 review, Claxton discussed a number of factors that affected the mutagenic response in salmonella assays. Citing the data from the Huisingh et al. (1978) study, the author noted that the mutagenic response could vary by a factor of 100 using different fuels in a single diesel engine. More recently, Crebelli et al. (1995) used salmonella to examine the effects of different fuel components. They reported that although mutagenicity was highly dependent on aromatic content, especially di- or triaromatics, there was no clear effect of sulfur content of the fuel. Later, Sjögren et al. (1996) using multivariate statistical methods with ten diesel fuels concluded that the most influential chemical factors in salmonella mutagenicity were sulfur contents, certain PAHs (1-nitropyrene) and naphthenes.

Matsushita et al. (1986) tested particle-free DE gas and a number of benzene nitro-derivatives and polycyclic aromatic hydrocarbons (PAHs) (many of which have been identified as components of DE gas). The particle-free exhaust gas was positive in both TA100 and TA98, but only without S9 activation. Of the 94 nitrobenzene derivatives tested, 61 were mutagenic, and the majority showed greatest activity in TA100 without S9. Twenty-eight of 50 PAHs tested were mutagenic, all required the addition of S9 for detection, and most appeared to show a stronger response in TA100. When 1,6-dinitropyrene was mixed with various PAHs or an extract of heavy-duty (HD) DE, the mutagenic activity in TA98 was greatly reduced when S9 was absent but was increased significantly when S9 was present. These latter results suggested that caution should be used in estimating mutagenicity (or other toxic effects) of complex mixtures from the specific activity of individual components.

Mitchell et al. (1981) reported mutagenic activity of DPM extracts of diesel emissions in the mouse lymphoma L5178Y mutation assay. Positive results were seen both with and without S9 activation in extracts from several different vehicles, with mutagenic activity only slightly lower in the presence of S9. These findings have been confirmed in a number of other mammalian cell systems using several different genetic markers. Casto et al. (1981), Chescheir et al. (1981), Li and Royer (1982), and Brooks et al. (1984) all reported positive responses at the HPRT locus in Chinese hamster ovary (CHO) cells. Morimoto et al. (1986) used the APRT and Oua^r loci in CHO cells; Curren et al. (1981) used Oua^r in BALB/c 3T3 cells. In all of these studies, mutagenic activity was observed without S9 activation. Liber et al. (1981) used the thymidine kinase (TK) locus in the TK6 human lymphoblast cell line and observed induced mutagenesis only in the presence of rat liver S9 when testing a methylene chloride extract of DE. Barfknecht et al. (1982) also used the TK6 assay to identify some of the chemicals responsible for this activation-dependent mutagenicity. They suggested that fluoranthene, 1-methylphenanthrene, and 9-methylphenanthrene could account for over 40% of the observed activity.

Morimoto et al. (1986) injected DPM extracts (250 to 4,000 mg/kg) into pregnant Syrian hamsters and measured mutations at the APRT locus in embryo cells cultivated 11 days after i.p.

injection. Although neutral fractions from both light-duty (LD) and HD particle extracts resulted in increased mutation frequency at 2,000 and 4,000 mg/kg, the response at 1,000 mg/kg was not different from controls. Also, because the authors did not present data on toxicity or cloning efficiency, the value of the apparent positive findings at extremely high concentrations is uncertain at best. Belisario et al. (1984) applied the Ames test to urine from Sprague-Dawley rats exposed to single applications of DPM administered by gastric intubation, i.p. injection, or s.c. gelatin capsules. In all cases, dose-related increases were seen in TA98 (without and with S9) from urine concentrates taken 24 h after particle administration. Urine from Swiss mice exposed by inhalation to filtered exhaust (particle concentration 6 to 7 mg/m^3) for 7 weeks (Pereira et al., 1981a) or Fischer 344 rats exposed to DPM at a concentration of 1.9 mg/m^3 for 3 months to 2 years (Ong et al., 1985) was negative in salmonella strains.

Schuler and Niemeier (1981) exposed drosophila males in a stainless steel chamber connected to the 3 m^3 chamber used for the chronic animal studies at EPA (see Hinners et al., 1980 for details). Flies were exposed for 8 h and mated to untreated females 2 days later. Although the frequency of sex-linked recessive lethals from treated males was not different from that of controls, the limited sample size precluded detecting less than a threefold increase over controls. The authors noted that, because there were no signs of toxicity, the flies might tolerate exposures to higher concentrations for longer time periods.

Driscoll et al. (1996) exposed Fischer 344 male rats to aerosols of carbon black (1.1, 7.1, and 52.8 mg/m^3) or air for 13 weeks (6 hr/day, 5 days/week) and measured *hprt* mutations in alveolar type II cells in animals immediately after exposure and at 12 and 32 weeks after the end of exposure. Both of the two higher concentrations resulted in significant increases in mutant frequency. Whereas the mutant frequency from the 7.1 mg/m^3 group returned to control levels by 12 weeks, the mutant frequency of the high-exposure group was still higher than controls even after 32 weeks. Carbon black particles have very little adsorbed PAHs, hence a direct chemically induced mechanism is highly unlikely. Induction of *hprt* mutations were also observed in rat alveolar epithelial cells after intratracheal instillation with carbon black, α-quartz, and titanium dioxide (Driscoll et al., 1997). All three types of particles elicited an inflammatory response as shown by significant increases of neutrophils in bronchoalveolar lavage (BAL) fluid. Culturing the BAL from exposed rats with a rat lung epithelial cell line also resulted in elevation of *hprt* mutational response. This response was effectively eliminated when catalase was included in the incubation mixture, providing evidence for cell-derived oxidative damage. Recently, Sato et al. (2000) exposed male Big Blue transgenic F344 rats to diluted DE (1 and 6 mg/m^3 suspended particle concentration) for 4 weeks. Mutant frequency in lung DNA was significantly elevated (4.8x control) at 6 mg/m^3 but not at 1 mg/m^3. Lung DNA adduct levels measured by ^{32}P-postlabeling and 8-hydroxydeoxyguanosine measured by HPLC were elevated at both particle concentrations, but to a lesser extent than mutant frequencies. Sequence analysis of mutants indicated that some, but not all, of the mutations could be explained by an oxidative damage mechanism.

Specific-locus mutations were not induced in (C3H × 101)F_1 male mice exposed to DE 8 h/day, 7 days/week for either 5 or 10 weeks (Russell et al., 1980). The exhaust was a 1:18 dilution and the average particle concentration was 6 mg/m^3. After exposure, males were mated to T-stock females and matings continued for the reproductive life of the males. The results were unequivocally negative; no mutants were detected in 10,635 progeny derived from postspermatogonial cells or in 27,917 progeny derived from spermatogonial cells.

Hou et al. (1995) measured DNA adducts and *hprt* mutations in peripheral lymphocytes of 47 bus maintenance workers and 22 control individuals. All were nonsmoking men from garages in the Stockholm area and the exposed group consisted of 16 garage workers, 25 mechanics, and 6 other garage workers. There were no exposure data, but the three groups were considered to be of higher to lower exposure to diesel engine exhaust. Levels of DNA adducts determined by ^{32}P-postlabeling were significantly higher in workers than controls (3.2 versus 2.3 × 10^{-8}), but *hprt* mutant frequencies were not different 8.6 versus 8.4 × 10^{-6}). Although group mean mutant frequencies were not different, both adduct level and mutagenicity were highest among the 16 most exposed and mutant frequency was significantly correlated with adduct level. All individuals were genotyped for glutathione transferase GSTM1 and aromatic amino transferase NAT2 polymorphism. Neither GSTM1 nulls nor NAT2 slow acetylators exhibited effects on either DNA adducts or *hprt* mutant frequencies.

4.2. CHROMOSOME EFFECTS

Mitchell et al. (1981) and Brooks et al. (1984) reported increases in sister chromatid exchanges (SCE) in CHO cells exposed to DPM extracts of emissions from both LD and HD diesel engines. Morimoto et al. (1986) observed increased SCE from both LD and HD DPM extracts in PAH-stimulated human lymphocyte cultures. Tucker et al. (1986) exposed human peripheral lymphocyte cultures from four donors to direct DE for up to 3 h. Exhaust was cooled by pumping through a plastic tube about 20 feet long; airflow was 1.5 L/min. Samples were taken at 16, 48, and 160 min of exposure. Cell cycle delay was observed in all cultures; significantly increased SCE levels were reported for two of the four cultures. Structural chromosome aberrations were induced in CHO cells by DPM extracts from a Nissan diesel engine (Lewtas, 1983) but not by similar extracts from an Oldsmobile diesel engine (Brooks et al., 1984).

DPM dispersed in an aqueous mixture containing dipalmitoyl lecithin (DPL), a component of pulmonary surfactant or extracted with dichloromethane (DCM) induced similar responses in SCE assays in Chinese hamster V79 cells (Keane et al., 1991), micronucleus tests in V79 and CHO cells (Gu et al., 1992), and unscheduled DNA synthesis (UDS) in V79 cells (Gu et al., 1994). After separating the samples into supernatant and sediment fractions, mutagenic activity was confined to the sediment fraction of the DPL sample and the supernatant of the DCM sample. These findings suggest that the mutagenic activity of DPM inhaled into the lungs could be made bioavailable through solubilization and dispersion of pulmonary surfactants. In a later study in the same laboratory, Liu et al. (1996) found increased micronuclei in V79 cells treated with crystalline quartz and a noncrystalline silica, but response was reduced after pretreatment of the particles with the simulated pulmonary surfactant.

Pereira et al. (1981a) exposed female Swiss mice to DE 8 h/day, 5 days/week for 1, 3, and 7 weeks. The incidence of micronuclei and structural aberrations was similar in bone marrow cells of both control and exposed mice. Increased incidences of micronuclei, but not SCE, were observed in bone marrow cells of male Chinese hamsters after 6 months of exposure to DE (Pereira et al., 1981b).

Guerrero et al. (1981) observed a linear concentration-related increase in SCE in lung cells cultured after intratracheal instillation of DPM at doses up to 20 mg/hamster. However, they did not observe any increase in SCE after 3 months of inhalation exposure to DE particles (6 mg/m^3).

Pereira et al. (1982) measured SCE in embryonic liver cells of Syrian hamsters. Pregnant females were exposed to DE diluted with air 1:9 to contain about 12 mg/m^3 particles from days 5 to 13 of gestation or injected intraperitoneally with diesel particles or particle extracts on gestational day 13 (18 h before sacrifice). Neither the incidence of SCE nor mitotic index was affected by exposure to DE. The injection of DPM extracts but not DPM resulted in a dose-related increase in SCE; however, the toxicity of the DPM was about twofold greater than the DPM extract.

In the only studies with mammalian germ cells, Russell et al. (1980) reported no increase in either dominant lethals or heritable translocations in males of T-stock mice exposed by inhalation to diesel emissions. In the dominant lethal test, T-stock males were exposed for 7.5 weeks and immediately mated to females of different genetic backgrounds (T-stock; [C3H × 101]; [C3H × C57BL/6]; [SEC × C57BL/6]). There were no differences from controls in any of the parameters measured in this assay. For heritable translocation analysis, T-stock males were exposed for 4.5 weeks and mated to (SEC × C57BL/6) females, and the F_1 males were tested for the presence of heritable translocations. Although no translocations were detected among 358 progeny tested, the historical control incidence is less than 1/1,000.

4.3. OTHER GENOTOXIC EFFECTS

Pereira et al. (1981b) exposed male strain A mice to DE emissions for 31 or 39 weeks using the same exposure regimen noted in the previous section. Analyses of caudal sperm for sperm-head abnormalities were conducted independently in three separate laboratories. Although the incidence of sperm abnormalities was not significantly above controls in any of the three laboratories, there were extremely large differences in scoring among the three (control values were 9.2%, 14.9%, and 27.8% in the three laboratories). Conversely, male Chinese hamsters exposed for 6 mo (Pereira et al., 1981c) exhibited almost a threefold increase in sperm-head abnormalities. It is noted that the control incidence in the Chinese hamsters was less than 0.5%. Hence, it is not clear whether the differing responses reflect true species differences or experimental artifacts.

A number of studies measuring DNA adducts in animals exposed to DPM, carbon black or other particles have been reported and are reviewed by Shirnamé-Moré (1995). Although modest increases in DNA adducts have been observed in lung tissue of rats after inhalation of DPM (Wong et al., 1986; Bond et al., 1990), the magnitude of the increases is small in comparison with those induced by chemical carcinogens present in DE (Smith et al., 1993). While Gallagher et al. (1994) found no increases in total DNA adducts in lung tissue of rats exposed to DE, carbon black, or titanium dioxide they did observe an increase in an adduct with migration properties similar to nitrochrysene and nitro-benzo(a)pyrene adducts from diesel but not carbon black or titanium dioxide exposures. The majority of the studies used the ^{32}P-postlabeling assay to detect adducts. Although this method is sensitive, chemical identity of adducts can only be inferred if an adduct spot migrates to the same location as a known prepared adduct.

DNA adducts have also been measured in humans occupationally exposed to DE. Distinct adduct patterns were found among garage workers occupationally exposed to DE when compared to nonexposed controls (Nielsen and Autrup, 1994). Furthermore, the findings were concordant with the adduct patterns observed in groups exposed to low concentrations of PAHs from combustion processes. Hemminki et al. (1994) also reported significantly elevated levels of DNA adducts in lymphocytes from garage workers with known DE exposure compared with unexposed mechanics. Hou et al. (1995) found elevated adduct levels in bus maintenance workers exposed to DE. Although no difference in mutant frequency was observed between the groups, the adduct levels were significantly different (3.2 vs. 2.3×10^{-8}). Nielsen et al. (1996) reported significantly increased levels of three biomarkers (lymphocyte DNA adducts, hydroxyethylvaline adducts in hemoglobin, and 1-hydroxypyrene in urine) in DE-exposed bus garage workers.

The role of oxidative damage in causing mutations has received increasing focus recently. More than 50 different chemicals have been studied in rodents usually measuring the formation of 8-hydroxydeoxyguanosine (8-OH-dG), a highly mutagenic adduct (Loft et al., 1998). Increases in the mutagenic DNA adduct 8-hydroxydeoxyguanosine were found in mouse lung DNA after intratracheal instillation of diesel particles (Nagashima et al., 1995). The response was dose dependent. Mice fed on a high-fat diet showed an increased response whereas the responses were partially reduced when the antioxidant, β-carotene, was included in the diet (Ichinose et al., 1997). Oxidative damage also has been measured in rat lung tissue after intratracheal instillation of quartz (Nehls et al., 1997) and in rat alveolar macrophages after in vitro treatment with silica dust (Zhang et al., 2000). Arimoto et al. (1999) demonstrated that redissolved methanol extracts of DPM also induced the formation of 8-OH-dG adducts in L120 mouse cells. The response was dependent on both DPM concentration and P450 reductase. A detailed discussion of the potential role of oxidative damage in DE carcinogenesis is presented in Chapter 7, Section 7.4.

4.4. SUMMARY AND DISCUSSION

Extensive studies with salmonella have unequivocally demonstrated mutagenic activity in both particulate and gaseous fractions of DE. In most of the studies using salmonella, DPM extracts and individual nitropyrenes exhibited the strongest responses in strain TA98 when no exogenous activation was provided. Gaseous fractions reportedly showed greater response in TA100, whereas benzo[*a*]pyrene and other unsubstituted PAHs are mutagenic only in the presence of S9 fractions. The induction of gene mutations has been reported in several in vitro mammalian cell lines after exposure to extracts of DPM. Note that only the TK6 human cell line did not give a positive response to DPM extracts in the absence of S9 activation. Mutagenic activity was recovered in urine from animals treated with DPM by gastric intubation and i.p. and s.c. implants, but not by inhalation of DPM or diluted diesel exhaust. Dilutions of whole diesel exhaust did not induce sex-linked recessive lethals in drosophila or specific-locus mutations in male mouse germ cells.

Structural chromosome aberrations and SCE in mammalian cells have been induced by particles and extracts. Whole exhaust induced micronuclei but not SCE or structural aberrations in bone marrow of male Chinese hamsters exposed to whole diesel emissions for 6 mo. In a shorter exposure (7 weeks), neither micronuclei nor structural aberrations were increased in bone marrow of female Swiss mice. Likewise, whole DE did not induce dominant lethals or heritable translocations in male mice exposed for 7.5 and 4.5 weeks, respectively.

The application of mutagenicity data to the question of the potential carcinogenicity of diesel emissions is based on the premise that genetic alterations are found in all cancers and that several of the chemicals found in diesel emissions possess mutagenic activity in a variety of genetic assays. These genetic alterations can be produce by gene mutations, deletions, translocations, aneuploidy, or amplification of genes, hence no single genotoxicity assay should be expected to either qualitatively or quantitatively predict rodent carcinogenicity. With diesel emissions or other mixtures, additional complications arise because of the complexity of the material being tested. Exercises that combined the salmonella mutagenic potency with the total concentration of mutagenic chemicals deposited in the lungs could not account for the observed tumor incidence in exposed rats (Rosenkranz, 1993; Goldstein et al., 1998). However, such calculations ignored the contribution of gaseous phase chemicals which have been estimated to contribute from less than 50% (Rannug et al., 1983) to over 90% (Matsushita et al., 1986) of the total mutagenicity. This wide range is partly reflective of the differences in material tested, semivolatile extracts in the former and whole gaseous emission in the latter. Of greater importance is that these calculations are based on a reverse mutation assay in bacteria with metabolic processes strikingly different from mammals. This is at least partly reflected in the observations that different nitro-PAHs give different responses in bacteria and in CHO cells (Li and Dutcher, 1983) or in human hepatoma-derived cells (Eddy et al., 1986).

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5. NONCANCER HEALTH EFFECTS OF DIESEL EXHAUST

The objective of this chapter is to review and evaluate potential health effects other than cancer associated with inhalation exposure to diesel engine exhaust (DE). Data have been obtained from diverse human, laboratory animal, and in vitro test systems. The human studies comprise both occupational and human experimental exposures, the former consisting of exposure to DE in the occupational environment, and the latter consisting of exposure to diluted DE or diesel particulate matter (DPM) under controlled conditions. The laboratory animal studies consist of both acute and chronic exposures of laboratory animals to DE or DPM. Diverse in vitro test systems composed of human and laboratory animal cells treated with DPM or components of DPM have also been used to investigate the effects of DPM at the cellular and molecular levels. DPM mass (mg/m^3) has been used almost exclusively as a measure of DE exposure in human and experimental studies. The noncancer health effects of DPM have been reviewed previously by the Health Effects Institute (HEI, 1995) and in the Air Quality for Particulate Matter Criteria Document, the PM CD (U.S. EPA, 1996). The noncancer health effects attributable to ambient particulate matter (PM), which is composed in part of DPM, as well as the potential mechanisms underlying these effects have also been previously reviewed in the PM CD (U.S. EPA, 1996) and have been summarized in this document in Chapter 6, Section 6.4.

This chapter begins with descriptions of studies that have shown various health effects occurring as a result of exposure to DE/DPM (Section 5.1). The human studies portion of this section (5.1.1) discusses results from both short-term and long-term studies as well as specialized studies such as those of populations contiguous to major highways (5.1.2). Studies using laboratory animals are ordered into various subsections under Section 5.1.3. Investigations devoted to elucidating the possible modes of action of DE/DPM are covered in Section 5.2; the mode-of-action issue of particle overload in animals is discussed elsewhere in the document (Chapter 3, Section 3.4). Section 5.3 describes evidence for the various interactions of DPM with other conditions such as disease. Other sections address issues such as species-comparative responses to DE/DPM (Section 5.4) and influence of dose rate (Section 5.5). The summary/conclusion of this chapter, relating the totality of this information to possible human effects of DE/DPM, is in Section 5.6.

5.1. HEALTH EFFECTS OF WHOLE DIESEL EXHAUST

5.1.1. Human Studies

5.1.1.1. *Short-Term Exposures*

In a controlled human study, Rudell et al. (1990, 1994) exposed eight healthy subjects in an exposure chamber to diluted exhaust from a diesel engine for 1 h, with intermittent exercise. Dilution of the DE was controlled to provide a median NO_2 level of approximately 1.6 ppm. Median particle number was $4.3 \times 10^6/cm^3$, and median levels of NO and CO were 3.7 and 27 ppm, respectively (particle size and mass concentration were not provided). There were no effects on spirometry or on closing volume using nitrogen washout. Five of eight subjects experienced unpleasant smell, eye irritation, and nasal irritation during exposure. Bronchoalveolar lavage (BAL) was performed 18 hours after exposure and was compared with a control BAL performed 3 weeks prior to exposure; there was no control air exposure. Small but statistically significant reductions were seen in numbers of BAL mast cells, extent of AM phagocytosis of opsonized yeast particles, and lymphocyte CD4/CD8 ratios. A small increase in recovery of polymorphonuclear cells (PMNs) was also observed. These findings suggest that DE may induce mild airway inflammation in the absence of spirometric changes. This study provides an intriguing glimpse of the effect of DE exposure in humans, but only one exposure level was used, the number of subjects was low, and a limited range of endpoints was reported, so the data are inadequate to generalize about the human response.

Rudell et al. (1996) exposed volunteers to DE for 1 h in an exposure chamber. Light work on a bicycle ergometer was performed during exposure. Exposures included either DE or exhaust with particle numbers reduced 46% by a particle trap. The engine used was a new Volvo model 1990, a six-cylinder direct-injection turbocharged diesel with an intercooler, which was run at a steady speed of 900 rpm during the exposures. Comparison of this study with others was difficult because neither exhaust dilution ratios nor particle concentrations were reported. Carbon monoxide concentrations of 27-30 ppm and NO of 2.6-2.7 ppm, however, suggested DPM concentrations may have equaled several mg/m^3. The most prominent symptoms during exposure were irritation of the eyes and nose and an unpleasant smell. Both airway resistance and specific airway resistance increased significantly during the exposures. Despite the 46% reduction in particle numbers by the trap, effects on symptoms and lung function were not significantly attenuated.

Nordenhall et al. (2000) had 15 healthy human subjects (13 males, 2 females) breathe in an exposure chamber diluted DE from an idling diesel engine to give a PM_{10} concentration of 300 $\mu g/m^3$, which was also associated with a median steady-state NO_2 concentration of 1.6 ppm.

Exposures were for 1 h, with each individual serving as their own control by being exposed to filtered air, also for 1 h but at a different time. Sputum production was then induced and sputum examined at 6 and 24 hr postexposure (for both air and DPM) with differential cell counts and soluble protein counts performed. In comparing the same individual's results after exposure to air and after exposure to DE, increases were found in the percentage of sputum neutrophiles (37.7% vs. 26.2%) after 6 hr, along with increases in concentrations of the soluble proteins interleukin-6 (12.0 vs. 6.3 pg/mL) and methylhistamine (0.11 vs. 0.12 ug/L). These differences between air and DPM were not present at 24 hr. Thus, breath exposure to DE produces early induction of an inflammatory response in healthy humans that can be detected using sputum analysis.

Wade and Newman (1993) describe the situation of three railroad workers who developed persistent asthma associated with overexposure to DE from locomotives. The overexposure was a consequence of multiple hours of high levels of diesel exposure from riding in locomotive units trailing immediately behind the lead locomotive. Lines of evidence supporting railroad locomotive DE inducing asthma in these individuals include, (1) all three exhibited clear signs of asthma leading (in two of the three cases) to immediate first-time hospitalization and treatment for asthma, (2) all three developed symptoms within a few hours of the overexposure, and (3) all three experienced exacerbation of symptoms upon reexposure to locomotive DE. Although this report and that of Kahn et al. (1988) described below both provide supporting evidence for DE being able to cause asthma in humans under extreme but uncharacterized conditions, both suffer from the same limitations, including no reliable data on the concentration of diesel emissions and associated gaseous components, the duration of the exposures, or information on others that were exposed under these conditions but who did not develop asthma symptoms.

Kahn et al. (1988) reported the occurrence of 13 cases of acute overexposure to DE among Utah and Colorado coal miners. Twelve miners had symptoms of mucous membrane irritation, headache, and lightheadedness. Eight individuals reported nausea; four reported a sensation of unreality; four reported heartburn; three reported weakness, numbness, and tingling in their extremities; three reported vomiting; two reported chest tightness; and two others reported wheezing. Each miner lost time from work because of these symptoms, which resolved within 24 to 48 h. No air monitoring data were presented; poor work practices were described as the predisposing conditions for overexposure. No follow-up was available for these exposed individuals.

El Batawi and Noweir (1966) reported that among 161 workers from two garages where diesel-powered buses were serviced and repaired, 42% complained of eye irritation, 37% of headaches, 30% of dizziness, 19% of throat irritation, and 11% of cough and phlegm. Ranges of mean concentrations of DE components in the two diesel bus garages were as follows: 0.4 to 1.4 ppm NO_2, 0.13 to 0.81 ppm SO_2, 0.6 to 44.1 ppm aldehydes, and 1.34 to 4.51 mg/m^3 of DPM; the highest concentrations were obtained close to the exhaust systems of the buses.

Eye irritation was reported by Battigelli (1965) in six subjects after 40 s of chamber exposure to diluted DE containing 4.2 ppm NO_2, 1 ppm SO_2, 55 ppm CO, 3.2 ppm total hydrocarbons, and 1 to 2 ppm total aldehydes; after 3 min and 20 s of exposure to diluted DE containing 2.8 ppm NO_2, 0.5 ppm SO_2, 30 ppm CO, 2.5 ppm total hydrocarbons, and <1 to 2 ppm total aldehydes; and after 6 min of exposure to diluted DE containing 1.3 ppm NO_2, 0.2 ppm SO_2, <20 ppm CO, <2.0 ppm total hydrocarbons, and <1.0 ppm total aldehydes. The concentration of DPM was not reported.

Katz et al. (1960) described the experience of 14 chemists and their assistants monitoring the environment of a train tunnel used by diesel-powered locomotives. Although workers complained on three occasions of minor eye and throat irritation, no correlation was established with concentrations of any particular component of DE.

The role of radicals generated from particulate matter, including DPM, in producing toxicity has been discussed in the literature (Valavanidis et al., 2000), as has the role of antioxidant defenses in protecting against species such as radicals that may arise from acute DE exposure. Blomberg et al. (1998) investigated changes in the antioxidant defense network within the respiratory tract lining fluids of human subjects following DE exposure. Fifteen healthy, nonsmoking, asymptomatic subjects were exposed to filtered air or DE (DPM 300 μg/m^3) for 1 h on two separate occasions at least 3 weeks apart. Nasal lavage fluid and blood samples were collected prior to, immediately after, and 5 ½ h post exposure. Bronchoscopy was performed 6 h after the end of DE exposure. Nasal lavage ascorbic acid concentration increased tenfold during DE exposure, but returned to basal levels 5.5 h postexposure. DE had no significant effects on nasal lavage uric acid or GSH concentrations, and did not affect plasma, bronchial wash, or bronchoalveolar lavage antioxidant concentrations, nor malondialdehyde or protein carbonyl concentrations. The authors concluded that the physiological response to acute DE exposure is an acute increase in the level of the antioxidant ascorbic acid in the nasal cavity.

5.1.1.1.1. ***Diesel exhaust odor***. The odor of DE is considered by most people to be objectionable; at high intensities, it may produce sufficient physiological and psychological effects to warrant concern for public health. The intensity of the odor of DE is an exponential function of its concentration such that a tenfold change in the concentration will alter the intensity of the odor by one unit. Two human panel rating scales have been used to measure DE odor intensity. In the first (Turk, 1967), combinations of odorous materials were selected to simulate DE odor; a set of 12 mixtures, each having twice the concentration of that of the previous mixture, is the basis of the diesel odor intensity scale (D-scale). The second method is the TIA (total intensity of aroma) scale based on seven steps, ranging from 0 to 3, with 0 being undetectable, ½ very slight, and 1 slight and increasing in one-half units up to 3, strong (Odor Panel of the CRC-APRAC Program Group on Composition of Diesel Exhaust, 1979; Levins, 1981).

Surveys, utilizing volunteer panelists, have been taken to evaluate the general public's response to the odor of DE. Hare and Springer (1971) and Hare et al. (1974) found that at a D rating of about 2 (TIA = 0.9, slight odor intensity), about 90% of the participants perceived the odor, and almost 60% found it objectionable. At a D rating of 3.2 (TIA = 1.2, slight to moderate odor intensity), about 95% perceived the odor, and 75% objected to it, and, at a D rating of 5 (TIA = 1.8, almost moderate), about 95% objected to it.

Linnell and Scott (1962) reported odor threshold measurement in six subjects and found that the dilution factor needed to reach the threshold ranged from 140 to 475 for this small sample of people. At these dilutions, the concentrations of formaldehyde ranged from 0.012 to 0.088 ppm.

5.1.1.1.2. ***Pulmonary and respiratory effects***. Battigelli (1965) exposed 13 volunteers to three dilutions of DE obtained from a one-cylinder, four-cycle, 7-hp diesel engine (fuel type unspecified) and found that 15-min to 1-h exposures had no significant effects on pulmonary resistance. Pulmonary resistance was measured by plethysmography utilizing the simultaneous recording of esophageal pressure and airflow determined by electrical differentiation of the volume signal from a spirometer. The concentrations of the constituents in the three diluted exhausts were 1.3, 2.8, and 6.2 ppm NO_2; 0.2, 0.5, and 1 ppm SO_2; <20, 30, and 55 ppm CO; and <1.0, <1 to 2, and 1 to 2 ppm total aldehydes, respectively. DPM concentrations were not reported.

A number of studies have evaluated changes in pulmonary function occurring over a workshift in workers occupationally exposed to DE (specific time period not always reported but assumed to be 8 h). In a study of coal miners, Reger (1979) found that both forced expiratory volume in 1 s (FEV_1) and forced vital capacity (FVC) decreased by 0.05 L in 60 diesel-exposed miners, an amount not substantially different from reductions seen in non-diesel-exposed miners (0.02 and 0.04 L, respectively). Decrements in peak expiratory flow rates were similar between diesel and non-DE-exposed miners. Although the monitoring data were not reported, the authors stated that there was no relationship between the low concentrations of measured respirable dust or NO_2 (personal samplers) when compared with shift changes for any lung function parameter measured for the diesel-exposed miners. In summary, this study (available as an abstract only) states that no evidence was found for additional lung function effect over a shift for miners exposed to diesel emissions as compared with controls, i.e., nonexposed office workers and coal miners not exposed to diesel emissions.

Ames et al. (1982) compared the pulmonary function of 60 coal miners exposed to DE with that of a control group of 90 coal miners not exposed to DE for evidence of acute respiratory effects associated with exposure to DE. Changes over the workshift in FVC, FEV_1, and forced expiratory flow rate at 50% FVC (FEF_{50}) were the indices for acute respiratory effects. The environmental concentrations of the primary pollutants were 2.0 mg/m^3 respirable dust (<10 µm MMAD), 0.2 ppm NO_2, 12 ppm CO, and 0.3 ppm formaldehyde. The investigators reported a statistically significant decline in FVC and FEV_1 over the workshift in both the diesel-exposed and comparison groups. Current smokers had greater decrements in FVC, FEV_1, and FEF_{50} than did ex-smokers and nonsmokers. There was a marked disparity between the ages and the time spent underground for the two study groups. Diesel-exposed miners were about 15 years younger and had worked underground for 15 fewer years (4.8 versus 20.7 years) than miners not exposed to DE. The significance to the results of these differences between the populations is difficult to ascertain.

Except for the expected differences related to age, 120 underground iron ore miners exposed to DE had no workshift changes in FVC and FEV_1 when compared with 120 matched surface miners (Jörgensen and Svensson, 1970). Both groups had equal numbers (30) of smokers and nonsmokers. The frequency of bronchitis was higher among underground workers, much higher among smokers than nonsmokers, and also higher among older than younger workers. The authors reported that the underground miners had exposures of 0.5 to 1.5 ppm NO_2 and between 3 and 9 mg/m^3 particulate matter, with 20% to 30% of the particles <5 µm MMAD. The majority of the particles were iron ore; quartz was 6% to 7% of the fraction <5 µm MMAD.

Gamble et al. (1979) measured preshift FEV_1 and FVC in 187 salt miners and obtained peak flow forced expiratory flow rates at 25%, 50%, and 75% of FVC (FEF_{25}, FEF_{50}, or FEF_{75}). Postshift pulmonary function values were determined from total lung capacity and flows at preshift percentages of FVC. The miners were exposed to mean NO_2 levels of 1.5 ppm and mean respirable particulate levels of 0.7 mg/m^3. No statistically significant changes were found between changes in pulmonary function and in NO_2 and respirable particles combined. Slopes of the regression of NO_2 and changes in FEV_1, FEF_{25}, FEF_{50}, and FEF_{75} were significantly different from zero. The authors concluded that these small reductions in pulmonary function were attributable to variations in NO_2 within each of the five salt mines that contributed to the cohort.

Gamble et al. (1987a) investigated the acute effects of DE in 232 workers in four diesel bus garages using an acute respiratory questionnaire and before and after workshift spirometry.

The prevalence of burning eyes, headaches, difficult or labored breathing, nausea, and wheeze experienced at work was higher in the diesel bus garage workers than in a comparison population of lead/acid battery workers who had not previously shown a statistically significant association of acute symptoms with acid exposure. Comparisons between the two groups were made without adjustment for age and smoking. There was no detectable association of exposure to NO_2 (0.23 ppm ± 0.24 S.D.) or inhalable (less than 10 µm MMAD) particles (0.24 mg/m^3 ± 0.26 S.D.) and acute reductions in FVC, FEV_1, peak flows, FEF_{50}, and FEF_{75}. Workers who had respiratory symptoms had slightly greater but statistically insignificant reductions in FEV_1 and FEF_{50}.

Ulfvarson et al. (1987) evaluated workshift changes in the pulmonary function of 17 bus garage workers, 25 crew members of two types of car ferries, and 37 workers on roll-on/roll-off ships. The latter group was exposed primarily to DE; the first two groups were exposed to both gasoline and DE. The diesel-only exposures that averaged 8 h consisted of 0.13 to 1.0 mg/m^3 particulate matter, 0.02 to 0.8 mg/m^3 (0.016 to 0.65 ppm) NO, 0.06 to 2.3 mg/m^3 (0.03 to 1.2 ppm) NO_2, 1.1 to 5.1 mg/m^3 (0.96 to 4.45 ppm) CO, and up to 0.5 mg/m^3 (0.4 ppm) formaldehyde. The largest decrement in pulmonary function was observed during a workshift following no exposure to DE for 10 days. Forced vital capacity and FEV_1 were significantly reduced over the workshift (0.44 L and 0.30 L, $p<0.01$ and $p<0.001$, respectively). There was no difference between smokers and nonsmokers. Maximal midexpiratory flow, closing volume expressed as the percentage of expiratory vital capacity, and alveolar plateau gradient (phase 3) were not affected. Similar but less pronounced effects on FVC (−0.16 L) were found in a second, subsequent study of stevedores (n = 24) only following 5 days of no exposure to diesel truck exhaust. Pulmonary function returned to normal after 3 days without occupational exposure to DE. No exposure-related correlation was found between the observed pulmonary effects and concentrations of NO, NO_2, CO, or formaldehyde; however, it was suggested that NO_2 adsorbed onto the DE particles may have contributed to the overall dose of NO_2 to the lungs. In a related study, six workers (job category not defined) were placed in an exposure chamber and exposed to diluted DE containing 0.6 mg/m^3 DPM and 3.9 mg/m^3 (2.1 ppm) NO_2. The exhaust was generated by a 6-cylinder, 2.38-L diesel engine, operated for 3 h and 40 min at constant speed, equivalent to 60 km/h, and at about one-half full engine load. No effect on pulmonary function was observed.

In a hypothesis-generating study, Kilburn (2000) examined neurobehavioral and pulmonary function of a small group of workers exposed to DE either as railroad workers (n=10) over a range of 15 to 50 years or as electricians (n=6) over a range of 0.6 to 1.5 years. Neurobehavioral and visual functions batteries showed nearly all of these individuals to be neurobehaviorally impaired in relation to a referent population in one or more areas, including reaction time, balance, blink reflex latency, verbal recall, and color vision confusion indices. Pulmonary function tests also showed that 10 of the 16 had airway obstruction and another group of 10 of the 16 had chronic bronchitis, chest pain, tightness, and hyperreactive airways. This work implies that with sufficiently sensitive methods, noncancer effects from DPM/DE exposure may be detectable in sufficiently exposed human populations.

5.1.1.1.3. ***Immunological effects***. Salvi et al. (1999) exposed healthy human subjects to diluted DE (DPM 300 µg/m^3) for 1 h with intermittent exercise. Although there were no changes in pulmonary function, there were significant increases in neutrophils and B lymphocytes as well as histamine and fibronectin in airway lavage fluid. Bronchial biopsies obtained 6 h after DE exposure showed a significant increase in neutrophils, mast cells, and CD4+ and CD8+ T lymphocytes, along with upregulation of the endothelial adhesion molecules ICAM-1 and VCAM-1 and increases in the number of LFA-1+ in the bronchial tissue. Significant increases in neutrophils and platelets were observed in peripheral blood following exposure to DE.

In a follow-up investigation of potential mechanisms underlying the DE-induced airway leukocyte infiltration, Salvi et al. (2000) exposed healthy human volunteers to diluted DE, on two separate occasions for 1 h each, in an exposure chamber. Fiber-optic bronchoscopy was performed 6 h after each exposure to obtain endobronchial biopsies and bronchial wash (BW) cells. These workers observed that DE exposure enhanced gene transcription of IL-8 in the bronchial tissue and BW cells and increased growth-regulated oncogene-a protein expression and IL-8 in the bronchial epithelium; there was also a trend toward an increase in IL-5 mRNA gene transcripts in the bronchial tissue.

In an attempt to evaluate the potential allergenic effects of DPM in humans, Diaz-Sanchez and associates carried out a series of clinical investigations. In the first of these (Diaz-Sanchez et al., 1994), healthy human volunteers were challenged by spraying either saline or 0.30 mg (300 µg) DPM into their nostrils. The authors considered this dose to be equivalent to breathing the outdoor air in Los Angeles for a 24-h period on an average day. Enhanced IgE levels were noted in nasal lavage cells in as little as 24 h, with peak production observed 4 days after DPM challenge. The effects seemed to be somewhat isotype-specific, because in contrast to IgE results, DPM challenge had no effect on the levels of IgG, IgA, IgM, or albumin. The selective enhancement of local IgE production was demonstrated by a dramatic increase in IgE-secreting cells.

Although direct effects of DPM on B-cells have been demonstrated by in vitro studies, it was considered likely that other cells regulating the IgE response may also be affected. Cytokine production was therefore measured in nasal lavage cells from healthy human volunteers challenged with DPM (0 or 0.15 mg in 200 µL saline) sprayed into each nostril (Diaz-

Sanchez et al., 1996). Before challenge with DPM, most subjects' nasal lavage cells had detectable levels of only interferon-γ, IL-2, and IL-13 *m*RNA. After challenge with DPM, the cells produced readily detectable levels of *m*RNA for IL-2, IL-4, IL-5, IL-6, IL-10, IL-13, and interferon-γ. Although the cells in the nasal lavage before and after challenge do not necessarily represent the same ones either in number or type, the broad increase in cytokine production was considered by the authors not to be simply the result of an increase in T cells recovered in the lavage fluid. On the basis of these findings, the authors concluded that the increase in nasal cytokine expression after exposure to DPM can be predicted to contribute to enhanced local IgE production and thus play a role in pollutant-induced airway disease.

The ability of DPM to act as an adjuvant to the ragweed allergen Amb a I was also examined by nasal provocation in ragweed-allergic subjects using 0.3 mg (300 µg) DPM, Amb a I, or both (Diaz-Sanchez et al., 1997). Although allergen and DPM each enhanced ragweed-specific IgE, DPM plus allergen promoted a 16-times greater antigen-specific IgE production. Nasal challenge with DPM also influenced cytokine production. Ragweed challenge resulted in a weak response, DPM challenge caused a strong but nonspecific response, and allergen plus DPM caused a significant increase in the expression of mRNA for TH0 and TH2-type cytokines (IL-4, IL-5, IL-6, IL-10, IL-13), with a pronounced inhibitory effect on IFN-γ gene expression. The author concluded that DPM can enhance B-cell differentiation and, by initiating and elevating IgE production, may be a factor in the increased incidence of allergic airway disease.

In a further extension of these studies, Diaz-Sanchez et al. (1999) examined the potential for DPM to lead to primary sensitization of humans by driving a de novo mucosal IgE response to a neoantigen, keyhole limpet hemocyanin (KLH). Ten atopic subjects were given an initial nasal immunization of KLH followed by two biweekly nasal challenges with KLH. Fifteen different atopic subjects were treated identically, except that DPM was administered 24 h before each KLH exposure. Intranasal administration of KLH alone led to the generation of an anti-KLH IgG and IgA humoral response, which was detected in nasal fluid samples. No anti-KLH IgE was observed in any of these subjects. In contrast, when challenged with KLH preceded by DPM, 9 of the 15 subjects produced anti-KLH-specific IgE. KLH-specific IgG and IgA at levels similar to those seen with KLH alone were also detected. Subjects who received DPM and KLH had significantly increased IL-4, but not IFN-gamma, levels in nasal lavage fluid, whereas these levels were unchanged in subjects receiving KLH alone. These investigators concluded that DPM can function as a mucosal adjuvant to a de novo IgE response and may increase allergic sensitization among atopic individuals.

5.1.1.1.4. ***Human cell culture studies*****.** The potential mechanisms by which DPM may act to cause allergenic effects has been examined in human cell culture studies. Takenaka et al. (1995)

reported that DPM extracts enhanced IgE production from purified human B cells. IgE production in these cells (stimulated by exogenous addition of interleukin-4 plus monoclonal antibody) was enhanced (i.e., further stimulated) 20% to 360% by the addition of DPM extracts (1-50 ng/mL) over a period of 10-14 days. DPM extracts in the absence of exogenously added IL-4 and/or monoclonal antibodies did not themselves induce IgE production or synergize with interleukin-4 alone to induce IgE from purified B cells, suggesting that the extracts were enhancing ongoing IgE production rather than inducing germline transcription or isotype switching. The authors concluded that enhancement of IgE production in the human airway resulting from the organic fraction of DPM may be an important factor in the increasing incidence of allergic airway disease.

Terada et al. (1997) examined the effects of DPM and DPM extract on eosinophil adhesion, survival rate, and degranulation. Eosinophils, human mucosal microvascular endothelial cells (HMMECs), and human nasal epithelial cells (HNECs) were preincubated in the presence of DPM and DPM extract. 35S-labeled eosinophils were allowed to adhere to monolayers of HMMECs and HNECs. Although neither DPM nor DPM extract affected the adhesiveness of HMMECs and HNECs to eosinophils, DPM and DPM extract each significantly increased eosinophil adhesiveness to HNECs; neither affected eosinophil adhesiveness to HMMECs. DPM extract also induced eosinophil degranulation without changing the eosinophil survival rate. These results indicate that DPM may play an important role in promoting the nasal hypersensitivity induced by enhanced eosinophil infiltration of epithelium and eosinophil degranulation. It should also be noted that eosinophils are major components of allergic inflammatory disorders, including asthma and nasal allergy.

Terada et al. (1999) examined the effects of DPM extract on the expression of histamine H1 receptor (H1R) mRNA in HNECs and HMMECs, and on the production of IL-8 and GM-CSF induced by histamine. HNECs and HMMECs, isolated from human nasal mucosa specimens, were cultured with DPM extract. DPM extract increased the expression of H1R mRNA in both HNECs and HMMECs. The amount of IL-8 and GM-CSF induced by histamine was also significantly higher in HNECs and HMMECs treated with DPM extract. These results strongly suggest that DPM accelerates the inflammatory change by not only directly upregulating H1R expression but also by increasing histamine-induced IL-8 and GM-CSF production. Histamine is the most important chemical mediator in the pathogenesis of nasal allergy.

Steerenberg et al. (1998) studied the effects of exposure to DPM on airway epithelial cells, the first line of defense against inhaled pollutants. Cells from a human bronchial cell line (BEAS-2B) were cultured in vitro and exposed to DPM (0.04-0.33 mg/mL) and the effects on IL-6 and IL-8 production were observed. Increases in IL-6 and IL-8 production compared to the nonexposed cells (11- and 4-fold, respectively) were found after 24 or 48 h exposure to DPM. This increase was lower (17- and 3.3-fold) compared to silica and higher compared to titanium dioxide, which showed no increase for either IL-6 or IL-8. The study was extended to observe the effects of DPM on inflammation-primed cells. BEAS-2B cells were exposed to TNF-α followed by DPM. Additive effects on IL-6 and IL-8 production by BEAS-2B cells were found after TNF-α priming and subsequent exposure to DPM only at a low dose of DPM and TNF-α (0.05-0.2 ng/mL). The investigators concluded that BEAS-2B phagocytized DPM and produced an increased amount of IL-6 and IL-8, and that in TNF-α-primed BEAS-2B cells DPM increased interleukin production only at low concentrations of DPM and TNF-α.

Ohtoshi et al. (1998) studied the effect of suspended particulate matter (SPM), obtained from high-volume air samplers, and DPM obtained from exhaust of a stationary diesel engine on the production of IL-8 and granulocyte-colony stimulating factor (GM-CSF) by human airway epithelial cells in vitro. Nontoxic doses of DPMs stimulated production of IL-8 and GM-CSF by three kinds of human epithelial cells (nasal polyp-derived upper airway, normal bronchial, and transformed bronchial epithelial cells) in a dose- and time-dependent fashion at a DPM concentration as low as 10 µg/mL. SPM applied at 250 and 2,500 µg/mL had a stimulatory effect on GM-CSF, but not on IL-8 production. The effects could be blocked with a protein synthesis inhibitor, suggesting that the process required de novo protein synthesis, and appeared to be due to an extractable component because neither charcoal nor graphite showed such stimulatory effects. The authors concluded that SPM and DPM, a component of SPM, may be important air pollutants in the activation of airway cells for the release of cytokines relevant to allergic airway inflammation.

The mechanisms underlying DPM-induced injury to airway cells were investigated in human bronchial epithelial cells (HBECs) in culture (Bayram et al., 1998a). HBECs from bronchial explants obtained at surgery were cultured and exposed to DPM (10-100 µg/mL) suspended in a serum-free supplemented medium (SF-medium) or to a SF-medium filtrate of DPM. The filtrate was obtained by incubating DPM (50 µg/mL) in SF-medium for 24 h. The effects of DPM and DPM filtrate on permeability, ciliary beat frequency (CBF), and release of inflammatory mediators were observed. DPM and filtered solution of DPM significantly increased the electrical resistance of the cultures but did not affect movement of bovine serum albumin across cell cultures. DPM and filtered DPM solution significantly attenuated the CBF of these cultures and significantly increased the release of IL-8. DPM also increased the release by these cultures of GM-CSF and soluble intercellular adhesion molecule-1 (sICAM-1). These authors also observed that activated charcoal was not able to induce changes in electrical resistance, attenuate CBF, and increase the release of inflammatory mediators from HBEC, and proposed that these effects were due most likely to the compounds adsorbed onto the DPM rather than the size of DPM. The authors concluded that exposure of airway cells to DPM may lead to functional changes and release of proinflammatory mediators and that these effects may influence the development of airway disease.

Bayram et al. (1998b) investigated the sensitivity of cultured airway cells from asthmatic patients to DPM. Incubation with DPM (10-100 μg/mL) significantly attenuated the CBF in both the asthmatic and nonasthmatic bronchial epithelial cell cultures. Cultured airway cells from asthmatic patients constitutively released significantly greater amounts of IL-8, GM-CSF, and sICAM-1 than cell cultures from nonasthmatic subjects. Only cultures from asthmatic patients additionally released RANTES. The authors concluded that cultured airway cells from asthmatic subjects differ with regard to the amounts and types of proinflammatory mediators they can release and that the increased sensitivity of bronchial epithelial cells of asthmatic subjects to DPM may result in exacerbation of their disease symptoms.

Devalia et al. (1999) investigated the potential sensitivity of HBECs biopsied from atopic mild asthmatic patients and non-atopic nonasthmatic subjects to DPM. HBECs from asthmatic patients constitutively released significantly greater amounts of IL-8, GM-CSF, and sICAM-1 than HBECs from nonasthmatic subjects. RANTES was only released by HBECs of asthmatic patients. Incubation of the asthmatic cultures with 10 μg/mL DPM significantly increased the release of IL-8, GM-CSF, and sICAM-1 after 24 h. In contrast, only higher concentrations (50-100 μg/mL DPM) significantly increased the release of IL-8 and GM-CSF from HBECs of nonasthmatics. The authors conclude that the increased sensitivity of the airways of asthmatics to DPM may be, at least in part, a consequence of greater constitutive and DPM-induced release of specific pro-inflammatory mediators from bronchial epithelial cells.

Abe and co-workers have demonstrated formation of increased cytokine levels in cultured human bronchial epithelial cells exposed to freshly generated DE, but not to filtered DE, i.e., particle-free DE (Abe et al., 2000). Cytokine IL-8 protein as well as transforming growth factor (TGF)-β1 mRNAs were induced in a time-dependent manner (from 0.5 to 14 h of exposure) in BET-1A human bronchial epithelial cells in response to exposure to freshly generated, cooled, humidified DE that was diluted to 2.9 mg DPM/m^3. The gas obtained by filtration of DE alone did not show any sustained increase in these indicators, suggesting that DE particles play a more important role in eliciting these responses than do the accompanying gases (10.6 ppm CO, 7.3 ppm NO_2, and 3.3 ppm SO_2).

To elucidate the intracellular signal transduction pathway regulating IL-8 and RANTES production, Hashimoto et al. (2000) examined the role of p38 mitogen-activated protein (MAP) kinase in DPM-induced (DPM = 10, 50, or 100 μg/mL) IL-8 and RANTES production by HBECs. They also examined the effect of a thiol-reducing agent, N-acetylcysteine (NAC), on DPM-induced p38 MAP kinase activation and cytokine production. The authors conclude that p38 MAP kinase plays an important role in the DPM-activated signaling pathway that regulates IL-8 and RANTES production by HBECs and that the cellular redox state is critical for DPM-induced p38 MAP kinase activation leading to IL-8 and RANTES production.

Boland et al. (1999) compared the biological effects of carbon black and DPM (2.5 $\mu g/cm^2$ culture surface) collected from catalyst- and noncatalyst-equipped diesel vehicles in cultures of both human bronchial epithelial cells and human nasal epithelial cells. Transmission electron microscopy indicated that DPM was phagocytosed by epithelial cells and translocated through the epithelial cell sheet. The time and dose dependency of phagocytosis and its nonspecificity for different particles (DPM, carbon black, and latex particles) were established by flow cytometry. DPM also induced a time-dependent increase in interleukin-8, GM-CSF, and interleukin-1β release. The inflammatory response occurred later than phagocytosis and, because carbon black had no effect on cytokine release, its extent appeared to depend on the content of adsorbed organic compounds. Furthermore, treatment of the exhaust gas to decrease the adsorbed organic fraction reduced the DPM-induced increase in GM-CSF factor release. These results indicate that DPM can be phagocytosed by and induce a specific inflammatory response in airway epithelial cells.

5.1.1.1.5. ***Summary.*** In the available exposure studies, considerable variability is reported in DE detection threshold. The odor scales described in some of these studies have no general use at present because they are not objectively defined; however, the studies do clearly indicate substantial interindividual variability in the ability to detect odor and the level at which it becomes objectionable. Much of what is known about the acute effects of DE comes from case reports that lack clear measurements of exposure concentrations. The studies of pulmonary function changes in exposed humans have looked for changes occurring over a workshift or after a short-term exposure. The overall conclusion of these studies is that reversible changes in pulmonary function in humans can occur in relation to DE exposure, although it is not possible to relate these changes to specific exposure levels. Numerous studies described in this section, conducted in humans and in isolated cell systems derived from humans exposed to DPM, revealed various biochemical and pathophysiological alterations, such as IgE changes, altered levels of cytokines/chemokines, and goblet-cell hyperplasia, with nearly all these responses being key changes and markers of allergic inflammatory disorders of the airways such as asthma and nasal allergies (Nel et al., 1998). Thus, a major point of significance about these findings is that they indicate that DPM could be viewed as having the potential to elicit inflammatory and immunological responses and responses typical of asthma, and that DPM may be a likely factor in the increasing incidence of allergic hypersensitivity. These studies have also shown that effects are due primarily to the organic fraction and that DPM enhances the allergic response to known allergens. Results from these studies, including those wih laboratory animals, indicate that DPM could be viewed as having the potential to influence the development of airway inflammation and disease through its adjuvant properties and by causing the release of proinflammatory mediators.

5.1.1.2. *Long-Term Exposures*

Several epidemiologic studies have evaluated the effects of chronic exposure to DE on occupationally exposed workers.

Battigelli et al. (1964) measured several indices of pulmonary function, including vital capacity, FEV_1, peak flow, nitrogen washout, and diffusion capacity in 210 locomotive repairmen exposed to DE in 3 engine houses. The average exposure of these locomotive repairmen to DE was 9.6 years. When compared with a control group matched for age, body size, “past extrapulmonary medical history” (no explanation given), and job status (154 railroad yard workers), no significant clinical differences were found in pulmonary function or in the prevalence of dyspnea, cough, or sputum between the DE-exposed and nonexposed groups. Exposure to DE showed marked seasonal variations because the doors of the engine house were open in the summer and closed in the winter. For the exposed group, the maximum daily workplace concentrations of air pollutants measured were 1.8 ppm NO_2, 1.7 ppm total aldehydes, 0.15 ppm acrolein, 4.0 ppm SO_2, and 5.0 ppm total hydrocarbons. The concentration of airborne particles was not reported.

Gamble et al. (1987b) examined 283 diesel bus garage workers from four garages in two cities to determine if there was excess chronic respiratory morbidity associated with exposure to DE. Tenure of employment was used as a surrogate of exposure; mean tenure of the study population was 9 years ± 10 years S.D. Exposure-effect relationships within the study population showed no detectable associations of symptoms with tenure. Reductions in FVC, FEV_1, peak flow, and FEF_{50} (but not FEF_{75}) were associated with increasing tenure. Compared with a control population (716 nonexposed blue-collar workers) and after indirect adjustment for age, race, and smoking, the exposed workers had a higher incidence of cough, phlegm, and wheezing; however, there was no correlation between symptoms and length of employment. Dyspnea showed an exposure-response trend but no apparent increase in prevalence. Mean FEV_1, FVC, FEF_{50}, and peak flow were not reduced in the total cohort compared with the reference population, but were reduced in workers with 10 years or more tenure.

Purdham et al. (1987) evaluated respiratory symptoms and pulmonary function in 17 stevedores employed in car ferry operations who were exposed to both diesel and gasoline exhausts and in a control group of 11 on-site office workers. Twenty-four percent of the exposed group and 36% of the controls were smokers. If a particular symptom was considered to be influenced by smoking, smoking status was used as a covariate in the logistic regression analysis; pack-years smoked was a covariate for lung function indices. The frequency of respiratory symptoms was not significantly different between the two groups; however, baseline pulmonary function measurements were significantly different. The latter comparisons were measured by multiple regression analysis using the actual (not percentage predicted) results and correcting for age, height, and pack-years smoked. The stevedores had significantly lower FEV_1, FEV_1/FVC, FEF_{50}, and FEF_{75} ($p<0.021$, $p<0.023$, $p<0.001$, and $p<0.008$, respectively), but not FVC. The results from the stevedores were also compared with those obtained from a study of the respiratory health status of Sydney, Nova Scotia, residents. These comparisons showed that the dock workers had higher FVC, similar FEV_1, but lower FEV_1/FVC and flow rates than the residents of Sydney. Based on these consistent findings, the authors concluded that the lower baseline function measurements in the stevedores provided evidence of an obstructive ventilatory defect, but caution in interpretation was warranted because of the small sample size. There were no significant changes in lung function over the workshift, nor was there a difference between the two groups. The stevedores were exposed to significantly ($p<0.04$) higher concentrations of particulate matter (0.06 to 1.72 mg/m^3, mean 0.50 mg/m^3) than the controls (0.13 to 0.58 mg/m^3, mean not reported). Exposures of stevedores to SO_2, NO_2, aldehydes, and PAHs were very low; occasional CO concentrations in the 20 to 100 ppm range could be detected for periods up to 1 h in areas where blockers were chaining gasoline-powered vehicles.

Additional epidemiologic studies on the health hazards posed by exposure to DE have been conducted for mining operations. Reger et al. (1982) evaluated the respiratory health status of 823 male coal miners from six diesel-equipped mines compared with 823 matched coal miners not exposed to DE. The average tenure of underground work for the underground miners and their controls was only about 5 years; on average, the underground workers in diesel mines spent only 3 of those 5 years underground in diesel-use mines. Underground miners exposed to DE reported a higher incidence of symptoms of cough and phlegm but proportionally fewer symptoms of moderate to severe dyspnea than their matched counterparts. These differences in prevalence of symptoms were not statistically significant. The diesel-exposed underground miners, on the average, had lower FVC, FEV_1, FEF_{50}, FEF_{75}, and FEF_{90} but higher peak flow and FEF_{25} than their matched controls. These differences, however, were not statistically significant. Health indicators for surface workers and their matched controls were directionally the same as for matched underground workers. There were no consistent relationships between the findings of increased respiratory symptoms, decreased pulmonary function, smoking history, years of exposure, or monitored atmosphere pollutants (NO_x, CO, particles, and aldehydes). Mean concentrations of NO_x at the six mines ranged from 0 to 0.6 ppm for short-term area samples, 0.13 to 0.28 ppm for full-shift personal samples, and 0.03 to 0.80 for full-shift area samples. Inhalable particles (less than 10 μm MMAD) averaged 0.93 to 2.73 mg/m^3 for personal samples and 0 to 16.1 mg/m^3 for full-shift area samples. Ames et al. (1984), using a portion of the miners studied by Reger, examined 280 diesel-exposed underground miners in 1977 and again in 1982. Each miner in this group had at least 1 year of underground mining work history in 1977. The control group was 838 miners with no exposure to DE. The miners were evaluated for prevalence of respiratory symptoms, chronic cough, phlegm, dyspnea, and changes in FVC, FEV_1, and FEF_{50}. No air monitoring data were reported; exposure to DE gases and mine dust particles were described as very low. These authors found no decrements in pulmonary function or increased prevalence of respiratory symptoms attributable to exposure to DE. In fact, the 5-year incidences of cough, phlegm, and dyspnea were greater in miners without exposure to DE.

Attfield (1978) studied 2,659 miners from 21 mines (8 metal, 6 potash, 5 salt, and 2 trona). Diesels were employed in only 18 of the mines, but the 3 mines not using diesels were not identified. The years of diesel usage, ranging from 8 in trona mines to 16 in potash mines, were used as a surrogate for exposure to DE. Based on a questionnaire, an increased prevalence of persistent cough was associated with exposure to aldehydes; this finding, however, was not supported by the pulmonary function data. No adverse respiratory symptoms or pulmonary function impairments were related to CO_2, CO, NO_2, inhalable dust, or inhalable quartz. The author failed to comment on whether the prevalence of cough was related to the high incidence (70%) of smokers in the cohort.

Questionnaire, chest radiograph, and spirometric data were collected by Attfield et al. (1982) on 630 potash miners from six potash mines. These miners were exposed for an average of 10 years (range 5 to 14 years) to 0.1 to 3.3 ppm NO_2, 0.1 to 4.0 ppm aldehyde, 5 to 9 ppm CO, and total dust concentrations of 9 to 23 mg/m^3. No attempt was made to measure diesel-derived particles separately from other dusts. The ratio of total to inhalable (<10 μm MMAD) dust ranged from 2 to 11. An increased prevalence of respiratory symptoms was related solely to smoking. No association was found between symptoms and tenure of employment, dust exposure, NO_2, CO, or aldehydes. A higher prevalence of symptoms of cough and phlegm was found, but no differences in pulmonary function (FVC and FEV_1) were found in these diesel-exposed potash miners when compared with the predicted values derived from a logistics model based on blue-collar workers working in nondusty jobs.

Gamble et al. (1983) investigated respiratory morbidity in 259 miners from 5 salt mines in terms of increased respiratory symptoms, radiographic findings, and reduced pulmonary function associated with exposure to NO_2, inhalable particles (<10 μm MMAD), or years worked underground. Two of the mines used diesel extensively; no diesels were used in one salt mine. Diesels were introduced into each mine in 1956, 1957, 1963, or 1963 through 1967. Several working populations were compared with the salt miner cohort. After adjustment for age and smoking, the salt miners showed no increased prevalence of cough, phlegm, dyspnea, or airway obstruction (FEV_1/FVC) compared with aboveground coal miners, potash miners, or blue-collar workers. The underground coal miners consistently had an elevated level of symptoms. Forced expiratory volume at 1 s, FVC, FEF_{50}, and FEF_{75} were uniformly lower for salt miners in relation to all the comparison populations. There was, however, no association between changes in pulmonary function and years worked, estimated cumulative inhalable particles, or estimated NO_2 exposure. The highest average exposure to particulate matter was 1.4 mg/m^3 (particle size not reported, measurement includes NaCl). Mean NO_2 exposure was 1.3 ppm, with a range of 0.17 ppm to 2.5 ppm. In a continuation of these studies, Gamble and Jones (1983) grouped the salt miners into low-, intermediate-, and high-exposure categories based on tenure in jobs with DE exposure. Average concentrations of inhalable particles and NO_2 were 0.40, 0.60, and 0.82 mg/m^3 and 0.64, 1.77, and 2.21 ppm for the three diesel exposure categories, respectively. A statistically significant concentration-response association was found between the prevalence of phlegm in the salt miners and exposure to DE ($p<0.0001$) and a similar, but nonsignificant, trend for cough and dyspnea. Changes in pulmonary function showed no association with diesel tenure. In a comparison with the control group of nonexposed, blue-collar workers, adjusted for age and smoking, the overall prevalence of cough and phlegm (but not dyspnea) was elevated in the diesel-exposed workers. Forced expiratory volumes at 1 s and FVC were within 4% of expected, which was considered to be within the normal range of variation for a nonexposed population.

In a preliminary study of three subcohorts from bus company personnel (clerks [lowest exposure], bus drivers [intermediate exposure], and bus garage workers [highest exposure]) representing different levels of exposure to DE, Edling and Axelson (1984) found a fourfold higher risk ratio for cardiovascular mortality in bus garage workers, even after adjusting for smoking history and allowing for at least 10 years of exposure and 15 years or more of induction latency. Carbon monoxide was hypothesized as the etiologic agent for the increased cardiovascular disease but was not measured. However, in a more comprehensive epidemiologic study, Edling et al. (1987) evaluated mortality data covering a 32-year period for a cohort of 694 bus garage employees and found no significant differences between the observed and expected number of deaths from cardiovascular disease. Information on exposure components and their concentrations was not reported.

The absence of reported noncancerous human health effects, other than infrequently occurring effects related to respiratory symptoms and pulmonary function changes, is notable. Unlike studies in laboratory animals, to be described later in this chapter, studies of the impact of DE on the defense mechanisms of the human lung have not been performed. No direct evidence is available in humans regarding doses of DE, gas phase, particulate phase, or total exhaust that lead to impaired particle clearance or enhanced susceptibility to infection. A summary of epidemiologic studies is presented in Table 5-1.

Table 5-1. Human studies of exposure to diesel exhaust

Study	Description	Findings
	Acute exposures	
Kahn et al. (1988)	13 cases of acute exposure, Utah and Colorado coal miners.	Acute reversible sensory irritation, headache, nervous system effects, bronchoconstriction were reported at unknown exposures.
El Batawi and Noweir (1966)	161 workers, two diesel bus garages.	Eye irritation (42%), headache (37%), dizziness (30%), throat irritation (19%), and cough and phlegm (11%) were reported in this order of incidence by workers exposed in the service and repair of diesel-powered buses.
Battigelli (1965)	Six subjects, eye exposure chamber, three dilutions.	Time to onset was inversely related and severity of eye irritation was associated with the level of exposure to DE.
Katz et al. (1960)	14 persons monitoring DE in a train tunnel.	Three occasions of minor eye and throat irritation; no correlation established with concentrations of DE components.
Hare and Springer (1971) Hare et al. (1974)	Volunteer panelists who evaluated general public's response to odor of DE.	Slight odor intensity, 90% perceived, 60% objected; slight to moderate odor intensity, 95% perceived, 75% objected; moderate odor intensity, 100% perceived, almost 95% objected.
Linnell and Scott (1962)	Odor panel under highly controlled conditions determined odor threshold for DE.	In six panelists, the volume of air required to dilute raw DE to an odor threshold ranged from a factor of 140 to 475.
Rudell et al. (1990, 1994)	Eight healthy nonsmoking subjects exposed for 60 min in chamber to DE (3.7 ppm NO, 1.5 ppm NO_2, 27 ppm CO, 0.5 mg/m^3 formaldehyde, particles (4.3×10^6/cm^3). Exercise, 10 of each 20 min (75 W).	Odor, eye and nasal irritation in 5/8 subjects. BAL findings: small decrease in mast cells, lymphocyte subsets and macrophage phagocytosis; small increase in PMNs.
Rudell et al. (1996)	Volunteers exposed to DE for 1 h while doing light work. Exposure concentrations uncertain.	Unpleasant smell along with irritation of eyes and nose reported. Airway resistance increased. Reduction of particle concentration by trapping did not affect results.
Battigelli (1965)	13 volunteers exposed to three dilutions of DE for 15 min to 1 h.	No significant effects on pulmonary resistance were observed as measured by plethysmography.
Wade and Newman (1993)	Three railroad workers acutely exposed to DE.	The workers developed symptoms of asthma.
Diaz-Sanchez et al. (1994)	Volunteers challenged by a nasal spray of 0.30 mg DPM.	Enhancement of IgE production reported due to a dramatic increase in IgE-secreting cells.

Table 5-1. Human studies of exposure to diesel exhaust (continued)

Study	Description	Findings
Takenaka et al. (1995)	Volunteers challenged by a nasal spray of 0.30 mg DPM.	DPM extracts enhanced interleukin-4 plus monoclonal antibody-stimulated IgE production as much as 360%, suggesting an enhancement of ongoing IgE production rather than inducing germline transcription or isotype switching.
Diaz-Sanchez et al. (1996)	Volunteers challenged by a nasal spray of 0.30 mg DPM.	A broad increase in cytokine expression predicted to contribute to enhanced local IgE production.
Diaz-Sanchez et al. (1997)	Ragweed-sensitive volunteers challenged by a nasal spray of 0.30 mg DPM alone or in combination with ragweed allergen.	Ragweed allergen plus DPM-stimulated ragweed-specific IgE to a much greater degree than ragweed alone, suggesting DPM may be a key feature in stimulating allergen-induced respiratory allergic disease.
Salvi et al. (1999)	Volunteers exposed to diluted DE (DPM 300 $\mu g/m^3$) for 1 h with intermittent exercise.	• No changes in pulmonary function, but significant increases in neutrophils, B lymphocytes, histamine, and fibronectin in airway lavage fluid. • Bronchial biopsies 6 h after exposure showed significant increase in neutrophils, mast cells, CD4+ and CD8+ T lymphocytes; upregulation of ICAM-1 and VCAM-1; increases in the number of LFA-1+ in bronchial tissue. • Significant increases in neutrophils and platelets observed in peripheral blood.
Salvi et al. (2000)	Volunteers exposed to diluted DE (DPM 300 $\mu g/m^3$) for 1 h.	• DPM enhanced gene transcription of IL-8 in bronchial tissue and bronchial wash cells • Increased expression of growth-regulated oncogene-α and IL-8 in bronchial epithelium; trend towards increased IL-5 mRNA gene transcripts.
Nightingale et al. (2000)	Volunteers exposed to resuspended DPM (200 ug/m^3) for 2 h at rest	• DPM increased exhaled levels of CO • DPM increased sputum neutrophils and myeloperoxidase
Studies of cross-shift changes		
Reger (1979)	Five or more VC maneuvers by each of 60 coal miners exposed to DE at the beginning and end of a workshift.	FEV_1, FVC, and PEFR were similar between diesel and non-diesel-exposed miners. Smokers had an increased number of decrements over shift than nonsmokers.

Table 5-1. Human studies of exposure to diesel exhaust (continued)

Study	Description	Findings
Ames et al. (1982)	Pulmonary function of 60 diesel-exposed compared with 90 non-diesel-exposed coal miners over workshift.	Significant workshift decrements occurred in miners in both groups who smoked; no significant differences in ventilatory function changes between miners exposed to DE and those not exposed.
Jörgensen and Svensson (1970)	240 iron ore miners matched for diesel exposure, smoking, and age were given bronchitis questionnaires and spirometry pre- and postworkshift.	Among underground (surrogate for diesel exposure) miners, smokers, and older age groups, frequency of bronchitis was higher. Pulmonary function was similar between groups and subgroups except for differences accountable to age.
Gamble et al. (1979)	200 salt miners performed before- and after-workshift spirometry. Personal environmental NO_2 and inhalable particle samples were collected.	Smokers had greater but not significant reductions in spirometry than ex- or nonsmokers. NO_2 but not particulate levels significantly decreased FEV1, FEF_{25}, FEF_{50}, and FEF_{75} over the workshift.
Gamble et al. (1987a)	232 workers in 4 diesel bus garages administered acute respiratory questionnaire and before and after workshift spirometry. Compared to lead/acid battery workers previously found to be unaffected by their exposures.	Prevalence of burning eyes, headache, difficult or labored breathing, nausea, and wheeze were higher in diesel bus workers than in comparison population.
Ulfvarson et al. (1987)	Workshift changes in pulmonary function were evaluated in crews of roll-on/ roll-off ships and car ferries and bus garage staff. Pulmonary function was evaluated in six volunteers exposed to diluted DE, 2.1 ppm NO_2, and 0.6 mg/m^3 particulate matter.	Pulmonary function was affected during a workshift exposure to DE, but it normalized after a few days with no exposure. Decrements were greater with increasing intervals between exposures. No effect on pulmonary function was observed in the experimental exposure study.
	Cross-sectional and longitudinal studies	
Battigelli et al. (1964)	210 locomotive repairmen exposed to DE for an average of 9.6 years in railroad engine houses were compared with 154 railroad yard workers of comparable job status but no exposure to DE.	No significant differences in VC, FEV_1, peak flow, nitrogen washout, or diffusion capacity or in the prevalence of dyspnea, cough, or sputum were found between the DE-exposed and nonexposed groups.

Table 5-1. Human studies of exposure to diesel exhaust (continued)

Study	Description	Findings
Gamble et al. (1987b)	283 male diesel bus garage workers from four garages in two cities were examined for impaired pulmonary function (FVC, FEV_1, and flow rates). Study population with a mean tenure of 9 ± 10 years S.D. was compared to a nonexposed blue-collar population.	Analyses within the study population showed no association of respiratory symptoms with tenure. Reduced FEV_1 and FEF_{50} (but not FEF_{75}) were associated with increasing tenure. The study population had a higher incidence of cough, phlegm, and wheezing unrelated to tenure. Pulmonary function was not affected in the total cohort of diesel-exposed but was reduced with 10 or more years of tenure.
Purdham et al. (1987)	Respiratory symptoms and pulmonary function were evaluated in 17 stevedores exposed to both diesel and gasoline exhausts in car ferry operations; control group was 11 on-site office workers.	No differences between the two groups for respiratory symptoms. Stevedores had lower baseline lung function consistent with an obstructive ventilatory defect compared with controls and those of Sydney, Nova Scotia, residents. Caution in interpretation is warranted because of small sample size. No significant changes in lung function over workshift or difference between two groups.
Reger et al. (1982)	Differences in respiratory symptoms and pulmonary function were assessed in 823 coal miners from 6 diesel-equipped mines compared to 823 matched coal miners not exposed to DE.	Underground miners in diesel-use mines reported more symptoms of cough and phlegm and had lower pulmonary function. Similar trends were noted for surface workers at diesel-use mines. Pattern was consistent with small airway disease but factors other than exposure to DE thought to be responsible.
Ames et al. (1984)	Changes in respiratory symptoms and function were measured during a 5-year period in 280 diesel-exposed and 838 nonexposed U.S. underground coal miners.	No decrements in pulmonary function or increased prevalence of respiratory symptoms were found attributable to DE. In fact, 5-year incidences of cough, phlegm, and dyspnea were greater in miners without exposure to DE than in miners exposed to DE.
Attfield (1978)	Respiratory symptoms and function were assessed in 2,659 miners from 21 underground metal mines (1,709 miners) and nonmetal mines (950 miners). Years of diesel usage in the mines were surrogate for exposure to DE.	Questionnaire found an association between an increased prevalence of cough and aldehyde exposure; this finding was not substantiated by spirometry data. No adverse symptoms or pulmonary function decrements were related to exposure to NO_2, CO, CO_2, dust, or quartz.

Table 5-1. Human studies of exposure to diesel exhaust (continued)

Study	Description	Findings
Attfield et al. (1982)	Respiratory symptoms and function were assessed in 630 potash miners from 6 potash mines through a questionnaire, chest radiographs, and spirometry. A thorough assessment of the environment of each mine was made concurrently.	No obvious association indicative of diesel exposure was found between health indices, dust exposure, and pollutants. Higher prevalences of cough and phlegm but no differences in FVC and FEV_1 were found in these diesel-exposed potash workers when compared with predicted values from a logistic model based on blue-collar staff working in nondusty jobs.
Gamble et al. (1983)	Respiratory morbidity was assessed in 259 miners in 5 salt mines by respiratory symptoms, radiographic findings, and spirometry. Two mines used diesels extensively, two had limited use, and one used no diesels in 1956, 1957, 1963, or 1963 through 1967. Several working populations were compared with the salt-mine cohort.	After adjustment for age and smoking, salt miners showed no symptoms or increased prevalence of cough, phlegm, dyspnea, or air obstruction (FEV_1/FVC) compared with aboveground coal miners, potash workers, or blue-collar workers. FEV_1, FVC, FEF_{50}, and FEF_{75} were uniformly lower for salt miners in comparison with all the comparison populations. No changes in pulmonary function were associated with years of exposure or cumulative exposure to inhalable particles or NO_2.
Gamble and Jones (1983)	Same as above. Salt miners were grouped into low-, intermediate-, and high-exposure categories based on tenure in jobs with diesel exposure.	A statistically significant dose-related association of phlegm and diesel exposure was noted. Changes in pulmonary function showed no association with diesel tenure. Age- and smoking-adjusted rates of cough, phlegm, and dyspnea were 145%, 169%, and 93% of an external comparison population. Predicted pulmonary function indices showed small but significant reductions; there was no dose-response relationship.
Edling and Axelson (1984)	Pilot study of 129 bus company employees classified into 3 diesel-exhaust exposure categories: clerks (0), bus drivers (1), and bus garage workers.	The most heavily exposed group (bus garage workers) had a fourfold increase in risk of dying from cardiovascular disease, even after correction for smoking and allowing for 10 years of exposure and 14 years or more of induction latency time.
Edling et al. (1987)	Cohort of 694 male bus garage employees followed from 1951 through 1983 was evaluated for mortality from cardiovascular disease. Subcohorts categorized by levels of exposure were clerks (0), bus drivers (1), and bus garage employees (2).	No increased mortality from cardiovascular disease was found among the members of these five bus companies when compared with the general population or grouped as subcohorts with different levels of exposure.

To date, no large-scale epidemiologic study has looked for effects of chronic exposure to DE on pulmonary function. In the long-term longitudinal and cross-sectional studies, a relationship was generally observed between work in a job with diesel exposure and respiratory symptoms (such as cough and phlegm), but there was no consistent effect on pulmonary function. The interpretation of these results is hampered by lack of measured DE exposure levels and the short duration of exposure in these cohorts. The studies are further limited in that only active workers were included, and it is possible that workers who have developed symptoms or severe respiratory disease are likely to have moved away from these jobs. The relationship between work in a job with diesel exposure and respiratory symptoms may be due to short-term exposure.

5.1.2. Traffic Studies

The relationship between traffic density and respiratory health in children has been examined in a series of studies in Holland in children attending schools located near major freeways. Cough, wheeze, runny nose, and doctor-diagnosed asthma were reported more often for children living within 100 m of freeways carrying between 80,000 and 150,000 vehicles per day (van Vliet et al., 1997). Separate counts for truck traffic indicated a range from 8,000 to 17,500 trucks per day. Truck traffic intensity and concentration of "black smoke," considered by the authors to be a proxy for DPM, measured in schools were found to be significantly associated with chronic respiratory symptoms, with the relationships being more pronounced in girls than in boys.

Brunekreef et al. (1997) measured lung function in children in six areas located near major motorways and assessed their exposure to traffic-related air pollution using separate traffic counts for automobiles and trucks. They also measured air pollution in the children's schools. Although lung function was associated with truck traffic density, there was a lesser association with automobile traffic density. The association was stronger in those children living closest (300 m) to the roadways. Lung function was also associated with concentration of "black smoke" (source and constitution unclear from the study) measured inside the schools. The associations were stronger in girls than in boys. The authors conclude that exposure to vehicular pollution, in particular DPM, may lead to reduced lung function in children living near major motorways.

In a follow-up study of traffic-related air pollution and its effect on the respiratory health of children living near roadways, Brunekreef et al. (2000) showed that the intensity of truck traffic was significantly associated with the prevalence of wheeze, phlegm, bronchitis, eye symptoms, and allergy to dust and pets. Associations with yearly averaged $PM_{2.5}$ and "soot" concentrations measured inside and outside the schools showed similar patterns. Truck traffic intensity was also significantly associated with a positive skin prick test or elevated IgE for outdoor allergens. There were no associations between traffic intensity or $PM_{2.5}$ and “soot” concentrations and lung function, bronchial responsiveness, and allergic reactions to indoor allergens. Further analysis of the data showed that the associations between traffic-related air pollution and symptoms were almost entirely related to children with bronchial hyperreactivity or sensitization to common allergens.

5.1.3. Laboratory Animal Studies

Because humans and laboratory animals show similar nonneoplastic responses to inhaled particles (ILSI, 2000), animal studies have been conducted to assess the pathophysiologic effects of DPM. Because of the large number of statistical comparisons made in the laboratory animal studies, and to permit uniform, objective evaluations within and among studies, data will be reported as significantly different (i.e., $p<0.05$) unless otherwise specified. The exposure regimens used and the resultant exposure conditions employed in the laboratory animal inhalation studies are summarized in Tables 5-2 through 5-16. Other than the pulmonary function studies performed by Wiester et al. (1980) on guinea pigs during their exposure in inhalation chambers, the pulmonary function studies performed by other investigators, although sometimes unreported, were interpreted as being conducted on the following day or thereafter and not immediately following exposure.

5.1.3.1. *Acute Exposures*

The acute toxicity of undiluted DE to rabbits, guinea pigs, and mice was assessed by Pattle et al. (1957). Four engine operating conditions were used, and 4 rabbits, 10 guinea pigs, and 40 mice were tested under each exposure condition for 5 h (no controls were used). Mortality was assessed up to 7 days after exposure. With the engine operating under light load, the exhaust was highly irritating but not lethal to the test species, and only mild tracheal and lung damage was observed in the exposed animals. The exhaust contained 74 mg/m^3 DPM (particle size not reported), 560 ppm CO, 23 ppm NO_2, and 16 ppm aldehydes. Exhaust containing 5 mg/m^3 DPM, 380 ppm CO, 43 ppm NO_2, and 6.4 ppm aldehydes resulted in low mortality rates (mostly below 10%) and moderate lung damage. Exhaust containing 122 mg/m^3 DPM, 418 ppm CO, 51 ppm NO_2, and 6.0 ppm aldehydes produced high mortality rates (mostly above 50%) and severe lung damage. Exhaust containing 1,070 mg/m^3 DPM, 1,700 ppm CO, 12 ppm NO_2, and 154 ppm aldehydes resulted in 100% mortality in all three species. High CO levels, which resulted in a carboxyhemoglobin value of 60% in mice and 50% in rabbits and guinea pigs, were considered to be the main cause of death in the latter case. High NO_2 levels were considered to be the main cause of lung damage and mortality seen in the other three tests. Aldehydes and NO_2 were considered to be the main irritants in the light load test.

Kobayashi and Ito (1995) administered 1, 10, or 20 mg/kg DPM in phosphate-buffered saline to the nasal mucosa of guinea pigs. The administration increased nasal airway resistance, augmented increased airway resistance and nasal secretion induced by a histamine aerosol, increased vascular permeability in dorsal skin, and augmented vascular permeability induced by histamine. The increases in nasal airway resistance and secretion are considered typical responses of nasal mucosa against allergic stimulation. Similar results were reported for guinea pigs exposed via inhalation for 3 h to DE diluted to DPM concentrations of either 1 or 3.2 mg/m^3 (Kobayashi et al., 1997). These studies show that short-term exposure to DPM augments nasal mucosal hyperresponsiveness induced by histamine in guinea pigs.

5.1.3.2. *Short-Term and Subchronic Exposures*

A number of inhalation studies have employed a regimen of 20 h/day, 7 days/week for varying exposure periods up to 20 weeks to differing concentrations of airborne particulate matter, vapor, and gas concentrations of diluted DE. Exposure regimens and characterization of gas-phase components for these studies are summarized in Table 5-2.

Pepelko et al. (1980a) evaluated the pulmonary function of cats exposed under these conditions for 28 days to 6.4 mg/m^3 DPM. The only significant functional change observed was a decrease in maximum expiratory flow rate at 10% vital capacity. The excised lungs of the exposed cats appeared charcoal gray, with focal black spots visible on the pleural surface. Pathologic changes included a predominantly peribronchial localization of black-pigmented macrophages within the alveoli characteristic of focal pneumonitis or alveolitis.

The effects of a short-term DE exposure on arterial blood gases, pH, blood buffering, body weight changes, lung volumes, and deflation pressure-volume (PV) curves of young adult rats were evaluated by Pepelko (1982a). Exposures were 20 h/day, 7 days/week for 8 days to a concentration of 6.4 mg/m^3 DPM in the nonirradiated exhaust (RE) and 6.75 mg/m^3 in the irradiated exhaust (IE). In spite of the irradiation, levels of gaseous compounds were not substantially different between the two groups (Table 5-2). Body weight gains were significantly reduced in the RE-exposed rats and to an even greater degree in rats exposed to IE. Arterial blood gases and standard bicarbonate were unaffected, but arterial blood pH was significantly reduced in rats exposed to IE. Residual volume and wet lung weight were not affected by either exposure, but vital capacity and total lung capacity were increased significantly following exposure to RE. The shape of the deflation PV curves were nearly identical for the control, RE, and IE groups.

Table 5-2. Short-term effects of diesel exhaust on laboratory animals

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg \cdot h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, F344, M; Mouse, A/J, M; Hamster, Syrian, M	20 h/day 7 days/week 10-13 weeks	1.5 0.19 µm MMD	2,100 to 2,730	6.9	0.49	—	Increase in lung wt; increase in thickness of alveolar walls; minimal species difference	Kaplan et al. (1982)
Rat, F344, M, F; Mouse, CD-1, M, F	7 h/day 5 days/week 19 weeks	0.21 1.0 4.4	140 665 2,926	— — —	— — —	— — —	No effects on lung function in rats (not done in mice); increase in PMNs and proteases and AM aggregation in both species	Mauderly et al. (1981)
Cat, Inbred, M	20 h/day 7 days/week 4 weeks	6.4	3,584	14.6	2.1	2.1	Few effects on lung function; focal pneumonitis or alveolitis	Pepelko et al. (1980a)
Rat, Sprague-Dawley, M	20 h/day 7 days/week 4 weeks	6.4 6.8[a]	3,584 3,808	16.9 16.1[a]	2.49 2.76[a] (<0.01 ppm O_3)[a]	2.10 1.86[a]	Decreased body wt; arterial blood pH reduced; vital capacity, total lung capacities increased	Pepelko (1982a)
Guinea Pig, Hartley, M, F	20 h/day 7 days/week 4 weeks	6.8[a]	3,808	16.7	2.9 (<0.01 ppm O_3)[a]	1.9	Exposure started when animals were 4 days old; increase in pulmonary flow; bardycardia	Wiester et al. (1980)
Rat, F344, M	20 h/day 5.5 days/week 4 weeks	6.0 6.8 µm MMD	2,640	—	—	—	Macrophage aggregation; increase in PMNs; Type II cell proliferation; thickened alveolar walls	White and Garg (1981)
Guinea Pig, Hartley, M	30 min	1-2 mg DPM Intranasally	—	—	—	—	Augmented increases in nasal airway resistance and vascular permeability induced by a histamine aerosol	Kobayashi and Ito (1995)
Guinea Pig, Hartley, M	3 h	1 3.2	0.5 1.6	5.9 12.9	1.4 4.4	0.13 0.34	Similar results to those reported in the previous study using intranasal challenge	Kobayashi et al. (1997)

Table 5-2. Short-term effects of diesel exhaust on laboratory animals (continued)

Species/sex	Exposure period	Particles (mg/m^3)	C × T (mg·h/m^3)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Guinea Pig, Hartley, M, F	20 h/day 7 days/week 8 weeks	6.3	7,056	17.4	2.3	2.1	Increase in relative lung wt. AM aggregation; hypertrophy of goblet cells; focal hyperplasia of alveolar epithelium	Wiester et al. (1980)
Mouse ICR, M	6 weeks	100 µg DPM intranasally	—	—	—	—	DPM aggravated ovalbumin-induced airway inflammation and provided evidence that DPM can enhance manifestations of allergic asthma	Takano et al. (1997)
Rat, Sprague-Dawley, M	24 h	5-100 µg/10^6 AM/mL of DPM	—	—	—	—	Unchanged, but not organic-free DPM enhanced production of proinflammatory cytokines	Yang et al. (1997)

[a]Irradiated exhaust.
PMN = Polymorphonuclear leukocyte.
AM = Alveolar macrophage.

In related studies, Wiester et al. (1980) evaluated pulmonary function in 4-day-old guinea pigs exposed for 20 h/day, 7 days/week for 28 days to IE having a concentration of 6.3 mg/m^3 DPM. When housed in the exposure chamber, pulmonary flow resistance increased 35%, and a small but significant sinus bradycardia occurred as compared with controls housed and measured in control air chambers (p<0.002). Respiratory rate, tidal volume, minute volume, and dynamic compliance were unaffected, as were lead-1 electrocardiograms.

A separate group of adult guinea pigs was necropsied after 56 days of exposure to IE, to diluted RE, or to clean air (Wiester et al., 1980). Exposure resulted in a significant increase in the ratio of lung weight to body weight (0.68% for controls, 0.78% for IE, and 0.82% for RE). Heart/body weight ratios were not affected by exposure. Microscopically, there was a marked accumulation of black pigment-laden AMs throughout the lung, with a slight to moderate accumulation in bronchial and carinal lymph nodes. Hypertrophy of goblet cells in the tracheobronchial tree was frequently observed, and focal hyperplasia of alveolar lining cells was occasionally observed. No evidence of squamous metaplasia of the tracheobronchial tree, emphysema, peribronchitis, or peribronchiolitis was noted.

White and Garg (1981) studied pathologic alterations in the lungs of rats (16 exposed and 8 controls) after exposure to DE containing 6 mg/m^3 DPM. Two rats from the exposed group and one rat from the control group (filtered room air) were sacrificed after each exposure interval of 6 h and 1, 3, 7, 14, 28, 42, and 63 days; daily exposures were for 20 h and were 5.5 days/week. Evidence of AM recruitment and phagocytosis of diesel particles was found at the 6-h sacrifice; after 24 h of exposure there was a focal, scattered increase in the number of Type II cells. After 4 weeks of exposure, there were morphologic changes in size, content, and shape of AM, septal thickening adjacent to clusters of AMs, and an appearance of inflammatory cells, primarily within the septa. At 9 weeks of exposure, focal aggregations of particle-laden macrophages developed near the terminal bronchi, along with an influx of PMNs, Type II cell proliferation, and thickening of alveolar walls. The affected alveoli occurred in clusters that, for the most part, were located near the terminal bronchioles, but occasionally were focally located in the lung parenchyma. Hypertrophy of goblet cells in the tracheobronchial tree was frequently observed, and focal hyperplasia of alveolar lining cells was occasionally observed. No evidence of squamous metaplasia of the tracheobronchial tree, emphysema, peribronchitis, or peribronchiolitis was noted.

Mauderly et al. (1981) exposed rats and mice by inhalation to diluted DE for 545 h over a 19-week period on a regimen of 7 h/day, 5 days/week at concentrations of 0, 0.21, 1.02, or 4.38 mg/m^3 DPM. Indices of health effects were minimal following 19 weeks of exposure. There were no significant exposure-related differences in mortality or body weights of the rats or mice. There also were no significant differences in respiratory function (breathing patterns, dynamic lung mechanics, lung volumes, quasi-static PV relationships, forced expirograms, and CO-diffusing capacity) in rats; pulmonary function was not measured in mice. No effect on tracheal mucociliary or deep lung clearances were observed in the exposed groups. Rats, but not mice, had elevated immune responses in lung-associated lymph nodes at the two higher exposure levels. Inflammation in the lungs of rats exposed to 4.38 mg/m^3 DPM was indicated by increases in PMNs and lung tissue proteases. Histopathologic findings included AMs that contained DPM, an increase in Type II cells, and the presence of particles in the interstitium and tracheobronchial lymph nodes.

Kaplan et al. (1982) evaluated the effects of subchronic exposure to DE on rats, hamsters, and mice. The exhaust was diluted to a concentration of 1.5 mg/m^3 DPM; exposures were 20 h/day, 7 days/week. Hamsters were exposed for 86 days, rats and mice for 90 days. There were no significant differences in mortality or growth rates between exposed and control animals. Lung weight relative to body weight of rats exposed for 90 days was significantly higher than the mean for the control group. Histological examination of tissues of all three species indicated particle accumulation in the lungs and mediastinal lymph nodes. Associated with the larger accumulations, there was a minimal increase in the thickness of the alveolar walls, but the vast majority of the particles elicited no response. After 6 mo of recovery, considerable clearance of the DPM from the lungs occurred in all three species, as evaluated by gross pathology and histopathology. However, no quantitative estimate of clearance was provided.

Toxic effects in animals from acute exposure to DE appear to be primarily attributable to the gaseous components (i.e., mortality from CO intoxication and lung injury caused by cellular damage resulting from NO_2 exposure). The results from short-term exposures indicate that rats experience minimal lung function impairment even at DE levels sufficiently high to cause histological and cytological changes in the lung. In subchronic studies of durations of 4 weeks or more, frank adverse health effects are not readily apparent and, when found, are mild and result from exposure to concentrations of about 6 mg/m^3 DPM and durations of exposures of 20 h/day. There is ample evidence that subchronic exposure to lower levels of DE affects the lung, as indicated by accumulation of particles, evidence of inflammatory response, AM aggregation and accumulation near the terminal bronchioles, Type II cell proliferation, and thickening of alveolar walls adjacent to AM aggregates. Little evidence exists, however, that subchronic exposure to DE impairs lung function.

5.1.3.3. *Chronic Exposures*

5.1.3.3.1. ***Effects on growth and longevity.*** Changes in growth, body weight, absolute or relative organ weights, and longevity can be measurable indicators of chronic toxic effects.

Such effects have been observed in some, but not all, of the long-term studies conducted on laboratory animals exposed to DE. There was limited evidence for an effect on survival in the published chronic animal studies; deaths occurred intermittently early in one study in female rats exposed to 3.7 mg/m^3 DPM; however, the death rate began to decrease after 15 mo, and the survival rate after 30 mo was slightly higher than that of the control group (Ishinishi et al., 1988). Studies of the effects of chronic exposure to DE on survival and body weight or growth are detailed in Table 5-3.

Increased lung weights and lung-to-body weight ratios have been reported in rats, mice, and hamsters. These data are summarized in Table 5-4. In rats exposed for up to 36 weeks to 0.25 or 1.5 mg/m^3 DPM, lung wet weights (normalized to body weight) were significantly higher in the 1.5 mg/m^3 exposure group than control values after 12 weeks of exposure (Misiorowski et al., 1980). Rats and Syrian hamsters were exposed for 2 years (five 16-h periods per week) to DE diluted to achieve concentrations of 0.7, 2.2, and 6.6 mg/m^3 DPM (Brightwell et al., 1986). At necropsy, a significant increase in lung weight was seen in both rats and hamsters exposed to DE compared with controls. This finding was more pronounced in the rats in which the increase was progressive with both duration of exposure and particulate matter level. The increase was greatest at 30 mo (after the end of a 6-mo observation period in the high-concentration male group where the lung weight was 2.7 times the control and at 24 mo in the high-concentration female group [3.9 times control]). Heinrich et al. (1986a,b; see also Stöber, 1986) found a significant increase in wet and dry weights of the lungs of rats and mice exposed at 4.24 mg/m^3 DPM for 1 year in comparison with controls. After 2 years, the difference was a factor of 2 (mice) or 3 (rats). After the same exposure periods, the hamsters showed increases of 50% to 75%, respectively. Exposure to equivalent filtered DE (i.e., without DPM) caused no significant effects in any of the species. Vinegar et al. (1980, 1981a,b) exposed hamsters to two levels of DE with resultant concentrations of about 6 and 12 mg/m^3 DPM for 8 h/day, 7 days/week for 6 mo. Both exposures significantly increased lung weight and lung-weight to body-weight ratios. The difference between lung weights of exposed and control hamsters exposed to 12 mg/m^3 DPM was approximately twice that of those exposed to 6 mg/m^3.

Heinrich et al. (1995) reported that rats exposed to 2.5 and 7 mg/m^3 DPM for 18 h/day, 5 days/week for 24 mo showed significantly lower body weights than controls starting at day 200 in the high-concentration group and at day 440 in the low-concentration group. Body weight in the low-concentration group was unaffected, as was mortality in any group. Lung weight was increased in the 7 mg/m^3 group starting at 3 mo and persisting throughout the study, while the 2.5 mg/m^3 group showed increased lung weight only at 22 and 24 mo of exposure. Mice (NMRI strain) exposed to 7 mg/m^3 in this study for 13.5 mo had no increase in mortality and insignificant decreases in body weight. Lung weights were dramatically affected, with

Table 5-3. Effects of chronic exposures to diesel exhaust on survival and growth of laboratory animals

Species/sex	Exposure period	Particles (mg/m³)	C × T (mg·h/m³)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, F344, M, F; Monkey, Cynomolgus, M	7 h/day 5 days/week 104 weeks	2.0 0.23–0.36μ m MMD	7,280	11.5	1.5	0.8	No effects on growth or survival	Lewis et al. (1989)
Rat, F344, M; Guinea Pig, Hartley, M	20 h/day 5 days/week 106 weeks	0.25 0.75 1.5 0.19 μm MMD	2,650 7,950 15,900	2.7[a] 4.4[a] 7.1[a]	0.1[b] 0.27[b] 0.5[b]	— — —	Reduced body weight in rats at 1.5 mg/m³	Schreck et al. (1981)
Hamster, Chinese, M	8 h/day 7 days/week 26 weeks	6.0 12.0	8,736 17,472	— —	— —	— —	No effect on growth	Vinegar et al. (1981a,b)
Rat, Wistar, M	6 h/day 5 days/week 87 weeks	8.3 0.71 μm MMD	21,663	50.0	4.0–6.0	—	No effect on growth or mortality rates	Karagianes et al. (1981)
Rat, F344, M, F; Mouse, CD-1, M, F	7 h/day 5 days/week 130 weeks	0.35 3.5 7.1 0.25 μm MMD	1,592 15,925 31,850	2.9 16.5 29.7	0.05 0.34 0.68	— — —	No effect on growth or mortality rates	Mauderly et al. (1984, 1987a)
Rat, Wistar, F; Mouse, MMRI, F	19 h/day 5 days/week 104 weeks	4.24 0.35 μm MMD	41,891	12.5	1.5	1.1	Reduced body wts; increased mortality in mice	Heinrich et al. (1986a)
Rat, F344 M, F	16 h/day 5 days/week 104 weeks	0.7 2.2 6.6	5,824 18,304 54,912	— — 32.0	— — —	— — —	Growth reduced at 2.2 and 6.6 mg/m³	Brightwell et al. (1986)
Rat[c] F344/Jcl.	16 h/day 6 days/week 130 weeks	0.11[d] 0.41[d] 1.08[d] 2.31[d] 3.72[e] 0.2–0.3 μm MMD	1,373 5,117 13,478 28,829 46,426	1.23 2.12 3.96 7.10 12.9	0.08 0.26 0.70 1.41 3.00	0.38 1.06 2.42 4.70 4.57	Concentration-dependent decrease in body weight; earlier deaths in females exposed to 3.72 mg/m³, stabilized by 15 mo	Research Committee for HERP Studies (1988)
Rat, Wistar, F; Mouse, NMRI, F (7 mg/m³ only)	18 h/day 5 days/week 24 mo	0.84 2.5 6.98	7,400 21,800 61,700	2.6 8.3 21.2	0.3 1.2 3.8	0.3 1.1 3.4	Reduced body weight in rats at 2.5 and 6.98 mg/m³ and no effect in mice	Heinrich et al. (1995)

Table 5-3. Effects of chronic exposures to diesel exhaust on survival and growth of laboratory animals (continued)

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg \cdot h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Mice, NMRI, F; C57BL/6N, F	18 h/day 5 days/week 13.5 mo (NMRI) 24 mo (C57BL/N)	6.98	35,500 - NMRI 38,300 - C57	14.2	2.3	2.8	Reduced body weight in NMRI mice but not in C57BL/6N mice	Heinrich et al. (1995)
Rats, F344, M	16 h/day 5 days/week 23 mo	2.44 6.33	19,520 50,640	— —	— —	— —	Reduced survival in 6.33 mg/m^3 after 300 days. Body weight significantly lower at 6.33 mg/m^3	Nikula et al. (1995)
Mouse, CD-1, M,F	7 h/day 5 days/week 104 weeks	0.35 3.5 7.1 0.25 µm MDD	1,274 12,740 25,844	3 17 30	0.1 0.3 0.7	— — —	No effect on growth or mortality rates	Mauderly et al. (1996)

[a]Estimated from graphically depicted mass concentration data.
[b]Estimated from graphically presented mass concentration data for NO_2 (assuming 90% NO and 10% NO_2).
[c]Data for tests with light-duty engine; similar results with heavy-duty engine.
[d]Light-duty engine.
[e]Heavy-duty engine.

Table 5-4. Effects of chronic exposures to diesel exhaust on organ weights and organ-to-body-weight ratios

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg·h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, F344, M; Mouse, A/J, M; Hamster, Syrian, M	20 h/day 7 days/week 12-13 weeks	1.5 0.19 µm MMD	2,520-2,730	—	—	—	No effect on liver, kidney, spleen, or heart weights	Kaplan et al. (1982)
Rat, F344, M, F	7 h/day 5 days/week 52 weeks	2.0 0.23–0.36 µm MMD	3,640	12.7	1.6	0.83	No effects on weights of lungs, liver, heart, spleen, kidneys, and testes	Green et al. (1983)
Rat, F344, M	20 h/day 5.5 days/ week 36 weeks	0.25 1.5 0.19 µm MMD	990 5,940	— —	— —	— —	Increase in relative lung weight at 1.5 mg/m^3 only initially seen at 12 weeks	Misiorowski et al. (1980)
Rat, F344, F	7 h/day 5 days/week 104 weeks	2.0 0.23–0.36 µm MMD	7,280	11.5	1.5	0.81	No effects on heart weights	Vallyathan et al. (1986)
Rat, F344; M Guinea Pig, Hartley, M	20 h/day 5.5 days/ week 78 weeks	0.25 0.75 1.5 0.19 µm MMD	2,145 6,435 12,870	— — —	— — —	— — —	No effects on heart mass	Penney et al. (1981)
Hamster, Chinese, M	8 h/day 7 days/week 26 weeks	6.0 12.0	8,736 17,472	— —	— —	— —	Increase in lung weight and lung/body weight ratio	Vinegar et al. (1981a,b)
Rat, Wistar, F; Hamster, Syrian, M, F Mouse, NMRI, F	19 h/day 5 days/week 120-140 weeks	4.24 0.35 µm MMD	48,336-56,392	12.5	1.5	1.1	Increase in rat, mouse, and hamster lung weight and dry weights	Heinrich et al. (1986a,b) Stöber (1986)
Rat, F344, M, F; Hamster, Syrian, M, F	16 h/day 5 days/week 104 weeks	0.7[a] 2.2[b] 6.6	5,824 18,304 54,912	— — 32.0	— — —	— — —	Increase in lung weight concentration related in rats; heart weight/body weight ratio greater at 6.6 mg/m^3	Brightwell et al. (1986)
Cat, inbred, M	8 h/day 7 days/week 124 weeks	6.0[a] 12.0[b]	41,664 83,328	20.2 33.2	2.7 4.4	2.7 5.0	Decrease in lung and kidney weights	Pepelko et al. (1980b, 1981) Moorman et al. (1985)
Mouse, NMRI, F (7 mg/m^3 only)	18 h/day 5 days/week 24 mo	0.84 2.5 6.98	7,400 21,800 61,700	2.6 8.3 21.2	0.3 1.2 3.8	0.3 1.1 3.4	Increased rat and mouse lung weight at 7 mg/m^3 from 6 mo and at 2.5 mg/m^3 at 22 and 24 mo	Heinrich et al. (1995)

Table 5-4. Effects of chronic exposures to diesel exhaust on organ weights and organ-to-body-weight ratios (continued)

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg·h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Mouse, NMRI, F; C57BL/6N, F	18 h/day 5 days/week 13.5 mo (NMRI) 24 mo (C57BL/N)	6.98	35,500 - NMRI 38,300 - C57	14.2	2.3	2.8	Increased lung weight	Heinrich et al. (1995)
Rats, F344, M	16 h/day 5 days/week 23 mo	2.44 6.33	19,520 50,640	— —	— —	— —	Increase in lung weight was significant at 2 and 6 mg/m^3	Nikula et al. (1995)
Rat		0.8 2.5 6.98					Increased lung weight in rats and mice at 3.5 and 7.1 mg/m^3	Henderson et al. (1988a)
Mouse		6.98 4.5						

[a]1 to 61 weeks of exposure.
[b]62 to 124 weeks of exposure.

increases progressing throughout the study from 1.5-fold at 3 mo to 3-fold at 12 mo. Mice (NMRI and C57BL/6N strains) were also exposed to 4.5 mg/m^3 for 23 mo. In NMRI mice, the body weights were reported to be significantly lower than controls, but the magnitude of the change is not reported, so biological significance cannot be assessed. Mortality was slightly increased, but statistical significance is not reported. The C57BL/6N mice showed minimal effects on body weight and mortality, which were not statistically significant. Lung weights were dramatically affected in both strains.

Nikula et al. (1995) exposed male and female F344 rats to DPM concentrations of 2.4 and 6.3 mg/m^3 for 16 h/day, 5 days/week for 23 mo in a study designed to compare the effects of DPM with those of carbon black. Significantly reduced survival was observed in males exposed to 6.3 mg/m^3 but not in females or at the lower concentration. Body weights were decreased by exposure to 6.3 mg/m^3 DPM in both male and female rats throughout the exposure period. Significant increases in lung weight were first seen at 6 mo in the high-exposure group and at 12 to 18 mo in the low-exposure group.

No evidence was found in the published literature that chronic exposure to DE affected the weight of body organs other than the lung and heart (e.g., liver, kidney, spleen, or testes) (Table 5-4). Morphometric analysis of hearts from rats and guinea pigs exposed to 0.25, 0.75, or 1.5 mg/m^3 DPM 20 h/day, 5.5 days/week for 78 weeks revealed no significant alteration in mass at any exposure level or duration of exposure (Penney et al., 1981). The analysis included relative wet weights of the right ventricle, left ventricle, combined atria, and ratio of right to left ventricle. Vallyathan et al. (1986) found no significant differences in heart weights and the ratio of heart weight to body weight between rats exposed to 2 mg/m^3 DPM for 7 h/day, 5 days/week for 24 mo and their respective clean-air chamber controls. No significant differences were found in the lungs, heart, liver, spleen, kidney, and testes of rats exposed for 52 weeks, 7 h/day, 5 days/week to diluted DE containing 2 mg/m^3 DPM compared with their respective controls (Green et al., 1983).

5.1.3.3.2. ***Effects on pulmonary function***. The effect of long-term exposure to DE on pulmonary function has been evaluated in laboratory studies of rats, hamsters, cats, and monkeys. These studies are summarized in Table 5-5, along with more details on the exposure characteristics, in general order of increasing dose ($C \times T$) of DPM. The text will be presented using the same approach.

Lewis et al. (1989) evaluated functional residual capacity and airway resistance and conductance in 10 control and 10 diesel-exposed rats (2 mg/m^3 DPM, 7 h/day, 5 days/week for 52 or 104 weeks). At the 104-week evaluation, the rats were also examined for maximum flow volume impairments. No evidence of impaired pulmonary function as a result of the exposure to

Table 5-5. Effects of diesel exhaust on pulmonary function of laboratory animals

Species/sex	Exposure period	Particles (mg/m³)	C × T (mg·h/m³)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, F344, M, F	7 h/day 5 days/week 104 weeks	2.0 0.23–0.36 µm MMD	7,280	11.5	1.5	0.8	No effect on pulmonary function	Lewis et al. (1989)
Monkey, Cynomolgus, M	7 h/day 5 days/week 104 weeks	2.0 0.23-0.36 µm MMD	7,280	11.5	1.5	0.8	Decreased expiratory flow; no effect on vital or diffusing capacities	Lewis et al. (1989)
Rat, F344, M	20 h/day 5.5 days/week 87 weeks	1.5 0.19 µm MMD	14,355	7.0	0.5	—	Increased functional residual capacity, expiratory volume, and flow	Gross (1981)
Rat, Wistar, F	7-8 h/day 5 days/week 104 weeks	3.9 0.1 µm MMD	14,196-16,224	18.5	1.2	3.1	No effect on minute volume, compliance, or resistance	Heinrich et al. (1982)
Hamster, Chinese, M	8 h/day 7 days/week 26 weeks	6.0 12.0	8,736 17,472	— —	— —	— —	Decrease in vital capacity, residual volume, and diffusing capacity; increase in static deflation lung volume	Vinegar et al. (1980, 1981a,b)
Rat, F344, M, F	7 h/day 5 days/week 130 weeks	0.35 3.5 7.1 0.23–0.26 µm MMD	1,593 15,925 31,850	2.9 16.5 29.7	0.05 0.34 0.68	— — —	Diffusing capacity, lung compliance reduced at 3.5 and 7.1 mg/m³	Mauderly et al. (1988) McClellan et al. (1986)
Rat, F344, M, F; Hamster, Syrian, M, F	16 h/day 5 days/week 104 weeks	0.7 2.2 6.6	5,824 18,304 54,912	— — —	— — —	— — —	Large number of pulmonary function changes consistent with obstructive and restrictive airway diseases at 6.6 mg/m³ (no specific data provided)	Brightwell et al. (1986)
Hamster, Syrian, M, F	19 h/day 5 days/week 120 weeks	4.24 0.35 µm MMD	48,336	12.5	1.5	1.1	Significant increase in airway resistance	Heinrich et al. (1986a)
Rat, Wistar, F	19 h/day 5 days/week 140 weeks	4.24 0.35 µm MMD	56,392	12.5	1.5	1.1	Decrease in dynamic lung compliance; increase in airway resistance	Heinrich et al. (1986a)
Cat, inbred, M	8 h/day 7 days/week 124 weeks	6.0[a] 12.0[b]	41,664 83,328	20.2 33.3	2.7 4.4	2.1 5.0	Decrease in vital capacity, total lung capacity, and diffusing capacity after 2 years; no effect on expiratory flow	Pepelko et al. (1980b, 1981) Moorman et al. (1985)

[a]1 to 61 weeks exposure.
[b]62 to 124 weeks of exposure.

DE was found in rats. Lewis et al. (1989) exposed male cynomolgus monkeys to DE for 7 h/day, 5 days/week for 24 mo. Groups of 15 monkeys were exposed to air, DE (2 mg/m^3), coal dust, or combined coal dust and DE. Pulmonary function was evaluated prior to exposure and at 6-mo intervals during the 2-year exposure, including compliance and resistance, static and dynamic lung volumes, distribution of ventilation, diffusing capacity, and maximum ventilatory performance. There were no effects on lung volumes, diffusing capacity, or ventilation distribution, so there was no evidence of restrictive disease. There was, however, evidence of obstructive airway disease as measured by low maximal flow rates in diesel-exposed monkeys. At 18 mo of exposure, forced expiratory flow at 25% of vital capacity and forced expiratory flow normalized to FVC were decreased. The measurement of forced expiratory flow at 40% of total lung capacity was significantly decreased at 12, 18, and 24 mo of exposure. The finding of an obstructive effect in monkeys contrasts with the finding of restrictive type effects in other laboratory animal species (Vinegar et al., 1980, 1981a; Mauderly et al., 1988; Pepelko et al., 1980b, 1981) and suggests a possible difference in effect between primate and small animal respiratory tracts. In these monkeys there were no specific histopathological effects reported (see next section), although particle aggregates were reported in the distal airways, suggesting more small airway deposition.

Gross (1981) exposed rats for 20 h/day, 5.5 days/week for 87 weeks to DE containing 1.5 mg/m^3 DPM. When the data were normalized (e.g., indices expressed in units of airflow or volume for each animal by its own forced expiratory volume), there were no apparent functionally significant changes occurring in the lungs at 38 weeks of exposure that might be attributable to the inhalation of DE. After 87 weeks of exposure, functional residual capacity (FRC) and its component volumes (expiratory reserve [ER] and residual volume [RV]), maximum expiratory flow (MEF) at 40% FVC, MEF at 20% FVC, and $FEV_{0.1}$ were significantly greater in the diesel-exposed rats. An observed increase in airflow at the end of the forced expiratory maneuver when a decreased airflow would be expected from the increased FRC, ER, and RV data (the typical scenario of human pulmonary disease) showed these data to be inconsistent with known clinically significant health effects. Furthermore, although the lung volume changes in the diesel-exposed rats could have been indicative of emphysema or chronic obstructive lung disease, this interpretation was contradicted by the airflow data, which suggest simultaneous lowering of the resistance of the distal airways.

Heinrich et al. (1982) evaluated the pulmonary function of rats exposed to a concentration of 3.9 mg/m^3 DPM for 7 to 8 h/day, 5 days/week for 2 years. When compared with a control group, no significant changes in respiratory rate, minute volume, compliance, or resistance occurred in the exposed group (number of rats per group was not stated).

Chinese hamsters (eight or nine per group) were exposed 8 h/day, 7 days/week, for 6 mo to concentrations of either about 6 mg/m^3 or about 12 mg/m^3 DPM (Vinegar et al., 1980, 1981a,b). Vital capacity, vital capacity/lung weight ratio, residual lung volume by water displacement, and CO_2 diffusing capacity decreased significantly in hamsters exposed to 6 mg/m^3 DPM. Static deflation volume-pressure curves showed depressed deflation volumes for diesel-exposed hamsters when volumes were corrected for body weight and even greater depressed volumes when volumes were corrected for lung weight. However, when volumes were expressed as percentage of vital capacity, the diesel-exposed hamsters had higher lung volumes at 0 and 5 cm H_2O. In the absence of confirmatory histopathology, the authors tentatively concluded that these elevated lung volumes and the significantly reduced diffusing capacity in the same hamsters were indicative of possible emphysematous changes in the lung. Similar lung function changes were reported in hamsters exposed at 12 mg/m^3 DPM, but detailed information was not reported. It was stated, however, that the decrease in vital capacity was 176% greater in the second experiment than in the first.

Mauderly et al. (1988; see also McClellan et al., 1986) examined the impairment of respiratory function in rats exposed for 7 h/day, 5 days/week for 24 mo to diluted DE with 0.35, 3.5, or 7.1 mg/m^3 DPM. After 12 mo of exposure to the highest concentration of DE, the exposed rats (n = 22) had lower total lung capacity (TLC), dynamic lung compliance (C_{dyn}), FVC, and CO diffusing capacity than controls (n = 23). After 24 mo of exposure to 7.1 mg/m^3 DPM, mean TLC, C_{dyn}, quasi-static chord compliance, and CO diffusing capacity were significantly lower than control values. Nitrogen washout and percentage of FVC expired in 0.1 s were significantly greater than control values. There was no evidence of airflow obstruction. The functional alterations were attributed to focal fibrotic and emphysematous lesions and thickened alveolar membranes observed by histological examination. Similar functional alterations and histopathologic lesions were observed in the rats exposed to 3.5 mg/m^3 DPM, but such changes usually occurred later in the exposure period and were generally less pronounced. There were no significant decrements in pulmonary function for the 0.35 mg/m^3 group at any time during the study nor were there reported histopathologic changes in this group.

Mauderly et al. (1989) examined the effects of DE on normal rats and on rats with experimentally induced pulmonary emphysema to see if emphysematous rats have increased susceptibility to DPM. The results from parallel lifetime exposures of these 2 groups of rats at 3.5 mg/m^3 DPM showed that only possibly 1 of 65 measured parameters gave results suggesting that rats with emphysematous lungs might be more susceptible than rats with normal lungs to the effects of DE exposure.

Additional studies were conducted by Heinrich et al. (1986a,b; see also Stöber, 1986) on the effects of long-term exposure to DE on the pulmonary function of hamsters and rats. The exhaust was diluted to achieve a concentration of 4.24 mg/m^3 DPM; exposures were for 19 h/day, 5 days/week for a maximum of 120 weeks (hamsters) or 140 weeks (rats). After 1 year of exposure to the DE, the hamsters exhibited a significant increase in airway resistance and a nonsignificant reduction in lung compliance. For the same time period, rats showed increased lung weights, a significant decrease in C_{dyn}, and a significant increase in airway resistance. These indices did not change during the second year of exposure.

Syrian hamsters and rats were exposed to 0.7, 2.2, or 6.6 mg/m^3 DPM for five 16-h periods per week for 2 years (Brightwell et al., 1986). There were no treatment-related changes in pulmonary function in the hamster. Rats exposed to the highest concentration of DE exhibited changes in pulmonary function (data not presented) that were reported to be consistent with a concentration-related obstructive and restrictive disease.

Pepelko et al. (1980b; 1981; see also Pepelko, 1982b) and Moorman et al. (1985) measured the lung function of adult cats chronically exposed to DE. The cats were exposed for 8 h/day and 7 days/week for 124 weeks. Exposures were at 6 mg/m^3 for the first 61 weeks and 12 mg/m^3 from weeks 62 to 124. No definitive pattern of pulmonary function changes was observed following 61 weeks of exposure; however, a classic pattern of restrictive lung disease was found at 124 weeks. The significantly reduced lung volumes (TLC, FVC, FRC, and inspiratory capacity [IC]) and the significantly lower single-breath diffusing capacity, coupled with normal values for dynamic ventilatory function (mechanics of breathing), indicate the presence of a lesion that restricts inspiration but does not cause airway obstruction or loss of elasticity. This pulmonary physiological syndrome is consistent with an interstitial fibrotic response that was later verified by histopathology (Plopper et al., 1983).

Pulmonary function impairment has been reported in rats, hamsters, cats, and monkeys chronically exposed to DE. In all species but the monkey, the pulmonary function testing results have been consistent with restrictive lung disease. The monkeys demonstrated evidence of small airway obstructive responses. The disparity between the findings in monkeys and those in rats, hamsters, and cats could be in part the result of increased particle retention in the smaller species resulting from (1) exposure to DE that has higher airborne concentrations of gases, vapors, and particles and/or (2) longer duration of exposure. The nature of the pulmonary impairment is also dependent on the site of deposition and routes of clearance, which are determined by the anatomy and physiology of the test laboratory species and the exposure regimen. The data on pulmonary function effects raise the possibility that DE produces small airway disease in primates compared with primarily alveolar effects in small animals and that similar changes might be expected in humans and monkeys. The findings of Nikula et al. (1997a,b) suggest that a larger fraction of particles are translocated to the interstitium of the respiratory tract in primates that are heavily exposed than in rats that are heavily exposed, including the interstitium of the respiratory bronchioles, an anatomical site absent in rats. Nikula and co-workers' pulmonary histopathological findings may have a relationship to these functional findings (see Chapter 3 for a complete discussion). Unfortunately, the available data in primates are too limited to draw clear conclusions.

5.1.3.3.3. ***Lung morphology, biochemistry, and lung lavage analysis***. Several studies have examined the morphological, histological, and histochemical changes occurring in the lungs of laboratory animals chronically exposed to DE. The histopathological effects of diesel exposure in the lungs of laboratory animals are summarized in Table 5-6, ranked in order of C × T. Table 5-6 also contains an expanded description of exposures.

Kaplan et al. (1982) performed macroscopic and microscopic examinations of the lungs of rats, mice, and hamsters exposed for 20 h/day, 7 days/week for 3 mo to DE containing 1.5 mg/m^3 DPM. Gross examination revealed diffuse and focal deposition of the diesel particles that produced a grayish overall appearance of the lungs with scattered, denser black areas. There was clearance of particles via the lymphatics to regional lymph nodes. Microscopic examination revealed no anatomic changes in the upper respiratory tract; the mucociliary border was normal in appearance. Most of the particles were in macrophages, but some were free as small aggregates on alveolar and bronchiolar surfaces. The particle-laden macrophages were often in masses near the entrances of the lymphatic drainage and respiratory ducts. Associated with these masses was a minimal increase in the thickness of the alveolar walls; however, the vast majority of the particles elicited no response. After 6 mo of recovery, the lungs of all three species contained considerably less pigment, as assessed by gross pathological and histopathological examinations.

Lewis et al. (1989; see also Green et al., 1983) performed serial histological examinations of rat lung tissue exposed to DE containing 2 mg/m^3 DPM for 7 h/day, 7 days/week for 2 years. Accumulations of black-pigmented AMs were seen in the alveolar ducts adjacent to terminal bronchioles as early as 3 mo of exposure, and particles were seen within the interstitium of the alveolar ducts. These macular lesions increased in size up to 12 mo of exposure. Collagen or reticulum fibers were seen only rarely in association with deposited particles; the vast majority of lesions showed no evidence of fibrosis. There was no evidence of focal emphysema with the macules. Multifocal histiocytosis (24% of exposed rats) was observed only after 24 mo of exposure. These lesions were most commonly observed subpleurally and were composed of collections of degenerating macrophages and amorphous granular material within alveoli, together with fibrosis and chronic inflammatory cells in the interstitium.

Table 5-6. Histopathological effects of diesel exhaust in the lungs of laboratory animals

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg \cdot h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, F344, M; Mouse, A/J, M; Hamster, Syrian, M	20 h/day 7 days/week 12-13 weeks	1.5 0.19 µm MDD	2,520-2,730	—	—	—	Inflammatory changes, increase in lung weight, increase in thickness of alveolar walls	Kaplan et al. (1982)
Monkey, Cynomolgus, M	7 h/day 5 days/week 104 weeks	2.0 0.23–0.36 µm MDD	7,280	11.5	1.5	0.8	AM aggregation; no fibrosis, inflammation, or emphysema	Lewis et al. (1989)
Rat, F344, M, F	7 h/day 5 days/week 104 weeks	2.0 0.23–0.36 µm MDD	3,640	11.5	1.5	0.8	Multifocal histiocytosis, inflammatory changes, Type II cell proliferation, fibrosis	Bhatnagar et al. (1980) Pepelko (1982a)
Rat, Sprague-Dawley, M; Mouse, A/HEJ, M	8 h/day 7 days/week 39 weeks	6.0	13,104	—	—	—	Increase in lung protein content and collagen synthesis but a decrease in overall lung protein synthesis in both species; prolylhydroxylase activity increased in rats in utero	Bhatnagar et al. (1980) Pepelko (1982a)
Hamster, Chinese, M	8 h/day 5 days/week 26 weeks	6.0 12.0	6,240 12,480	— —	— —	— —	Inflammatory changes, AM accumulation, thickened alveolar lining, Type II cell hyperplasia,edema, increase in collagen	Pepelko (1982b)
Hamster, Syrian, M, F	7-8 h/day 5 days/week 120 weeks	3.9 0.1 µm MDD	16,380-18,720	18.5	1.2	3.1	Inflammatory changes, 60% adenomatous cell proliferation	Heinrich et al. (1982)
Rat, Wistar, M	6 h/day 5 days/week 87 weeks	8.3 0.71 µm MDD	21,663	50.0	4.0-6.0	—	Inflammatory changes, AM aggregation, alveolar cell hypertrophy, interstitial fibrosis, emphysema (diagnostic methodology not described)	Karagianes et al. (1981)
Rat, F344, F	8 h/day 7 days/week 104 weeks	4.9	28,538	7.0	1.8	13.1	Type II cell proliferation, inflammatory changes, bronchial hyperplasia, fibrosis	Iwai et al. (1986)
Rat, F344, M, F; Mouse, CD-1, M, F	7 h/day 5 days/week 130 weeks	0.35 3.5 7.1 0.23 µm MDD	1,592 15,925 31,850	2.9 16.5 29.7	0.05 0.34 0.68	— — —	Alveolar and bronchiolar epithelial metaplasia in rats at 3.5 and 7.0 mg/m^3, fibrosis at 7.0 mg/m^3 in rats and mice, inflammatory changes	Mauderly et al. (1987a) Henderson et al. (1988a)

Table 5-6. Histopathological effects of diesel exhaust in the lungs of laboratory animals (continued)

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg \cdot h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rats, SPF 344	7 h/day 5days/week 104 weeks	2 mg/m^3 coal dust (CD) 2 mg/m^3 DPM 1 mg/m^3 CD + 1 mg/m^3 DPM	—	—	—	—	• Assessed pharmacological responses of rat airway smooth muscle in vitro • Maximal contractile responses to acetylcholine of tissues from CD-, DPM-, and CD + DPM- exposed animals significantly increased; effects of CD and DPM were additive • Maximal relaxation response to isoproterenol increased significantly by CD + DPM exposure, but not by individual treatments • The results indicate that chronic exposure to CD, DPM, and CD + DPM produce differential modifications in the behavior of rat airway smooth muscle	Feden et al. (1985)
Rat, Wistar, F; Mouse, NMRI, F (7 mg/m^3 only)	18 h/day 5 days/week 24 mo	0.8 2.5 6.98	7,400 21,800 61,700	2.6 8.3 21.2	0.3 1.2 3.8	0.3 1.1 3.4	Bronchioalveolar hyperplasia, interstitial fibrosis in all groups. Severity and incidence increase with exposure concentration	Heinrich et al. (1995)
Mouse, NMRI, F; C57BL/6N, F	18 h/day 5 days/week 13.5 mo (NMRI) 24 mo (C57BL/N)	6.98	35,500 - NMRI 38,300 - C57	14.2	2.3	2.8	No increase in tumors. Noncancer effects not discussed	
Mouse		4.5					No increase in tumors Noncancer effects not discussed	
Rat, M, F, F344/Jcl.	16 h/day 6 days/week 130 weeks	0.11[a] 0.41[a] 1.08[a] 2.31[a] 3.72[b]	1,373 5,117 13,478 28,829 46,336	1.23 2.12 3.96 7.10 12.9	0.08 0.26 0.70 1.41 3.00	0.38 1.06 2.42 4.70 4.57	Inflammatory changes Type II cell hyperplasia and lung tumors seen at >0.4 mg/m^3; shortening and loss of cilia in trachea and bronchi	Research Committee for HERP Studies (1988)
Mouse, NMRI, F	19 h/day 5 days/week 120 weeks	4.24	48,336	12.5	1.5	1.1	Inflammatory changes, bronchiolo-alveolar hyperplasia, alveolar lipo-proteinosis, fibrosis	Heinrich et al. (1986a)

Table 5-6. Histopathological effects of diesel exhaust in the lungs of laboratory animals (continued)

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg \cdot h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, Wistar, F	19 h/day 5 days/week 140 weeks	4.24	56,392	12.5	1.5	1.1	Thickened alveolar septa; AM aggregation; inflammatory changes; hyperplasia; lung tumors	Heinrich et al. (1986a)
Guinea Pig, Hartley, M	20 h/day 5.5 days/week 104 weeks	0.25 0.75 1.5 6.0	2,860 8,580 17,160 68,640	— — — —	— — — —	— — — —	Minimal response at 0.25 and ultrastructural changes at 0.75 mg/m^3; thickened alveolar membranes; cell proliferation; fibrosis at 6.0 mg/m^3; increase in PMN at 0.75 mg/m^3 and 1.5 mg/m^3	Barnhart et al. (1981, 1982) Vostal et al. (1981) Wallace et al. (1987)
Cat, inbred, M	8 h/day 7 days/week 124 weeks	6.0[c] 12.0[d]	41,664 83,328	20.2 33.2	2.7 4.4	2.1 5.0	Inflammatory changes, AM aggregation, bronchiolar epithelial metaplasia, Type II cell hyperplasia, peribronchiolar fibrosis	Plopper et al. (1983) Hyde et al. (1985)
Rat, F344, M	16 h/day 5 days/week 23 mo	2.44 6.33	19,520 50,640	— —	— —	— —	AM hyperplasia, epithelial hyperplasia, inflammation, septal fibrosis, bronchoalveolar metaplasia	Nikula et al. (1995)
Mouse, CD-1, M,F	7 h/day 5 days/week 104 weeks	0.35 3.5 7.1 0.25 μm MDD	1,274 12,740 25,844	3 17 30	0.1 0.3 0.7	— — —	Exposure-related increase in lung soot, pigment-laden macrophages, lung lesions. Bronchiolization in alveolar ducts at 7.1 mg/m^3	Mauderly et al. (1996)

[a]Light-duty engine.
[b]Heavy-duty engine.
[c]1 to 61 weeks exposure.
[d]62 to 124 weeks of exposure.

AM = Alveolar macrophage.
PMN = Polymorphonuclear leukocyte.

Epithelial lining cells adjacent to collections of pigmented macrophages showed a marked Type II cell hyperplasia; degenerative changes were not observed in Type I cells. Histological examination of lung tissue from monkeys exposed for 24 mo in the same regimen as used for rats revealed aggregates of black particles, principally in the distal airways of the lung. Particles were present within the cytoplasm of macrophages in the alveolar spaces as well as the interstitium. Fibrosis, focal emphysema, or inflammation was not observed. No specific histopathological lesions were reported for the monkey.

Nikula et al. (1997a,b) reevaluated the lung tissue from this study. They concluded that there were no significant differences in the amount of retained particulate matter between monkeys and rats exposed under the same conditions. The rats, however, retained a greater portion of the particulate matter in lumens of the alveolar ducts and alveoli than did the monkeys. Conversely, monkeys retained a greater portion of the particulate material in the interstitium than did rats. Aggregations of particle-laden macrophages in the alveoli were rare, and there were few signs of particle-associated inflammation in the monkeys. Minimal histopathologic lesions were detected in the interstitium.

Histopathological effects of DE on the lungs of rats have been investigated by the Health Effects Research Program on Diesel Exhaust (HERP) in Japan (Ishinishi et al., 1986, 1988). Both light-duty (LD) and heavy-duty (HD) diesel engines were used. The exhaust was diluted to achieve nominal concentrations of 0.1 (LD only), 0.4 (LD and HD), 1 (LD and HD), 2 (LD and HD), and 4 (HD only) mg/m^3 DPM. Rats were exposed for 16 h/day, 6 days/week for 30 mo. No histopathological changes were observed in the lungs of rats exposed to 0.4 mg/m^3 DPM or less. At concentrations above 0.4 mg/m^3 DPM, severe morphological changes were observed. These changes consisted of shortened and absent cilia in the tracheal and bronchial epithelium, marked hyperplasia of the bronchiolar epithelium, and swelling of the Type II cellular epithelium. These lesions appeared to increase in severity with increases in exhaust concentration and duration of exposure. There was no difference in the degree of changes in pulmonary pathology at the same concentrations between the LD and the HD series.

Heinrich et al. (1982) investigated histological changes occurring in the respiratory tract of hamsters exposed to DE. Exposures were for 7 to 8 h/day, 5 days/week for 104 weeks to DE diluted to achieve a concentration of 3.9 mg/m^3 DPM. Significantly higher numbers of hamsters in the group exposed to DE exhibited definite proliferative changes in the lungs compared with the groups exposed to particle-free DE or clean air. Sixty percent of these changes were described as adenomatous proliferations.

Heinrich et al. (1995) reported increased incidence and severity of bronchioloalveolar hyperplasia in rats exposed to 0.8, 2.5, and 7 mg/m^3. The lesion in the lowest concentration group was described as very slight to moderate. Slight to moderate interstitial fibrosis also increased in incidence and severity in all exposed groups, but incidences were not reported. This chronic study also exposed NMRI mice to 7 mg/m^3 for 13.5 mo and both NMRI and C56BL/6N mice to 4.5 mg/m^3 for 24 mo. Noncancer histological endpoints are not discussed in any detail in the report, which is focused on the carcinogenicity of diesel as compared with titanium dioxide and carbon black.

Iwai et al. (1986) performed serial histopathology on the lungs of rats at 1, 3, 6, 12, and 24 mo of exposure to DE. Exposures were for 8 h/day, 7 days/week for 24 mo; the exposure atmosphere contained 4.9 mg/m^3 DPM. At 1 and 3 mo of exposure, there were minimal histological changes in the lungs of the exposed rats. After 6 mo of exposure, there were particle-laden macrophages distributed irregularly throughout the lung and a proliferation of Type II cells with adenomatous metaplasia in areas where the macrophages had accumulated. After 1 year of exposure, foci of heterotrophic hyperplasia of ciliated or nonciliated bronchiolar epithelium on the adjacent alveolar walls were more common, the quantity of deposited particulate matter increased, and the number of degenerative AMs and proliferative lesions of Type II or bronchiolar epithelial cells increased. After 2 years of exposure, there was a fibrous thickening of the alveolar walls, mast-cell infiltration with epithelial hyperplasia in areas where the macrophages had accumulated, and neoplasms.

Heinrich et al. (1986a; see also Stöber, 1986) performed histopathologic examinations of the respiratory tract of hamsters, mice, and rats exposed to DE that had 4 mg/m^3 DPM. Exposures were for 19 h/day, 5 days/week; the maximum exposure period was 120 weeks for hamsters and mice and 140 weeks for rats. Histological examination revealed different levels of response among the three species. In hamsters, the exhaust produced thickened alveolar septa, bronchioloalveolar hyperplasia, and what were termed emphysematous lesions (diagnostic methodology not described). In mice, bronchoalveolar hyperplasia occurred in 64% of the mice exposed to the exhaust and in 5% of the controls. Multifocal alveolar lipoproteinosis occurred in 71% and multifocal interstitial fibrosis occurred in 43% of the mice exposed to exhaust but in only 4% of the controls. In exposed rats, there were severe inflammatory changes in the lungs, as well as thickened septa, foci of macrophages, and hyperplastic and metaplastic lesions.

Nikula et al. (1995) reported in detail the nonneoplastic effects in male and female F344 rats exposed to 2.4 or 6.3 mg/m^3 of DPM. At 3 mo in the low-concentration group, enlarged particle-containing macrophages were found with minimal aggregation. With higher concentration and longer duration of exposure, the number and size of macrophages and aggregates increased. Alveolar epithelial hyperplasia was found starting at 3 mo and in all rats at 6 mo. These lesions progressed to chronic active inflammation, alveolar proteinosis, and septal fibrosis at 12 mo. Other lesions observed late in the study included bronchiolar-alveolar metaplasia, squamous metaplasia, and squamous cysts. This study reports in detail the progression of lesions in DE exposure and finds relatively little difference between the lesions caused by DE exposure and exposure to similar levels of carbon black particles.

The effects of DE on the lungs of rats exposed to 8.3 ± 2.0 mg/m^3 DPM were investigated by Karagianes et al. (1981). Exposures were for 6 h/day, 5 days/week, for 4, 8, 16, or 20 mo. Histological examinations of lung tissue noted focal aggregation of particle-laden AMs, alveolar histiocytosis, interstitial fibrosis, and alveolar emphysema (diagnostic methodology not described). Lesion severity was related to length of exposure. No significant differences were noted in lesion severity among the DE, the DE plus coal dust (5.8 ± 3.5 mg/m^3), or the high-concentration (14.9 ± 6.2 mg/m^3) coal dust exposure groups following 20 mo of exposure.

Histological changes in the lungs of guinea pigs exposed to diluted DE containing either 0.25, 0.75, 1.5, or 6.0 mg/m^3 DPM were reported by Barnhart et al. (1981; 1982). Exposures at 0.75 and 1.5 mg/m^3 for 2 weeks to 6 mo resulted in an uptake of exhaust particles by three alveolar cell types (AMs, Type I cells, and interstitial macrophages) and also by granulocytic leukocytes (eosinophils). The alveolar-capillary membrane increased in thickness as a result of an increase in the absolute tissue volume of interstitium and Type II cells. In a continuation of these studies, guinea pigs were exposed to DE (up to 6.0 mg/m^3 DPM) for 2 years (Barnhart et al., 1982). A minimal tissue response occurred at a concentration of 0.25 mg/m^3. After 9 mo of exposure, there was a significant increase, about 30%, in Type I and II cells, endothelial cells, and interstitial cells over concurrent age-matched controls; by 24 mo only macrophages and Type II cells were significantly increased. As in the earlier study, ultrastructural evaluation showed that Type I cells, AMs, and eosinophils phagocytized the diesel particles. Exposure to 0.75 mg/m^3 for 6 mo resulted in fibrosis in regions of macrophage clusters and in focal Type II cell proliferation. No additional information was provided regarding the fibrotic changes with increasing concentration or duration of exposure. With increasing concentration/duration of DE exposure, Type II cell clusters occurred in some alveoli. Intraalveolar debris was particularly prominent after exposures at 1.5 and 6.0 mg/m^3 and consisted of secretory products from Type II cells.

In studies conducted on hamsters, Pepelko (1982b) found that the lungs of hamsters exposed for 8 h/day, 7 days/week for 6 mo to 6 or 12 mg/m^3 DPM were characterized by large numbers of black AMs in the alveolar spaces, thickening of the alveolar epithelium, hyperplasia of Type II cells, and edema.

Lungs from rats and mice exposed to 0.35, 3.5, or 7.1 mg/m^3 (0.23 to 0.26 μm mass median diameter [MMD]) for 7 h/day and 5 days/week showed pathologic lesions (Mauderly et al., 1987a; Henderson et al., 1988a). After 1 year of exposure at 7.1 mg/m^3, the lungs of the rats exhibited focal areas of fibrosis; fibrosis increased with increasing duration of exposure and was observable in the 3.5-mg/m^3 group of rats at 18 mo. The severity of inflammatory responses and fibrosis was directly related to the exposure level. In the 0.35 mg/m^3 group of rats, there was no inflammation or fibrosis. Although the mouse lungs contained higher burdens of diesel particles per gram of lung weight at each equivalent exposure concentration, there was substantially less inflammatory reaction and fibrosis than was the case in rats. Fibrosis was observed only in the lungs of mice exposed at 7.1 mg/m^3 and consisted of fine fibrillar thickening of occasional alveolar septa.

Histological examinations were performed on the lungs of cats initially exposed to 6 mg/m^3 DPM for 61 weeks and subsequently increased to 12 mg/m^3 for Weeks 62 to 124 of exposure. Plopper et al. (1983; see also Hyde et al., 1985) concluded from the results of this study that exposure to DE produced changes in both epithelial and interstitial tissue compartments and that the focus of these lesions in the peripheral lung was the centriacinar region where the alveolar ducts join the terminal conducting airways. This conclusion was based on the following evidence. The epithelium of the terminal and respiratory bronchioles in exposed cats consisted of three cell types (ciliated, basal, and Clara cells) compared with only one type (Clara cells) in the controls. The proximal acinar region showed evidence of peribronchial fibrosis and bronchiolar epithelial metaplasia. Type II cell hyperplasia was present in the proximal interalveolar septa. The more distal alveolar ducts and the majority of the rest of the parenchyma were unchanged from controls. Peribronchial fibrosis was greater at the end of 6 mo in clean air following exposure, whereas the bronchiolar epithelial metaplasia was most severe at the end of exposure. Following an additional 6 mo in clean air, the bronchiolar epithelium more closely resembled the control epithelial cell population.

Wallace et al. (1987) used transmission electron microscopy (TEM) to determine the effect of DE on the intravascular and interstitial cellular populations of the lungs of exposed rats and guinea pigs. Exposed animals and matched controls were exposed to 0.25, 0.75, 1.5, or 6.0 mg/m^3 DPM for 2, 6, or 10 weeks or 18 mo. The results inferred the following: (1) exposure to 6.0 mg/m^3 for 2 weeks was insufficient to elicit any cellular response, (2) both species demonstrated an adaptive multicellular response to DE, (3) increased numbers of fibroblasts were found in the interstitium from week 6 of exposure through month 18, and (4) there was no significant difference in either cell type or number in alveolar capillaries, but there was a significant increase at 18 mo in the mononuclear population in the interstitium of both species.

Additional means for assessing the adverse effects of DE on the lung are to examine biochemical and cytological changes in bronchoalveolar lavage fluid (BALF) and in lung tissue. Fedan et al. (1985) performed studies to determine whether chronic exposure of rats affected the pharmacologic characteristics of rat airway smooth muscle. Concentration-response relationships for tension changes induced with acetylcholine, 5-hydroxytryptamine, potassium chloride, and isoproterenol were assessed in vitro on isolated preparations of airway smooth muscle (trachealis). Chronic exposure to DE significantly increased the maximal contractile responses to acetylcholine compared with control values; exposure did not alter the sensitivity

(EC_{50} values) of the muscles to the agonists. Exposures were to DE containing 2 mg/m^3 DPM for 7 h/day, 5 days/week for 2 years.

Biochemical studies of BALF obtained from hamsters and rats revealed that exposures to DE caused significant increases in lactic dehydrogenase, alkaline phosphatase, glucose-6-phosphate dehydrogenase (G6P-DH), total protein, collagen, and protease (pH 5.1) after approximately 1 year and 2 years of exposure (Heinrich et al., 1986a). These responses were generally much greater in rats than in hamsters. Exposures were to DE containing 4.24 mg/m^3 DPM for 19 h/day, 5 days/week for 120 (hamsters) to 140 (rats) weeks.

Protein, β-glucuronidase activity, and acid phosphatase activity were significantly elevated in BALF obtained from rats exposed to DE containing 0.75 or 1.5 mg/m^3 DPM for 12 mo (Strom, 1984). Exposure for 6 mo resulted in significant increases in acid phosphatase activity at 0.75 mg/m^3 and in protein, β-glucuronidase, and acid phosphatase activity at the 1.5 mg/m^3 concentration. Exposure at 0.25 mg/m^3 DPM did not affect the three indices measured at either time period. The exposures were for 20 h/day, 5.5 days/week for 52 weeks.

Additional biochemical studies (Misiorowski et al., 1980) were conducted on laboratory animals exposed under the same conditions and at the same site as reported on by Strom (1984). In most cases, exposures at 0.25 mg/m^3 did not cause any significant changes. The DNA content in lung tissue and the rate of collagen synthesis were significantly increased at 1.5 mg/m^3 DPM after 6 mo. Collagen deposition was not affected. Total lung collagen content increased in proportion to the increase in lung weight. The activity of prolyl hydroxylase was significantly increased at 12 weeks at 0.25 and 1.5 mg/m^3; it then decreased with age. Lysal oxidase activity did not change. After 9 mo of exposure, there were significant increases in lung phospholipids in rats and guinea pigs exposed to 0.75 mg/m^3 and in lung cholesterol in rats and guinea pigs exposed to 1.5 mg/m^3. Pulmonary prostaglandin dehydrogenase activity was stimulated by an exposure at 0.25 mg/m^3 but was not affected by exposure at 1.5 mg/m^3 (Chaudhari et al., 1980, 1981). Exposures for 12 or 24 weeks resulted in a concentration-dependent lowering of this enzyme activity. Exposure of male rats and guinea pigs at 0.75 mg/m^3 for 12 weeks did not cause any changes in glutathione levels of the lung, heart, or liver. Rats exposed for 2 mo at 6 mg/m^3 showed a significant depletion of hepatic glutathione, whereas the lung showed an increase of glutathione (Chaudhari and Dutta, 1982). Schneider and Felt (1981) reported that similar exposures did not substantially change adenylate cyclase and guanylate cyclase activities in lung or liver tissue of exposed rats and guinea pigs.

Bhatnagar et al. (1980; see also Pepelko, 1982a) evaluated changes in the biochemistry of lung connective tissue of diesel-exposed rats and mice. The mice were exposed for 8 h/day and 7 days/week for up to 9 mo to exhaust containing 6 mg/m^3 DPM. Total lung protein content was measured, as was labeled proline and labeled leucine. Leucine incorporation is an index of total protein synthesis, although collagen is very low in leucine. Proline incorporation reflects collagen synthesis. Amino acid incorporation was measured in vivo in the rat and in short-term organ culture in mice. Both rats and mice showed a large increase in total protein (41% to 47% in rats), while leucine incorporation declined and proline incorporation was unchanged. These data are consistent with an overall depression of protein synthesis in diesel-exposed animals and also with a relative increase in collagen synthesis compared to other proteins. The increase in collagen synthesis suggested proliferation of connective tissue and possible fibrosis (Pepelko, 1982a).

A number of reports (McClellan et al., 1986; Mauderly et al., 1987a, 1990a; Henderson et al., 1988a) have addressed biochemical and cytological changes in lung tissue and BALF of rodents exposed for 7 h/day, 5 days/week for up to 30 mo at concentrations of 0, 0.35, 3.5, or 7.1 mg/m^3 DPM. At the lowest exposure level (0.35 mg/m^3), no biochemical or cytological changes occurred in the BALF or in lung tissue in either Fischer 344 rats or CD-1 mice. Henderson et al. (1988a) provide considerable time-course information on inflammatory events taking place throughout a chronic exposure. A chronic inflammatory response was seen at the two higher exposure levels in both species, as evidenced by increases in inflammatory cells (macrophages and neutrophils), cytoplasmic and lysosomal enzymes (lactate dehydrogenase, glutathione reductase, and β-glucuronidase), and protein (hydroxyproline) in BALF. Analysis of lung tissue indicated similar changes in enzyme levels as well as an increase in total lung collagen content. After 18 mo of exposure, lung tissue glutathione was depleted in a concentration-dependent fashion in rats but was slightly increased in mice. Lavage fluid levels of glutathione and glutathione reductase activity increased in a concentration-dependent manner and were higher in mice than in rats.

Rats exposed for up to 17 days to diluted DE (3.5 mg/m^3 DPM) had a fivefold increase in the bronchoconstrictive prostaglandin $PGF_{2"}$ and a twofold increase in the inflammatory leukotriene LTB_4. In similarly exposed mice, there was a twofold increase in both parameters. These investigators (Henderson et al., 1988a,b) concluded that the release of larger amounts of such mediators of inflammation from the alveolar phagocytic cells of rats accounted for the greater fibrogenic response seen in that species.

Biochemical analysis of lung tissue from cats exposed for 124 weeks and held in clean air for an additional 26 weeks indicated increases of lung collagen; this finding was confirmed by an observed increase in total lung wet weight and in connective tissue fibers estimated morphometrically (Hyde et al., 1985). Exposures were for 7 h/day, 5 days/week at 6 mg/m^3 DPM for 61 weeks and at 12 mg/m^3 for weeks 62 to 124.

Heinrich et al. (1995) reported on bronchoalveolar lavage in animals exposed for 24 mo and found exposure-related increases in lactate dehydrogenase, β-glucuronidase, protein, and hydroxyproline in groups exposed to 2.5 or 7 mg/m^3, although detailed data are not presented. Lavage analyses were not carried out in concurrent studies in mice.

The pathogenic sequence following the inhalation of DE as determined histopathologically and biochemically begins with the interaction of diesel particles with airway epithelial cells and phagocytosis by AMs. The airway epithelial cells and activated macrophages release chemotactic factors that attract neutrophils and additional AMs. As the lung burden of DPM increases, there is an aggregation of particle-laden AMs in alveoli adjacent to terminal bronchioles, increases in the number of Type II cells lining particle-laden alveoli, and the presence of particles within alveolar and peribronchial interstitial tissues and associated lymph nodes. The neutrophils and macrophages release mediators of inflammation and oxygen radicals that deplete a biochemical defense mechanism of the lung (i.e., glutathione). As will be described later in more detail, other defense mechanisms are affected, particularly the decreased viability of AMs, which leads to decreased phagocytic activity and death of the macrophage. The latter series of events may result in the presence of pulmonary inflammatory, fibrotic, or emphysematous lesions. The data suggest that there may be a threshold of exposure to DE below which adverse structural and biochemical effects may not occur in the lung; however, differences in the anatomy and pathological responses of laboratory animals coupled with their lifespans compared with humans make a determination of human levels of exposure to DE without resultant pulmonary injury a difficult and challenging endeavor.

5.1.3.3.4. ***Effects on pulmonary defense mechanisms.*** The respiratory system has a number of defense mechanisms that negate or compensate for the effects produced by the injurious substances that repeatedly insult the upper respiratory tract, the tracheobronchial airways, and the alveoli. The effects of exposure to DE on the pulmonary defense mechanisms of laboratory animals as well as more details on exposure atmosphere are summarized in Table 5-7 and ranked by cumulative exposure (C × T).

Several studies have been conducted investigating the effect of inhaled DE on the deposition and fate of inert tracer particles or diesel particles themselves. Lung clearance of deposited particles occurs in two distinct phases: a rapid phase (hours to days) from the tracheobronchial region via the mucociliary escalator and a much slower phase (weeks to months) from the nonciliated pulmonary region via, primarily but not solely, AMs. Battigelli et al. (1966) reported impaired tracheal mucociliary clearance in vitro in excised trachea from rats exposed for single or repeated exposures of 4 to 6 h at two dilutions of DE that resulted in exposures of approximately 8 and 17 mg/m^3 DPM. The exposure to 17 mg/m^3 resulted in

Table 5-7. Effects of exposure to diesel exhaust on the pulmonary defense mechanisms of laboratory animals

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg·h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
				Alveolar macrophage status				
Guinea Pig, Hartley	20 h/day 5.5 days/week 8 weeks	0.25 1.5 0.19 µm MDD	220 1,320	2.9 7.5	— —	— —	No significant changes in absolute numbers of AMs	Chen et. al. (1980)
Rat, F344, M	7 h/day 5 days/week 104 weeks	2.0 0.23–0.36 µm MDD	7,280	11.5	1.5	0.81	Little effect on viability, cell number, oxygen consumption, membrane integrity, lyzomal enzyme activity, or protein content of AMs; decreased cell volume and ruffling of cell membrane and depressed luminescence of AM	Castranova et al. (1985)
Rat, F344, M	20 h/day 5.5 days/week 26, 48, or 52 weeks	0.25[a] 0.75[a] 1.5[b] 0.19 µm MDD	715-8,580	2.9 4.8 7.5	— — —	— — —	AM cell counts proportional to concentration of DPM at 0.75 and 1.5 mg/m^3; AM increased in lungs in response to rate of DPM mass entering lung rather than total DPM burden in lung; increased PMNs were proportional to inhaled concentrations and/or duration of exposure; PMNs affiliated with clusters of aggregated AM rather than DPM	Strom (1984) Vostal et al. (1982)
Rat F344/Crl, M, F Mouse, CD, M, F	7 h/day 5 days/week 104 weeks (rat), 78 weeks (mouse)	0.35 3.5 7.0 0.25 µm MDD	1,274[c] 12,740[c] 25,480[c]	2.9 16.5 29.7	0.05 0.34 0.68	— — —	Significant increases of AM in rats and mice exposed to 7.0 mg/m^3 DPM for 24 and 18 mo, respectively, but not at concentrations of 3.5 or 0.35 mg/m^3 DPM for the same exposure durations; PMNs increased in a dose-dependent fashion in both rats and mice exposed to 3.5 or 7.0 mg/m^3 DPM and were greater in mice than in rats	Henderson et al. (1988a)
Rat, Wistar, F	18 h/day 5 days/week 24 mo	0.8 2.5 7.1	7,400 21,800 61,700	2.6 8.3 21.2	0.3 1.1 3.4	— — —	Changes in differential cell counts in lung lavage	Heinrich et al. (1995)
Rat, F344/Crl, M	7 h/day 5 days/week 24 mo	3.49	12,704	9.8	1.2	—	Significantly reduced AM in lavage at 24 mo	Mauderly et al. (1990a)

Table 5-7. Effects of exposure to diesel exhaust on the pulmonary defense mechanisms of laboratory animals (continued)

Species/sex	Exposure period	Particles (mg/m³)	C × T (mg·h/m³)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
					Clearance			
Rat, M, F	7 h/day 5 days/week 12 weeks	0.2 1.0 4.5 0.25µm MDD	84 420 1,890	— — —	— — —	— — —	Evidence of apparent speeding of tracheal clearance at the 4.5 mg/m³ level after 1 week of ^{99m}Tc macroaggregated-albumin and reduced clearance of tracer aerosol in each of the three exposure levels at 12 weeks; indication of a lower percentage of ciliated cells at the 1.0 and 4.5 mg/m³ levels	Wolff and Gray (1980)
Rat, Wistar, F	18 h/day 5 days/week 24 mo	0.8 2.5 7.1	7,400 21,800 61,700	2.6 8.3 21.2	0.3 1.2 3.8	0.3 1.1 3.4	Significant increase in clearance half-time of inhaled labeled aerosols in all groups at 3-18 mo	Heinrich et al. (1995)
Rat, F344, M, developing 0-6 mo adult 6-12 mo	7 h/day 5 days/week 6 mo	3.55	3,321	7.9	9.5		Clearance of 2 µm, aluminosilicate particles. Half-time significantly increased in adult, not different in developing rats	Mauderly et al. (1987b)
Rat, F344, M, F	7 h/day 5 days/week 18 weeks	0.15 0.94 4.1 <0.5 µm MDD	94.5 592 2,583	— — —	— — —	— — —	Lung burdens of DPM were concentration-related; clearance half-time of DPM almost double in 4.1 mg/m³ group compared to 0.15 mg/m³ group	Griffis et al. (1983)
Rat, F344, M	7 h/day 5 days/week 26-104 weeks	2.0 0.23-0.36 µm MDD	1,820-7,280	11.5	1.5	0.8	No difference in clearance of $^{59}Fe_3O_4$ particles 1 day after tracer aerosol administration; 120 days after exposure tracer aerosol clearance was enhanced; lung burden of DPM increased significantly between 12 and 24 mo of exposure	Lewis et al. (1989)
Rat, Sprague-Dawley, M	4-6 h/day 7 days/week 0.1 to 14.3 weeks	0.9 8.0 17.0	2.5-10,210	— — —	5.0 2.7 8.0	0.2 0.6 1.0	Impairment of tracheal mucociliary clearance in a concentration-response manner	Battigelli et al. (1966)

Table 5-7. Effects of exposure to diesel exhaust on the pulmonary defense mechanisms of laboratory animals (continued)

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg \cdot h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, F344, M, F	7 h/day 5 days/week 130 weeks	0.35 3.5 7.1 0.25 µm MDD	1,593 15,925 31,850	2.9 16.5 29.7	0.1 0.3 0.7	— — —	No changes in tracheal mucociliary clearance after 6, 12, 18, 24, or 30 mo of exposure; increases in lung clearance half-times as early as 6 mo at 7.0 mg/m^3 level and 18 mo at 3.5 mg/m^3 level; no changes seen at 0.35 mg/m^3 level; after 24 mo of diesel exposure, long-term clearance half-times were increased in the 3.5 and 7.0 mg/m^3 groups	Wolff et al. (1987)
Rat, F344/Crl, M	7 h/day 5 days/week 24 mo	3.49	12,704	9.8	1.2	—	Doubling of long-term clearance half-time for clearance of 1.0 µm aluminosilicate particles. Less effect on clearance in animals with experimentally induced emphysema	Mauderly et al. (1990a)
Microbial-induced mortality								
Mice CD-1, F	7 h/day 5 days/week 4, 12, or 26 weeks	2.0 0.23–0.36 µm MDD	280-1,820	11.5	1.5	0.8	Mortality similar at each exposure duration when challenged with Ao/PR/8/34 influenza virus; in mice exposed for 3 and 6 mo, but not 1 mo, there were increases in the percentages of mice having lung consolidation, higher virus growth, depressed interferon levels, and a fourfold reduction in hemagglutinin antibody levels	Hahon et al. (1985)
Mice, CR/CD-1, F	8 h/day 7 days/week 2 h up to 46 weeks	5.3 to 7.9	11-20,350	19 to 22	1.8 to 3.6	0.9 to 2.8	Enhanced susceptibility to lethal effects of *S. pyogenes* infections at all exposure durations (2 and 6 h; 8, 15, 16, 307, and 321 days); inconclusive results with *S. typhimurium* because of high mortality rates in controls; no enhanced mortality when challenged with A/PR8-3 influenza virus	Campbell et al. (1980, 1981)

[a]Chronic exposure lasted 52 weeks.
[b]Chronic exposure lasted 48 weeks.
[c]Calculated for 104-week exposure.
DPM = Diesel particulate matter.
AM = Alveolar macrophage.
PMN = Polymorphonuclear leukocyte.

decreased clearance after a single exposure as well as after a cumulative exposure of 34 or 100 h. Clearance was reduced to a lesser extent and in fewer tracheas from animals exposed to 8 mg/m^3 for a cumulative exposure of 40 h. Lewis et al. (1989) found no difference in the clearance of $^{59}Fe_3O_4$ particles (1.5 µm MMAD, σ_g 1.8) 1 day after dosing control and DE-exposed rats (2 mg/m^3, 7 h/day, 5 days/week for 8 weeks).

Wolff et al. (1987) and Wolff and Gray (1980) studied the effects of both subchronic and chronic DE exposure on the tracheal clearance of particles. Tracheal clearance assessments were made by measuring the retention of radiolabeled technetium macroaggregated-albumin remaining 1 h after instillation in the distal trachea of rats. In the subchronic studies, rats were exposed to 0.2, 1.0, or 4.5 mg/m^3 DPM on a 7 h/day, 5 days/week schedule for up to 12 weeks. After 1 week there was an apparent speeding of tracheal clearance at the 4.5 mg/m^3 exposure level (p=0.10), which returned toward baseline after 6 weeks and was slightly below the baseline rate at 12 weeks. In the 1.0 mg/m^3 group, there was a progressive significant reduction in the clearance rate at 6 and 12 weeks of exposure. There was a trend toward reduced clearance in the 0.2 mg/m^3 group. Scanning electron micrographs indicated minimal changes in ciliary morphology; however, there was an indication of a lower percentage of ciliated cells at the 1.0 and 4.5 mg/m^3 levels. In the chronic studies, rats were exposed to 0, 0.35, 3.5, or 7.1 mg/m^3 for 7 h/day, 5 days/week for 30 mo. There were no significant differences in tracheal clearance rates between the control group and any of the exposure groups after 6, 12, 18, 24, or 30 mo of exposure. The preexposure measurements for all groups, however, were significantly lower than those during the exposure period, suggesting a possible age effect. The preexposure value for the 3.5-mg/m^3 group was also significantly lower than the control group.

There is a substantial body of evidence for an impairment of particle clearance from the bronchiole-alveolar region of rats following exposure to DE. Griffis et al. (1983) exposed rats 7 h/day, 5 days/week for 18 weeks to DE at 0.15, 0.94, or 4.1 mg/m^3 DPM. Lung burdens of the 0.15, 0.94, and 4.1 mg/m^3 levels were 35, 220, and 1,890 µg/g lung, respectively, 1 day after the 18-week exposure. The clearance half-time of the DPM was significantly greater, almost double, for the 4.1 mg/m^3 exposure group than for those of the lower exposure groups, 165 ± 8 days versus 99 ± 8 days (0.94 mg/m^3) and 87 ± 28 days (0.15 mg/m^3), respectively.

Chan et al. (1981) showed a dose-related slowing of ^{14}C-diesel particle clearance in rats preexposed to DE at 0.25 or 6 mg/m^3 particulate matter for 20 h/day, 7 days/week for 7 to 112 days. Clearance was inhibited in the 6 mg/m^3 group when compared by length of exposure or compared with the 0.25 mg/m^3 or control rats at the same time periods.

Heinrich et al. (1982) evaluated lung clearance in rats exposed for approximately 18 mo at 3.9 mg/m^3 DPM for 7 to 8 h/day, 5 days/week. Following exposure to $^{59}Fe_2O_3$-aerosol, the rats were returned to the DE exposure and the radioactivity was measured over the thoracic area at subsequent times. The biological half-life of the iron oxide deposited in the rats' lungs was nearly twice that of controls.

Heinrich also used labeled iron oxide aerosols to study clearance in rats exposed to 0.8, 2.5, or 7 mg/m^3 diesel DPM for 24 mo (Heinrich et al., 1995). Clearance measurements were carried out at 3, 12, and 18 mo of exposure. Half-times of clearance were increased in a concentration- and duration-related manner in all exposed groups, with a range of a 50% increase in the 0.8 mg/m^3 group at 3 mo to an 11-fold increase in the 7 mg/m^3 group at 19 mo. The differential cell counts in these animals were stated to have shown clear effects in the 2.5 and 7 mg/m^3 groups, but specific information about the changes is not reported.

Wolff et al. (1987) investigated alterations in DPM clearance from the lungs of rats chronically exposed to DE at 0, 0.35, 3.5, or 7.1 mg/m^3 DPM for 7 h/day, 5 days/week for up to 24 mo. Progressive increases in lung burdens were observed over time in all groups; levels of DPM in terms of milligrams per lung were 0.60, 11.5, and 20.5 after 24 mo of exposure at the 0.35, 3.5, or 7.1 mg/m^3 exposure levels, respectively. There were significant increases in 16-day clearance half-times of inhaled radiolabeled particles of $^{67}Ga_2O_3$ (0.1 μm MMD) as early as 6 mo at the 7.1 mg/m^3 level and 18 mo at the 3.5 mg/m^3 level; no significant changes were seen at the 0.35 mg/m^3 level at any time point examined. Rats inhaled fused aluminosilicate particles (2 μm MMAD) labeled with ^{134}Cs after 24 mo of DE exposure; long-term clearance half-times were 79, 81, 264, and 240 days for the 0, 0.35, 3.5, and 7.1 mg/m^3 groups, respectively. Differences were significant between the control and the 3.5 and 7.1 mg/m^3 groups ($p < 0.01$), but not between the control and the 0.35 mg/m^3 group.

Mauderly et al. (1987b) compared the effects of DE in the developing lung to the adult lung by exposing groups of male F344 rats to 3.5 mg/m^3 for 7 h/day, 5 days/week for 6 mo. One group (adult) was exposed between 6 and 12 mo of age, and the other was exposed beginning in utero and until 6 mo of age. Clearance of an inhaled monodisperse 2 μm aluminosilicate particle was measured after exposure for 6 mo. The clearance half-time of the slow phase was found to be doubled in the diesel-exposed adult rats compared with age-matched controls and was not significantly affected in developing rat lungs.

Mauderly et al. (1990a) compared the effects of DE in normal lungs with rats in which emphysema had been induced experimentally by instillation of elastase 6 weeks before DE exposures. The rats were exposed to 3.5 mg/m^3 DPM for 7 h/day, 5 days/week for 24 mo. Measurements included histopathology, clearance, pulmonary function, lung lavage, and immune response. In the rats that were not pretreated with elastase, there was a significant reduction in the number of macrophages recovered by pulmonary lavage in contrast to the increases in macrophages reported by Strom (1984) and Henderson et al. (1988). The half-time of the slow phase of clearance of inhaled, 1 μm, monodisperse particles was doubled in the animals without elastase pretreatment. The elastase pretreatment did not affect clearance in unexposed animals but significantly reduced the effect of diesel. The clearance half-time was significantly less in elastase-pretreated, diesel-exposed animals than in diesel-exposed normal animals. Many other effects measured in this study were also less affected by diesel exposure in elastase-treated animals. Measurements of lung burden of DPM showed that elastase-pretreated animals accumulated less than half as much DPM mass as normal animals exposed at the same time, suggesting that the difference in effect could be explained by differences in dose to the lung. The composite results of this study indicate that, at least in a murine laboratory animal species, the presence of a pulmonary restrictive disease such as emphysema does not seem to exacerbate the effects of chronic exposure to diesel.

Lewis et al. (1989) conducted lung burden and $^{59}Fe_3O_4$ tracer studies in rats exposed for 12 and 24 mo to 2 mg/m^3 DPM (7 h/day, 5 days/week). The slope of the Fe_3O_4 clearance curve of the DPM-exposed animals was significantly steeper than that of the controls, indicating a more rapid alveolar clearance of the deposited $^{59}Fe_3O_4$. After 120 days from the inhalation of the tracer particle, 19% and 8% of the initially deposited $^{59}Fe_3O_4$ were present in the lungs of control and DE-exposed rats, respectively. The lung burden of DPM, however, increased significantly between 12 and 24 mo of exposure (0.52 to 0.97% lung dry weight), indicating a later dose-dependent inhibition of clearance.

Alveolar macrophages, because of their phagocytic and digestive capabilities, are one of the prime defense mechanisms of the alveolar region of the lung against inhaled particles. Thus, characterization of the effects of DE on various properties of AMs provides information on the integrity or compromise of a key pulmonary defense mechanism. The physiological viability of AMs from diesel-exposed rats was assessed after 2 years of exposure by Castranova et al. (1985). The 7 h/day, 5 days/week exposure at 2 mg/m^3 DPM had little effect on the following: viability, cell number, oxygen consumption, membrane integrity, lysosomal enzyme activity, or protein content of the AMs. A slight decrease in cell volume, a decrease in chemiluminescence indicative of a decreased secretion of reactive oxygen species, and a decrease in ruffling of the cell membrane were observed. These latter findings could be reflective of an overall reduction in phagocytic activity.

Exposure to DE has been reported both to increase the number of recoverable AMs from the lung (Strom, 1984; Vostal et al., 1982; Henderson et al., 1988a) or to produce no change in numbers (Chen et al., 1980; Castranova et al., 1985). Strom (1984) found that in rats exposed to 0.25 mg/m^3 DPM for 20 h/day, 5.5 days/week for 6 mo or 1 year, as well as in the controls, BAL cells consisted entirely of AMs, with no differences in the cell counts in the lavage fluid. At the higher concentrations, 0.75 or 1.5 mg DPM/m^3, the count of AM increased proportionally with the exposure concentration; the results were identical for AMs at both 6 and 11 or 12 mo of exposure. The increase in AM counts was much larger after exposure to 1.5 mg/m^3 DPM for 6 mo than after exposure to 0.75 mg/m^3 for 1 year, although the total mass (calculated as C × T) of deposited particulate burden was the same. These data suggested to the authors that the number of lavaged AMs was proportional to the mass influx of particles rather than to the actual DPM burden in the lung. These results further implied that there may be a threshold for the rate of mass influx of DPM into the lungs of rats above which there was an increased recruitment of AMs. Henderson et al. (1988a) reported similar findings of significant increases of AMs in rats and mice exposed to 7.1 mg/m^3 DPM for 18 and 24 mo, respectively, for 7 h/day, 5 days/week, but not at concentrations of 3.5 or 0.35 mg/m^3 for the same exposure durations. Chen et al. (1980), using an exposure regimen of 0.25 and 1.5 mg/m^3 DPM for 2 mo and 20 h/day and 5.5 days/week, found no significant changes in absolute numbers of AMs from guinea pig BALF, nor did Castranova et al. (1985) in rat BALF following exposure to 2 mg/m^3 DPM for 7 h/day, 5 days/week for 2 years.

A similar inflammatory response was noted by Henderson et al. (1988a) and Strom (1984), as evidenced by an increased number of PMNs present in BALF from rodents exposed to DE. Henderson et al. (1988) found these changes in rats and mice exposed to 7.1 and 3.5 mg/m^3 DPM for 7 h/day, 5 days/week. Significant increases in BALF PMNs were observed in mice at 6 mo of exposure and thereafter at the 7.1 and 3.5 mg/m^3 exposure levels, but in rats only the 7.1 mg/m^3 exposure level showed an increase in BALF PMNs at 6 mo of exposure and thereafter. Significant increases in BALF PMNs occurred in rats at 12, 18, and 24 mo of exposure to 3.5 mg/m^3 DPM. Although increases in PMNs were usually greater in mice in terms of absolute numbers, the PMN response in terms of increase relative to controls was only about one-third that of rats. Strom (1984) reported that the increased numbers of PMNs in BALF were proportional to the inhaled concentrations and/or duration of exposure. The PMNs also appeared to be affiliated with clusters of aggregated AMs rather than to the diesel particles per se. Proliferation of Type II cells likewise occurred in response to the formed aggregates of AMs (White and Garg, 1981).

The integrity of pulmonary defense mechanisms can also be ascertained by assessing if exposure to DE affects colonization and clearance of pathogens and alters the response of the challenged animals to respiratory tract infections. Campbell et al. (1980, 1981) exposed mice to DE followed by infectious challenge with *Salmonella typhimurium, Streptococcus pyogenes*, or A/PR8-3 influenza virus and measured microbial-induced mortality. Exposures to DE were to 6 mg/m^3 DPM for 8 h/day, 7 days/week for up to 321 days. Exposure to DE resulted in enhanced susceptibility to the lethal effects of *S. pyogenes* infection at all exposure durations (2 h, 6 h; 8, 15, 16, 307, and 321 days). Tests with *S. typhimurium* were inconclusive because of high mortality rates in the controls. Mice exposed to DE did not exhibit an enhanced mortality when challenged with the influenza virus. Hatch et al. (1985) found no changes in the susceptibility of mice to Group C *Streptococcus* sp. infection following intratracheal injection of 100 μg of DPM suspended in unbuffered saline.

Hahon et al. (1985) assessed virus-induced mortality, virus multiplication with concomitant IFN levels (lungs and sera), antibody response, and lung histopathology in mice exposed to DE prior to infectious challenge with Ao/PR/8/34 influenza virus. Weanling mice were exposed to DE containing 2 mg/m^3 DPM for 7 h/day, 5 days/week. In mice exposed for 1, 3, and 6 mo, mortality was similar between the exposed and control mice. In mice exposed for 3 and 6 mo, however, there were significant increases in the percentage of mice having lung consolidation, higher virus growth, depressed IFN levels, and a fourfold reduction in hemagglutinin antibody levels; these effects were not seen after the 1-mo exposure.

The effects of DE on the pulmonary defense mechanisms appear to be determined by three critical factors related to exposure: the concentrations of the pollutants, the exposure duration, and the exposure pattern. Higher doses of DE as determined by an increase in one or more of these three variables have been reported to increase the numbers of AMs, PMNs, and Type II cells in the lung, whereas lower doses fail to produce such changes. In rats, the single most significant contributor to the impairment of the pulmonary defense mechanisms appears to be an excessive accumulation of DPM, particularly as particle-laden aggregates of AMs. Such an accumulation would result from an increase in deposition and/or a reduction in clearance. The deposition of particles does not appear to change significantly following exposure to equivalent DE doses over time. Because of the significant nonlinearity in particle accumulation between low and high doses of DE exposure, coupled with no evidence of increased particle deposition, an impairment in one or more of the mechanisms of pulmonary defense appears to be responsible for the DPM accumulation and subsequent pathological sequelae. The time of onset of pulmonary clearance impairment was dependent both on the magnitude and on the duration of exposures. For example, for rats exposed for 7 h/day, 5 days/week for 104 weeks, the concentration needed to induce pulmonary clearance impairment appears to lie between 0.35 and 2.0 mg/m^3 DPM.

5.1.3.3.5. ***Effects on the immune system—inhalation studies*.** The effects of DE on the immune system of guinea pigs were investigated by Dziedzic (1981). Exposures were to 1.5 mg/m^3 DPM for 20 h/day, 5.5 days/week for up to 8 weeks. There was no effect of diesel exposure when compared with matched controls for the number of B and T lymphocytes and null cells isolated from the tracheobronchial lymph nodes, spleen, and blood. Cell viability as measured by trypan blue exclusion was comparable between the exposed and control groups. The results of this study and others on the effects of exposure to DE on the immune system are summarized in Table 5-8.

Mentnech et al. (1984) examined the effect of DE on the immune system of rats. Exposures were to 2 mg/m^3 DPM for 7 h/day, 5 days/week for up to 2 years. Rats exposed for 12 and 24 mo were tested for immunocompetency by determining antibody-producing cells in the spleen 4 days after immunization with sheep erythrocytes. The proliferative response of splenic T-lymphocytes to the mitogens concanavalin A and phytohemagglutinin was assessed in rats exposed for 24 mo. There were no significant differences between the exposed and control animals. Results obtained from these two assays indicate that neither humoral immunity (assessed by enumerating antibody-producing cells) nor cellular immunity (assessed by the lymphocyte blast transformation assay) were markedly affected by the exposures.

Bice et al. (1985) evaluated whether or not exposure to DE would alter antibody immune responses induced after lung immunization of rats and mice. Exposures were to 0.35, 3.5, or 7.1 mg/m^3 DPM for 7 h/day, 5 days/week for 24 mo. Chamber controls and exposed animals were immunized by intratracheal instillation of SRBCs after 6, 12, 18, or 24 mo of exposure. No suppression in the immune response occurred in either species. After 12, 18, and 24 mo of exposure, the total number of anti-SRBC IgM antibody forming cells (AFCs) was elevated in rats, but not in mice, exposed to 3.5 or 7.1 mg/m^3 DPM; after 6 mo of exposure, only the 7.1 mg/m^3 level was found to have caused this response in rats. The number of AFCs per 10^6 lymphoid cells in lung-associated lymph nodes and the levels of specific IgM, IgG, or IgA in rat sera were not significantly altered. The investigators concluded that the increased cellularity and the presence of DPM in the lung-associated lymph nodes had only a minimal effect on the immune and antigen filtration function of these tissues.

The effects of inhaled DE and DPM have been studied in a murine model of allergic asthma (Takano et al., 1998a,b). ICR mice were exposed for 12 h/day, 7 days/week for 40 weeks to DE (0.3, 1.0, or 3.0 mg/m^3). The mice were sensitized with ovalbumin (OA) after 16 weeks exposure and subsequently challenged with aerosol allergen (1% OA in isotonic saline for 6 min) at 3-week intervals during the last 24 weeks of exposure. Exposure to DE enhanced allergen-related eosinophil recruitment to the submucosal layers of the airways and to the bronchoalveolar space, and increased protein levels of GM-CSF and IL-5 in the lung in a dose-dependent manner. In the DE-exposed mice, increases in eosinophil recruitment and local cytokine expression were accompanied by goblet-cell proliferation in the bronchial epithelium and airwayhyperresponsiveness to inhaled acetylcholine. In contrast, mice exposed to clean air or DE without allergen provocation showed no eosinophil recruitment to the submucosal layers of the airways or to the bronchoalveolar space, and few goblet-cells in the bronchial epithelium. The

Table 5-8. Effects of inhalation of diesel exhaust on the immune system of laboratory animals

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg \cdot h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Guinea Pig, Hartley, M	20 h/day 5.5 days/week 4 or 8 weeks	1.5 0.19 µm MDD	660 or 7,280	7.5	—	—	No alterations in numbers of B, T, and null lymphocytes or cell viability among lymphocytes isolated from tracheobronchial lymph nodes, spleen, or blood	Dziedzic (1981)
Rat, F344, M	7 h/day 5 days/week 52 or 104 weeks	2.0 0.23–0.36 µm MDD	3,640 or 7,280	11.5	1.5	0.8	Neither humoral immunity (assessed by enumerating antibody-producing cells) nor cellular immunity (assessed by the lymphocyte blast transformation assay) were markedly affected	Mentnech et al. (1984)
Rat, F344; Mouse, CD-1	7 h/day 5 days/week 104 weeks	0.35 3.5 7.1 0.25 µm MDD	1,274 12,740 25,480	2.9 16.5 29.7	0.05 0.34 0.68	— — —	Total number of anti-sheep red blood cell IgM AFC in the lung-associated lymph nodes was elevated in rats exposed to 3.5 or 7.0 mg/m^3 DPM (no such effects in mice); total number of AFC per 10^6 lymphoid cells in lung-associated lymph nodes and level of specific IgM, IgG, or IgA in rat sera were not altered	Bice et al. (1985)
Mouse, BALB/C, M	12 h/day, 7 days/week, 3 weeks Mice administered OA intranasally before, immediately after, and 3 weeks after exposure	3.0 6.0 0.4 µm	756 1,512	— —	2.8 4.1	1.7 2.7	Spleen weights in mice exposed to DE (6 mg/m^3) increased significantly. Serum anti-OA IgE antibody titers in mice exposed to 6 mg/m^3 significantly higher than control. Antigen-stimulated IL-4 and IL-10 production increased while IFN-g production decreased significantly in spleen cells from DE-exposed (6 mg/m^3) mice stimulated with OA in vitro. DE inhalation may affect antigen-specific IgE antibody production through alteration of the cytokine network.	Fujimaki et al. (1997)
Mouse, C3H/Hen, M	12 h /day, for 12 weeks. Before exposure mice injected IP with OA. After 3 weeks and every 3 weeks thereafter, mice challenged with OA aerosol.	1.0 3.0	1,008 3,024	—	1.42 4.02	0.87 1.83	DE + antigen challenge induced airway hyperresponsiveness and inflammation with increased eosinophils, mast cells, and goblet cells. DE alone induced airway hyperresponsiveness, but not eosinophilic infiltration or increased goblet cells. DE inhalation enhanced airway hyperresponsiveness and airway inflammation caused by OA sensitization.	Miyabara et al. (1998a)

Table 5-8. Effects of inhalation of diesel exhaust on the immune system of laboratory animals (continued)

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg{\cdot}h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Mouse, C3H/HeN, M	12 h/day, for 5 weeks. After 7 days mice injected IP with OA. At end of exposure mice challenged with OA aerosol for 15 minutes.	3.0	1,260	—	4.08	1.26	DE alone increased neutrophils and macrophages in BAL fluid; after DE + OA challenge eosinophils increased. OA alone increased eosinophils but the increase was enhanced by DE. DE + OA, but not DE alone, increased goblet cells, respiratory resistance, production of OA-specific IgE and Ig1 in the serum, and overexpression of IL-5 in lung tissue.	Miyabara et al. (1998b)
Mouse, ICR (murine model of allergic asthma)	12 h/day, 7days/week, 40 weeks. After 16 weeks sensitized to OA and challenged with OA aerosol for 6 min, at 3-week intervals during the last 24 weeks of exposure.	0.3 1.0 3.0	1,008 3,360 10,080	—	—	—	DE exposure enhanced allergen-related recruitment to the submucosal layers of the airways and the bronchoalveolar space, and increased GM-CSF and IL-5 in the lung in a dose-dependent manner. Increases in eosinophil recruitment and local cytosine expression accompanied by goblet cell proliferation in the bronchial epithelium and airway hyperresponsiveness to inhaled acetylcholine. Mice exposed to clean air or DE without allergen provocation showed no eosinophil recruitment to the submucosal layers of the airways nor to the bronchoalveolar space, and few goblet cells in the bronchial epithelium. Daily inhalation of DE may enhance allergen-related respiratory diseases such as allergic asthma, and effect may be mediated by the enhanced local expression of IL-5 and GM-CSF.	Takano et al. (1998a)

DPM = Diesel particulate matter.
AFC = Antibody-forming cells.

authors concluded that daily inhalation of DE can enhance allergen-related respiratory diseases such as allergic asthma, and that this effect may be mediated by the enhanced local expression of IL-5 and GM-CSF. The effect of DPM on a second characteristic of allergic asthma, airway hyperresponsiveness, was examined by Takano et al. (1998b). Laboratory mice were administered OA, DPM, or OA and DPM combined by intratracheal instillation for 6 wk. Respiratory resistance (Rrs) after acetylcholine challenge was measured 24 h after the final instillation. Rrs was significantly greater in the mice treated with OA and DPM than in the other treatments. The authors concluded that DPM can enhance airway responsiveness associated with allergen exposure.

In a series of inhalation studies following earlier instillation studies, Miyabara and co-workers investigated whether inhalation of DE could enhance allergic reactions in laboratory mice. C3H/HeN mice were exposed to DE (3 mg DPM/m^3) by inhalation for 5 weeks (Miyabara et al., 1998b) and, after 7 days of exposure, were sensitized to OA injected intraperitoneally. At the end of the DE exposure, the mice were challenged with an OA aerosol for 15 min. DE caused an increase in the numbers of neutrophils and macrophages in bronchoalveolar lavage fluid independent of OA sensitization, whereas a significant increase in eosinophil numbers occurred only after DE exposure was combined with antigen challenge. Even though OA alone caused an increase in eosinophil numbers in lung tissue, this response was enhanced further by DE. DE exposure combined with OA sensitization enhanced the number of goblet-cells in lung tissue, respiratory resistance, production of OA-specific IgE and IgG_1 in the serum, and overexpression of IL-5 in lung tissue. In a second study, C3H/HeN mice were sensitized with OA injected intraperitoneally and then exposed to DE by inhalation for 12 h/day for 3 mo at either 1 or 3 mg/m^3 (Miyabara et al., 1998a). After 3 weeks of DE exposure, and every 3 weeks thereafter, the mice were challenged with an OA aerosol. Exposure to DE with antigen challenge induced airway hyperresponsiveness and airway inflammation, which was characterized by increased numbers of eosinophils and mast cells in lung tissue. The increase in inflammatory cells was accompanied by an increase in goblet cells in the bronchial epithelium. Airway hyperresponsiveness, but not eosinophilic infiltration or increased goblet cells, was increased by DE exposure alone. These workers concluded that inhalation of DE can enhance airway hyperresponsiveness and airway inflammation caused by OA sensitization in mice.

The effects of DE on IgE antibody production were investigated in BALB/c mice sensitized with OA and exposed by inhalation to DE (3.0 and 6.0 mg/m^3) for 3 weeks (Fujimaki et al., 1997). The mice were sensitized by intranasal administration of OA alone before, immediately after, and 3 weeks after DE inhalation. While body and thymus weights were unchanged in the DE-exposed and control mice, spleen weights in mice exposed to 6 mg/m^3 DE increased significantly. Anti-OA IgE antibody titers in the sera of mice exposed to 6 mg/m^3 DE were significantly higher than control. Total IgE and anti-OA IgG in sera from DE-exposed and control mice remained unchanged. Cytokine production was measured in vitro stimulated with OA in spleen cells from mice exposed to DE (6 mg/m^3). Antigen-stimulated interleukin-4 (IL-4) and -10 (IL-10) production increased significantly in vitro in spleen cells from DE-exposed mice compared with controls, while IFN-γ production decreased markedly. The authors concluded that DE inhalation in mice may affect antigen-specific IgE antibody production through alteration of the cytokine network.

5.1.3.3.6. ***Effects on the immune system—noninhalation studies.*** The immune response of laboratory animals to DPM has been studied in various noninhalation models, and the results of these studies are presented in Table 5-9. Takafuji et al. (1987) evaluated the IgE antibody response of mice inoculated intranasally at intervals of 3 weeks with either 0.5 or 25 μg of DPM in ovalbumin per mouse. Antiovalbumin IgE antibody titers, assayed by passive cutaneous anaphylaxis, were enhanced by doses as low as 1 μg of particles compared with immunization with ovalbumin alone.

Muranaka et al. (1986) studied the effects of DPM on IgE antibody production in immunized mice. A greater IgE antibody response was noted in mice immunized by ip injection of ovalbumin (OA) mixed with DPM, either 0.02, 0.2, or 2mg per mouse, than in animals immunized with OA alone. This effect of DPM on IgE antibody production in mice was also demonstrated in mice immunized with repeated injections of dinitrophenylated-OA. Moreover, a persistent IgE-antibody response to Japanese cedar pollen (JCPA), a common pollen allergen causing allergic rhinitis in Japan, was observed in mice immunized with JCPA mixed with DPM but not in animals immunized with JCPA alone. The results suggest an association between the adjuvant activity of DPM and allergic rhinitis caused by JCPA.

Takano et al. (1997) designed a study to evaluate the effects of DPM on the manifestations of allergic asthma in mice, with emphasis on antigen-induced airway inflammation; the local expression of IL-5, GM-CSF, IL-2, and IFN-γ; and the production of antigen-specific IgE and IgG. Male ICR mice were intratracheally instilled with ovalbumin (OVA), DPM, and DPM+OVA. DPM was obtained from a 4JB1-type, light-duty 2.74 L, four-cylinder Isuzu diesel engine operated at a steady speed of 1,500 rpm under a load of 10 torque (kg/m). The OVA-group mice were instilled with 1 μg OVA at 3 and 6 weeks. The mice receiving DPM alone were instilled with 100 μg DPM weekly for 6 weeks. The OVA + DPM group received the combined treatment in the same protocol as the OVA and the DPM groups, respectively. Additional groups were exposed for 9 weeks. DPM aggravated OVA-induced airway inflammation, characterized by infiltration of eosinophils and lymphocytes and an

Table 5-9. Effects of diesel particulate matter on the immune response of laboratory animals

Model	Treatment	Effects	Reference
Mouse, BDFI, F		Intranasally delivered doses of DPM as low as 1 mg exerted an adjuvant activity for IgE antibody production.	Takafuji et al. (1987)
Mouse, ICR, w/w^-, M	Intratracheal instillation of DPM, once/week for 16 weeks	Infiltration of inflammatory cells, proliferation of goblet cells, increased mucus secretion, respiratory resistance, and airway constriction. Increased eosinophils in the submucosa of the proximal bronchi and medium bronchioles. Eosinophil infiltration suppressed by pretreatment with PEG-SOD. Bound sialic acid, an index of mucus secretion, in bronchial alveolar lavage fluids increased, but was suppressed by PEG-SOD. Increased respiratory resistance suppressed by PEG-SOD. Oxygen radicals produced by instilled DPM may cause features characteristic of bronchial asthma in mice.	Sagai et al. (1996)
Mouse, A/J, M	Mice immunized intranasally with Der f II + pyrene, or Der f II + DPM 7 times at 2-week intervals	IgE antibody responses to Der f II enhanced in mice immunized with Der f II+ pyrene or Der f II + DPM compared with Der f II alone. Response was dose related. DPM and pyrene contained in DPM have adjuvant activity on IgE and IgG1 antibody production in mice immunized with house dust mite allergen.	Suzuki et al. (1996)
Mouse, BDF_1, M	Mice were administered 25 mg of each of 5 fine particles (Kanto loam dust, fly ash, CB, DPM, and aluminum hydroxide [alum]) intranasally and exposed to aerosolized Japanese cedar pollen allergens (JCPA) for intervals up to 18 wk	Measurements were made of JCPA-specific IgE and IgG antibody titers, the protein-adsorbing capacity of each type of particle, and nasal rubbing movements (a parameter of allergic rhinitis in mice). The increases in anti-JPCA IgE and IgG antibody titers were significantly greater in mice treated with particles and aerosolized JCPA than in mice treated with aerosolized JCPA alone. In a subsequent experiment, the mice received the particles as before, but about 160,000 grains of Japanese cedar pollen (JCP) were dropped onto the tip of the nose of each mouse twice a week for 16 wk. After 18 wk there were no significant differences in the anti-JCPA IgE and IgG production, nasal rubbing, or histopathological changes. The workers concluded that the nature of the particle, the ability of the particle to absorb antigens, and/or particle size is not related to the enhancement of IgE antibody production or symptoms of allergic rhinitis. However, IgE antibody production did appear to occur earlier in mice treated with particles than in mice immunized with allergens alone.	Maejima et al. (1997)
Mouse, BALB/C, nu/nu, F	Inoculated OA with DPM or CB into hind footpad measured response using popliteal lymph node assay	Increased response (increased weight, cell numbers, cell proliferation) and longer response observed with DPM and OA, compared to DPM or OA alone. Response was specific and not an unspecific inflammatory response. CB was slightly less potent than DPM. Nonextractable carbon core contributes substantially to adjuvant activity of DPM.	Løvik et al. (1997)
Mouse, BALB/cA, F	Intranasal administration of DPM. Mice immunized with OA or OA combined with DPM or CB	Increased response to antigen in animals receiving DPM or CB. Increased number of responding animals and increased serum anti OA IgE antibody. Both DPM and CB have adjuvant activity for IgE production. DPM response more pronounced than CB, indicating both organic matter adsorbed to DPM and the nonextractable carbon core responsible for adjuvant activity.	Nilsen et al. (1997)
Mouse, ICR, M	Intratracheal instillation of OA, DPM, or OVA and DPM combined, once/week for 6 wk	Respiratory resistance (Rrs) measured 24 h after the final instillation. Rrs after acetylcholine challenge was significantly greater in the mice treated with OVA and DPM than other treatments. DPM can enhance airway responsiveness associated with allergen exposure.	Takano et al. (1998b)

OA - Ovalbumin.
DPM - Diesel particulate matter.
CB - Carbon black.

PEG-SOD - Polyethyleneglycol-conjugated superoxide dismutase.
IL-4 - Interleukin-4.
IL-5 - Interleukin-5.
IL-10 - Interleukin-10.
IFN - Interferon-g.
GM-CSF -Granulocyte-colony stimulating factor.
IP - Intraperitoneally.

increase in goblet cells in the bronchial epithelium. DPM in combination with antigen markedly increased IL-5 protein levels in lung tissue and bronchoalveolar lavage supernatants compared with either antigen or DPM alone. The combination of DPM and antigen induced significant increases in local expression of IL-4, GM-CSF, and IL-2, whereas expression of IFN-γ was not affected. In addition, DPM exhibited adjuvant activity for the antigen-specific production of IgG and IgE.

The potential role of oxygen radicals in injury caused by DPM was investigated by Sagai et al. (1996). These workers reported that repeated intratracheal instillation of DPM (either 0.1 or 0.2 mg per mouse, once/week for 16 weeks) in mice caused marked infiltration of inflammatory cells, proliferation of goblet cells, increased mucus secretion, respiratory resistance, and airway constriction. Eosinophils in the submucosa of the proximal bronchi and medium bronchioles increased eightfold following instillation. Eosinophil infiltration was significantly suppressed by pretreatment with polyethyleneglycol-conjugated superoxide dismutase (PEG-SOD), an inhibitor of oxygen radicals. Bound sialic acid concentrations in bronchial alveolar lavage fluids, an index of mucus secretion, increased with DPM, but were also suppressed by pretreatment with PEG-SOD. Goblet cell hyperplasia, airway narrowing, and airway constriction also were observed with DPM.

Respiratory resistance to acetylcholine in the DPM group was 11 times higher than in controls, and the increased resistance was significantly suppressed by PEG-SOD pretreatment. These findings indicate that oxygen radicals caused by intratracheally instilled DPM elicit responses characteristic of bronchial asthma.

Potential adjuvant effects of DPM on the response to the model allergen OA were investigated in BALB/c mice using the popliteal lymph node (PLN) assay (Løvik et al., 1997). DPM inoculated together with OA into one hind footpad (0.02 mL of a 5 mg/mL DPM suspension) gave a significantly augmented response (increase in weight, cell numbers, and cell proliferation) in the draining popliteal lymph node as compared to DPM or OA alone. The duration of the local lymph node response was also longer when DPM was given with the allergen. The lymph node response appeared to be of a specific immunologic character and not an unspecific inflammatory reaction. The OA-specific response IgE was increased in mice receiving OA together with DPM as compared with the response in mice receiving OA alone. Further studies using carbon black (CB) as a surrogate for the nonextractable core of DPM found that while CB resembled DPM in its capacity to increase the local lymph node response and serum-specific IgE response to OA, CB appeared to be slightly less potent than DPM. The results indicate that the nonextractable particle core contributes substantially to the adjuvant activity of DPM.

Nilsen et al. (1997) investigated which part of the particle was responsible, the carbon core and/or the adsorbed organic substances, for the adjuvant activity of DPM. Female

BALB/cA mice were immunized with OA alone or in combination with DPM or CB particles by intranasal administration a total of four times, once weekly, at 25 μg/inoculation. There was an increased response to the antigen in animals receiving OA together with DPM or CB, compared with animals receiving OA alone. The response was seen as both an increased number of responding animals and increased serum anti OA IgE response. The workers concluded that both DPM and CB have an adjuvant activity for specific IgE production, but that the activity of DPM may be more pronounced than that of CB. The results suggest that both the organic matter adsorbed to DPM and the nonextractable carbon are responsible for the observed adjuvant effect of DPM.

The effects of DPM and its components (extracted particles and particle extracts) on the release of proinflammatory cytokines, interleukin-1 (IL-1), and tumor necrosis factor-α (TNF-α) by alveolar macrophages (AMs) were investigated by Yang et al. (1997). Rat AMs were incubated with 0, 5, 10, 20, 50, or 100 $\mu g/10^6$ AM/mL of DPM, methanol-extracted DPM, or equivalent concentrations of DPM at 37 °C for 24 h. At high concentrations, both DPM and DPM extracts were shown to increase IL-1-like activity secreted by AMs, whereas extracted particles had no effect. Neither particles, particle extracts, or extracted particles stimulated secretion of TNF-α. DPM inhibited lipid polysaccharide (LPS)-stimulated production of IL-1 and TNF-α. In contrast, interferon (IFN)-γ-stimulated production of TNF-α was not affected by DPM. Results of this study indicate that the organic fraction of exhaust particles is responsible for the effects noted. Stimulation of IL-1 but not TNF-α suggests that IL-1, but not TNF-α, may play an important role in the development of DPM-induced inflammatory and immune responses. The cellular mechanism involved in inhibiting increased release of IL-1 and TNF-α by LPS is unknown, but may be a contributing factor to the decreased AM phagocytic activity and increased susceptibility to pulmonary infection after prolonged exposure to DPM.

Fujimaki et al. (1994) investigated the relationship between DPM and IgE antibody production, interleukin 4 (IL-4) production in BALB/c mice treated with DPM mixed with antigen OA or JCP antigen by intratracheal instillation. BALB/c mice were injected with DPM (300 μg) plus OA or OA alone and, after the last instillation, the proliferative response and lymphokine production by mediastinal lymph node cells (LNC) were examined in vitro. The proliferative response to OA in mediastinal LNC from mice injected with DPM plus OA was enhanced to 4-17 times that of control mice. IL-4 production by OA stimulation was also enhanced in mediastinal LNC from mice injected with DPM plus OA. A significantly larger amount of anti-OA IgE antibody was detected in sera from DPM- and OA-injected mice compared with those from control mice. The levels of IL-4, estimated by JCP antigen in mediastinal LNC, from mice injected with DPM plus JCP antigen were twofold higher than those from mice injected with JCP antigen alone. These results suggest that intratracheal instillation of DPM affects antigen-specific IgE antibody responses via local T-cell activation, especially enhanced IL-4 production.

Suzuki et al. (1993) investigated the adjuvant activity of pyrene, one of many PAHs contained in DPM, on IgE antibody production in mice. In the first experiment, mice were immunized with 1 mg of OA alone, 1 mg of OA plus 1 mg of pyrene, or 1 mg of OA plus 1 mg of DPM, respectively. The IgE antibody responses to OA in mice immunized with OA plus pyrene or OA plus DPM were enhanced as compared to those in mice immunized with OA alone; the highest responses were observed in mice immunized with OA plus DPM. In the second experiment, mice were immunized with 10 mg of JCPA alone or 10 mg of JCPA plus 5 mg of pyrene. The IgE antibody responses to JCPA in mice immunized with JCPA plus pyrene were higher than those in mice immunized with JCPA alone. The results indicate that pyrene contained in DPM acts as an adjuvant in IgE antibody production in immunized mice.

Suzuki et al. (1996) investigated the effect of pyrene on IgE and IgG1 antibody production in mice to clarify the relation between mite allergy and adjuvancy of the chemical compounds in DPM. The mite allergen was Der f II, one of the major allergens of house dust mite (*Dermatophagoides farinae*). Allergen mice were grouped and immunized with Der f II (5 μg), Der f II (5 μg) plus pyrene (200 μg), and Der f II (5 μg) plus DPM (100 μg) intranasally seven times at 2-week intervals. The separate groups of mice were also immunized with Der f II (10 μg) plus the same dose of adjuvants in the same way. The IgE antibody responses to Der f II in mice immunized with Der f II plus pyrene or Der f II plus DPM were markedly enhanced compared with those immunized with Der f II alone. The anti-Der f II IgE antibody production increased with increasing the dose of Der f II from 5 μg to 10 μg in mice immunized with Der f II plus the same dose of adjuvants. The IgG1 antibody responses to Der f II in mice immunized with Der f II (10 μg) plus pyrene (200 μg) or Der f II (10 μg) plus DPM (100 μg) were greater than those immunized with 10 μg of Der f II alone. In addition, when peritoneal macrophages obtained from normal mice were incubated with pyrene or DPM in vitro, an enhanced IL-1a production by the macrophages was observed. When spleen lymphocytes obtained from the mice immunized with Der f II (10 μg) plus DPM (100 μg) or Der f II (10 μg) plus pyrene (200 μg) were stimulated with 10 μg of Der f II in vitro, an enhanced IL-4 production of the lymphocytes was also observed compared with those immunized with Der f II alone. This study indicates that DPM and pyrene (one of the many PAHs adsorbed onto DPM) have an adjuvant activity on IgE and IgG1 antibody production in mice immunized intranasally with a house dust mite allergen.

Maejima et al. (1997) examined the potential adjuvant activity of several different fine particles. These workers administered 25 μg of each of 5 particles (Kanto loam dust, fly ash, CB, DPM, and aluminum hydroxide [alum]) intranasally in mice and exposed them to aerosolized JCPA for intervals up to 18 weeks. Measurements were made of JCPA-specific IgE and IgG antibody titers, the protein-adsorbing capacity of each type of particle, and nasal rubbing movements (a parameter of allergic rhinitis in mice). The increases in anti-JPCA IgE and IgG antibody titers were significantly greater in mice treated with particles and plus aerosolized JCPA than in mice treated with aerosolized JCPA alone. In a subsequent experiment, the mice received the particles as before, but about 160,000 grains of JCP were dropped onto the tip of the nose of each mouse twice a week for 16 weeks. After 18 weeks there were no significant differences in the anti-JCPA IgE and IgG production, nasal rubbing, or histopathological changes. The workers concluded that the nature of the particle, the ability of the particle to absorb antigens, and particle size are not related to the enhancement of IgE antibody production or symptoms of allergic rhinitis. However, IgE antibody production did appear to occur earlier in mice treated with particles than in mice immunized with allergens alone.

The potential for DPM to modulate cytokine production has been demonstrated in cultured mouse bone marrow-derived mast cells (BMMC). Saneyoshi et al. (1997) examined the production of cytokines in BMMC treated with DPM (0.8, 2 and 4 mg/mL). Production of interleukin-4 (IL-4) and IL-6 was higher in BMMC stimulated with A23187 and treated with low concentrations of DPM than in controls, but no increase was seen in BMMC treated with high DPM. After pretreatment with low DPM for 24 h, IL-4 production in BMMC stimulated with A23187 was lower than in controls. Antigen-induced IL-4 production increased significantly in BMMC treated with 0.4 or 0.8 mg/mL DPM, but did not increase with low DPM. Although the enhancement of IL-4 production of BMMC stimulated with A23187 plus DPM was not completely inhibited by 2-mercaptoethanol, treatment with dexamethasone inhibited further IL-4 production. Thus, DPM may affect the immune response via the modulation of cytokine production in mast cells.

Ormstad et al. (1998) investigated the potential for DPM as well as other suspended particulate matter (SPM) to act as a carrier for allergens into the airways. These investigators found both Can f 1 (dog) and Bet v 1 (birch pollen) on the surface of SPM collected in air from different homes. In an extension of the study, they found that DPM adhered to polycarbonate filters had the potential of binding both of these allergens as well as Fel d 1 (cat) and Der p 1 (house mite). The authors conclude that soot particles in indoor air house dust may act as carrier of several allergens in indoor air.

Knox et al. (1997) investigated whether free grass pollen allergen molecules, released from pollen grains by osmotic shock (Suphioglu et al., 1992) and dispersed in microdroplets of water in aerosols, can bind to DPM mounted on copper grids in air. Using natural highly purified Lol p 1, immunogold labeling with specific monoclonal antibodies, and a high-voltage transmission electron-microscopic imaging technique, these workers demonstrated binding of the major grass pollen allergen, Lol p 1, to DPM in vitro. These workers conclude that binding of

DPM with Lol p 1 might be a mechanism by which allergens can become concentrated in air and trigger attacks of asthma.

Murphy et al. (1999) examined the comparative toxicities to the lung of four different-sized CB particles and DPM, in primary cultures of mouse Clara and rat type II epithelial cells. Particle toxicity was assessed by cell attachment to an extracellular matrix substratum. The CB particles varied in toxicity to Clara and type II cells. DPM stored for 2 weeks was equally toxic to both cell types. DPM became progressively less toxic to type II cells with time of storage. Both primary epithelial cell types internalized the particles in culture. These workers concluded that bioreactivity was related to CB particle size and surface area, with the smaller particles having the larger surface area being the more toxic. Although freshly prepared DPM was equally toxic to type II and Clara cells, DPM became progressively less toxic to the type II cells with time.

Exposure studies in laboratory animals and isolated cell systems derived from animals also indicate that DPM can elicit both inflammatory and immunological changes. Moreover, the effects appear to be due to both the nonextractable carbon core and the adsorbed organic fraction of the diesel particle. Changes in IgE, goblet cell hyperplasia, mast cell influx, and cytokines in various animal models and in vitro model systems are all key markers of asthma. The data further indicate a role for oxygen radicals in DPM injury because the extent of the injury can be reduced by treatment with antioxidants. DPM also has the capacity to bind and transport airborne allergens.

5.1.3.3.7. ***Effects on the liver***. Meiss et al. (1981) examined alterations in the hepatic parenchyma of hamsters by using thin-section and freeze-fracture histological techniques. Exposures to DE were for 7 to 8 h/day, 5 days/week, for 5 mo at about 4 or 11 mg/m^3 DPM. The livers of the hamsters exposed to both concentrations of DE exhibited moderate dilatation of the sinusoids, with activation of the Kupffer cells and slight changes in the cell nuclei. Fatty deposits were observed in the sinusoids, and small fat droplets were occasionally observed in the peripheral hepatocytes. Mitochondria often had a loss of cristae and exhibited a pleomorphic character. Giant microbodies were seen in the hepatocytes, which were moderately enlarged, and gap junctions between hepatocytes exhibited a wide range in structural diversity. The results of this study and others on the effect of exposure of DE on the liver of laboratory animals are summarized in Table 5-10.

Table 5-10. Effects of exposure to diesel exhaust on the liver of laboratory animals

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg·h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, F344, M, F	7 h/day 5 days/week 52 weeks	2.0 0.23–0.36 μm MDD	3,640	12.7	1.6	0.83	No changes in absolute liver weight or liver/body weight ratio	Green et al. (1983)
Hamster, Syrian	7-8 h/day 5 days/week 22 weeks	4.0 8.0 11.0	3,080-9,680	12.0 19.0 25.0	0.5 1.0 1.5	3.0 6.0 7.0	Enlarged sinusoids, with activated Kupffer's cells and slight changes of nuclei; fatty deposits; mitochondria, loss of cristae and pleomorphic character; gap junctions between hepatocytes had wide range in structural diversity	Meiss et al. (1981)
Cat, inbred, M	8 h/day 7 days/week 124 weeks	6.0[a] 12.0[b]	41,664 83,328	20.2 33.3	2.7 4.4	2.1 5.0	No change in the absolute liver weight	Plopper et al. (1983)

[a]1 to 61 weeks of exposure.
[b]62 to 124 weeks of exposure.

Green et al. (1983) and Plopper et al. (1983) reported no changes in liver weights of rats exposed to 2 mg/m^3 DPM for 7 h/day, 5 days/week for 52 weeks or of cats exposed to 6 to 12 mg/m^3, 8 h/day, 7 days/week for 124 weeks. The use of light and electron microscopy revealed that long-term inhalation of varying high concentrations of DE caused numerous alterations to the hepatic parenchyma of guinea pigs. A less sensitive index of liver toxicity, increased liver weight, failed to detect an effect of DE on the liver of the rat and cat following long-term exposure to DE. These results are too limited to understand potential impacts on the liver.

5.1.3.3.8. ***Blood and cardiovascular systems.*** Several studies have evaluated the effects of DE exposure on hematological and cardiovascular parameters of laboratory animals. These studies are summarized in Table 5-11. Standard hematological indices of toxicological effects on red and white blood cells failed to detect dramatic and consistent responses. Erythrocyte (RBC) counts were reported as being unaffected in cats (Pepelko and Peirano, 1983), rats and monkeys (Lewis et al., 1989), guinea pigs and rats (Penney et al., 1981), and rats (Karagianes et al., 1981); lowered in rats (Heinrich et al., 1982); and elevated in rats (Ishinishi et al., 1988; Brightwell et al., 1986). Mean corpuscular volume was significantly increased in monkeys, 69 versus 64 (Lewis et al., 1989), and hamsters (Heinrich et al., 1982), and lowered in rats (Ishinishi et al., 1988). The only other parameters of erythrocyte status and related events were lowered mean corpuscular hemoglobin and mean corpuscular hemoglobin concentration in1 rats (Ishinishi et al., 1988), a 3% to 5% increase in carboxyhemoglobin saturation in rats (Karagianes et al., 1981), and a suggestion of an increase in prothrombin time (Brightwell et al., 1986). The biological significance of these findings regarding adverse health effects is deemed to be inconsequential.

Three investigators (Pepelko and Peirano, 1983; Lewis et al., 1989; Brightwell et al., 1986) reported an increase in the percentage of banded neutrophils in cats and rats. This effect was not observed in monkeys (Lewis et al., 1989). The health implications of an increase in abnormal maturation of circulating neutrophils are uncertain but indicate a toxic response of leukocytes following exposures to DE. Leukocyte counts were reported to be reduced in hamsters (Heinrich et al., 1982); increased in rats (Brightwell et al., 1986); and unaffected in cats, rats, and monkeys (Pepelko and Peirano, 1983; Ishinishi et al., 1988; Lewis et al., 1989). These inconsistent findings indicate that the leukocyte counts are more indicative of the clinical status of the laboratory animals than any direct effect of exposure to DE.

No significant changes in heart mass were found in guinea pigs or rats exposed to DE (Wiester et al., 1980; Penney et al., 1981; Lewis et al., 1989). Rats exposed to DE showed a greater increase in the medial wall thickness of pulmonary arteries of differing diameters and

Table 5-11. Effects of exposure to diesel exhaust on the hematological and cardiovascular systems of laboratory animals

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg \cdot h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Monkey, Cynomolgus, M	7 h/day 5 days/week 104 weeks	2 0.23–0.36 μm MDD	7,280	11.5	1.5	0.8	Increased MCV	Lewis et al. (1989)
Rat, F344, M, F	7 h/day 5 days/week 104 weeks	2 0.23–0.36 μm MDD	7,280	11.5	1.5	0.8	Increase in banded neutrophils; no effect on heart or pulmonary arteries	Lewis et al. (1989) Vallyathan et al. (1986)
Guinea Pig, Hartley, M, F	20 h/day 7 days/week 8 weeks	6.3[a] 6.8[b]	7,056 7,616	17.4 16.7	2.3 2.9	2.1 1.9	No effect on heart mass or ECG; small decrease in heart rate (IE only)	Wiester et al. (1980)
Hamster, Syrian, M, F	7-8 h/day 5 days/week 75 weeks	3.9 0.1 μm MDD	10,238-11,700	18.5	1.2	3.1	At 29 weeks, lower erythrocyte count; increased MCV; reduced leukocyte count	Heinrich et al. (1982)
Rat, F344; Guinea Pig, Hartley	20 h/day 5.5 days/week 78 weeks	0.25 0.75 1.5 0.19 μm MDD	2,145 6,435 12,870	3.0 4.8 6.9	0.11 0.27 0.49	— — —	No changes in heart mass or hematology at any exhaust level or duration of exposure in either species	Penney et al. (1981)
Rat, Wistar, M	6 h/day 5 days/week 78 weeks	8.3 0.71 μm MDD	19,422	50.0	4-6	—	3% increase in COHb	Karagianes et al. (1981)
Rat, F3444/Jcl, M, F	16 h/day 6 days/week 130 weeks	0.11[c] 0.41[c] 1.08[c] 2.31[c] 3.72[d] 0.1 μm MDD	1,373 5,117 13,478 28,829 46,426	1.23 2.12 3.96 7.10 12.9	0.08 0.26 0.70 1.41 3.00	0.38 1.06 2.42 4.70 4.57	At higher concentrations, RBC, Hb, Hct slightly elevated; MCV and mean corpuscular hemoglobin and concentration were lowered	Ishinishi et al. (1988)
Rat, F344	16 h/day 5 days/week 104 weeks	0.7 2.2 6.6	5,824 18,304 54,912	— — 32.0	— — —	— — —	Increases in RBC, Hb, Hct, and WBC, primarily banded neutrophils; suggestion of an increase in prothrombin time; increased heart/body weight and right ventricular/heart ratios and decreased left ventricular contractility in 6.6 mg/m^3 group	Brightwell et al. (1986)
Cat, Inbred, M	8 h/day 7 days/week 124 weeks	6.0[e] 12.0[f]	41,664 83,328	20.2 33.3	2.7 4.4	2.1 5.0	Increases in banded neutrophils; significant at 12 mo, but not 24 mo	Pepelko and Peirano (1983)

[a]Nonirradiated DE.
[b]Irradiated DE.
[c]Light-duty engine.
[d]Heavy-duty engine.
[e]1 to 61 weeks of exposure.
[f]62 to 124 weeks of exposure.

Key: MCV = Mean corpuscular volume.

right ventricular wall thickness; these increases, however, did not achieve statistically significant levels (Vallyathan et al., 1986). Brightwell et al. (1986) reported increased heart/body weight and right ventricular/heart weight ratios and decreased left ventricular contractility in rats exposed to 6.6 mg/m^3 DPM for 16 h/day, 5 days/week for 104 weeks.

The effects of DPM on the endothelium-dependent relaxation (EDR) of vascular smooth muscle cells have been investigated (Ikeda et al., 1995, 1998). Incubation of rat thoracic aortae with suspensions of DPM (10-100 μg/mL) markedly attenuated acetylcholine-induced EDR. The mechanism of this effect was studied further in cultured porcine endothelial cells (CPE). A 10-min incubation of CPE with DPM (0.1-100 μg/mL) inhibited endothelium-dependent relaxing factor (EDRF) or nitric oxide (NO) release. A 10-min incubation of DPM with NO synthase inhibited formation of NO_2^-, a product of NO metabolism. The authors concluded that DPM, at the concentrations tested, neither induced cell damage nor inhibited EDRF release from CPE, but scavenged and thereby blocked the physiological action of NO.

5.1.3.3.9. ***Serum chemistry.*** A number of investigators have studied the effects of exposure to DE on serum biochemistry, and no consistent effects have been found. Such studies are summarized in Table 5-12.

The biological significance of changes in serum chemistry reported by Lewis et al. (1989) in female but not male rats exposed at 2 mg/m^3 DPM for 7 h/day, 5 days/week for 104 weeks is difficult to interpret. Not only were the effects noted in one sex (females) only, but the serum enzymes, lactate dehydrogenase (LDH), serum glutamic-oxaloacetic transaminase (SGOT), and serum glutamic-pyruvic transaminase (SGPT), were elevated in the control group, a circumstance contrary to denoting organ damage in the exposed female rats. The elevations of liver-related serum enzymes in the control versus the exposed female rats appear to be a random event among these aged subjects. The incidence of age-related disease, such as mononuclear cell leukemia, can markedly affect such enzyme levels, seriously compromising the usefulness of a comparison to historical controls. The serum sodium values of 144 versus 148 mmol/L in control and exposed rats, respectively, although statistically different, would have no biological significance.

The increased serum enzyme activities, alkaline phosphatase, SGOT, SGPT, gamma-glutamyl transpeptidase, and decreased cholinesterase activity suggest an impaired liver; however, such an impairment was not established histopathologically (Heinrich et al., 1982; Ishinishi et al., 1988; Brightwell et al., 1986). The increased urea nitrogen, electrolyte levels, and gamma globulin concentration and reduction in total blood proteins are indicative of impaired kidney function. Again, there was no histopathological confirmation of impaired kidneys in these studies.

Table 5-12. Effects of chronic exposures to diesel exhaust on serum chemistry of laboratory animals

Species/sex	Exposure period	Particles (mg/m^3)	C × T (mg·h/m^3)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, F344, M, F	7 h/day 5 days/week 104 weeks	2.0 0.23 0.36 µm MDD	7,280	11.5	1.5	0.8	Decreased phosphate, LDH, SGOT, and SGPT; increased sodium in females but not males	Lewis et al. (1989)
Hamster, Syrian, M, F	7-8 h/day 5 days/week 75 weeks	3.9 0.1 µm MDD	10,238-11,700	18.5	1.2	3.1	After 29 weeks, increases in SGOT, LDH, alkaline phosphatase, gamma-glutamyl transferase, and BUN	Heinrich et al. (1982)
Rat, F344/JcL, M, F	16 h/day 6 days/week 130 weeks	0.11[a] 0.41[a] 1.08[a] 2.31[a] 3.72[b] 0.19–0.28 µm MDD	1,373 5,117 13,478 28,829 46,426	1.23 2.12 3.96 7.10 12.9	0.08 0.26 3.96 7.10 3.00	0.38 1.06 2.42 4.70 4.57	Lower cholinesterase activity in males in both the light-and heavy-duty series and elevated gamma globulin and electrolyte levels in males and females in both series	Research Committee for HERP Studies (1988)
Rat, F344; Hamster, Syrian	16 h/day 5 days/week 104 weeks	0.7 2.2 6.6	5,824 18,304 54,912	— — 32.0	— — —	— — —	Rats, 6.6 mg/m^3, reduction in blood glucose, blood proteins, triglycerides, and cholesterol; increase in BUN, alkaline phosphate alamine, and aspartate aminotransferases (SGPT and SGOT); hamsters, 6.6 mg/m^3, decrease in potassium, LDH, aspartate amino-transferase; increase in albumin and gamma-glutamyl transferase	Brightwell et al. (1986)
Cat inbred, M	8 h/day 7 days/week 124 weeks	6.0[c] 12.0[d]	41,664 83,328	20.2 33.3	2.7 4.4	2.1 5.0	BUN unaltered; SGOT and SGPT unaffected; LHD increase after 1 year of exposure	Pepelko and Peirano (1983)

[a]Light-duty engine.
[b]Heavy-duty engine.
[c]1 to 61 weeks of exposure.
[d]62 to 124 weeks of exposure.

Key:
- LDH = Lactate dehydrogenase.
- SGOT = Serum glutamic-oxaloacetic transaminase.
- BUN = Blood urea nitrogen.
- SGPT = Serum glutamic-pyruvic transaminase.

Clinical chemistry studies suggest impairment of both liver and kidney functions in rats and hamsters chronically exposed to high concentrations of DE. The absence of histopathological confirmation, the appearance of such effects near the end of the lifespan of the laboratory animal, and the failure to find such biochemical changes in cats exposed to a higher dose, however, tend to discredit the probability of hepatic and renal hazards to humans exposed at atmospheric levels of DE.

5.1.3.3.10. ***Effects on microsomal enzymes.*** Several studies have examined the effects of DE exposure on microsomal enzymes associated with the metabolism and possible activation of xenobiotics, especially polynuclear aromatic hydrocarbons (PAH). These studies are summarized in Table 5-13. Lee et al. (1980) measured the activities of aryl hydrocarbon hydroxylase (AHH) and epoxide hydrase (EH) in liver, lung, testis, and prostate gland of adult male rats exposed to 6.32 mg/m^3 DPM 20 h/day for 42 days. Maximal significant AHH activities (pmol/min/mg microsomal protein) occurred at different times during the exposure period, and differences between controls and exposed rats, respectively, were as follows: prostate 0.29 versus 1.31, lung 3.67 versus 5.11, and liver 113.9 versus 164.0. There was no difference in AHH activity in the testis between exposed and control rats. Epoxide hydrase activity was not significantly different from control values for any of the organs tested.

Pepelko and Peirano (1983) found no statistically significant differences in liver microsomal cytochrome P448-450 levels and liver microsomal AHH between control and diesel-exposed mice at either 6 or 8 mo of exposure. Small differences were noted in the lung microsomal AHH activities, but these were believed to be artifactual differences, due to increases in nonmicrosomal lung protein present in the microsomal preparations. Exposures to 6 mg/m^3 DPM were for 8 h/day, 7 days/week.

Rabovsky et al. (1984) investigated the effect of chronic exposure to DE on microsomal cytochrome P450-associated benzo[*a*]pyrene (B[*a*]P) hydroxylase and 7-ethoxycoumarin deethylase activities in rat lung and liver. Male rats were exposed for 7 h/day, 5 days/week for 104 weeks to 2 mg/m^3 DPM. The exposure had no effect on B[*a*]P hydroxylase or 7-ethoxycoumarin deethylase activities in lung or liver. In related studies, Rabovsky et al. (1986) examined the effects of DE on viral induced enzyme activity and interferon production in female mice. The mice were exposed for 7 h/day, 5 days/week for 1 mo to DE diluted to achieve a concentration of 2 mg/m^3 DPM. After the exposure, the mice were inoculated intranasally with influenza virus. Changes in serum levels of interferon and liver microsomal activities of 7-ethoxycoumarin, ethylmorphine demethylase, and nicotinamide adenine dinucleotide

Table 5-13. Effects of chronic exposures to diesel exhaust on microsomal enzymes of laboratory animals

Species/sex	Exposure period	Particles (mg/m^3)	C × t (mg·h/m^3)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, F344, M	—	—	—	—	—	—	Intratracheal administration of DPM extract required doses greater than 6 mg/m^3 before the lung AHH was barely doubled; liver AHH activity was unchanged	Chen (1986)
Mouse, CD-1, F	7 h/day 5 days/week 4 weeks	2.0 0.2–0.36 μm mdd	280	11.5	1.5	0.8	Mice inoculated intranasally with influenza virus had smaller increases in ethylmorphine demethylase activity on days 2 to 4 postvirus infection and abolition of day 4 postinfection increase in NADPH-dependent cytochrome c reductase	Rabovsky et al. (1986)
Rat, Sprague-Dawley, M	20 h/day 7 days/week 1-7 weeks	6.3	882-6,174	17.4	2.3	2.1	AHH induction occurred in lung, liver, and prostate gland but not in testes; maximum significant activities occurred at different times; liver has greatest overall activity, percent increase highest in prostate; expoxide hydrase activity was unaffected	Lee et al. (1980)
Rat, F344, M	20 h/day 5.5 days/week 4, 13, 26, or 39 weeks 20 h/day 5.5 days/week 4, 13, 26, or 39 weeks	0.75 1.5 0.19 μm mdd 0.75 1.5 0.19 μm mdd	330-6,435 330-6,435	4.8 7.5 4.8 7.5	— — — —	— — — —	Inhalation exposure had no significant effect on liver AHH activity; lung AHH activity was slightly reduced after 6-mo exposure to 1.5 mg/m^3 DPM; an ip dose of dp extract, estimated to be equivalent to inhalation exposure, had no effect on AHH activity in liver and lungs; cyt. P-50 was unchanged in lungs and liver following inhalation or ip administration	Chen and Vostal (1981)
Rat, F344, F	7 h/day 5 days/week 12, 26, or 104 weeks	2.0 0.23-0.36 μm mdd	840-7,280	11.5	1.5	0.8	No effect on B[*a*]p hydrolase or 7-exthoxycoumarin deethylase activities in the liver	Rabovsky et al. (1984)
Rat, F344, M	20 h/day 5.5 days/week 8-53 weeks	0.25 1.5 0.19 μm mdd	220-8,745	2.9 7.5	— —	— —	After 8 weeks, no induction of cyt. P-450, cyt. P-448, or NADPH-dependent cyt. c reductase; after 1 year of exposure, liver microsomal oxidation of B[*a*]p was not increased; 1 year of exposure to either 0.25 or 1.5 mg/m^3 DPM impaired lung microsomal metabolism of B[*a*]p	Navarro et al. (1981)
Mouse, A/J, M	8 days/week 7 days/week 26 or 35 weeks	6.0	17.4	17.4	2.3	2.1	No differences in lung and liver AHH activities and liver P-448, P-450 levels	Pepelko and Peirano (1983)

AHH = aryl hydrocarbon hydroxylase.
B[*a*]p = benzo[*a*]pyrene.

phosphate (NADPH)-dependent cytochrome c reductase were measured. In the absence of viral inoculation, exposure to DE had no significant effects on the activity levels of the two liver microsomal monooxygenases and NADPH-dependent cytochrome c reductase. Exposure to DE produced smaller increases in ethylmorphine demethylase activity on days 2 to 4 postvirus infection and also abolished the day 4 postinfection increase in NADPH-dependent cytochrome c reductase when compared with nonexposed mice. These data suggested to the authors that the relationship that exists between metabolic detoxification and resistance to infection in unexposed mice was altered during a short-term exposure to DE.

Chen and Vostal (1981) measured the activity of AHH and the content of cytochrome P450 in the lungs and livers of rats exposed by inhalation of DE or intraperitoneal (i.p.) injection of a dichloromethane extract of DPM. In the inhalation exposures, the exhaust was diluted to achieve concentrations of 0.75 or 1.5 mg/m^3 DPM, and the exposure regimen was 20 h/day, 5.5 days/week for up to 9 mo. The concentration of total hydrocarbons and particle-phase hydrocarbons was not reported. Parenteral administration involved repeated injections at several dose levels for 4 days. Inhalation exposure had no significant effect on liver microsomal AHH activity; however, lung AHH activity was slightly reduced after 6 mo exposure to 1.5 mg/m^3. An i.p. dose of DPM extract, estimated to be equivalent to the inhalation exposure, had no effect on AHH activity in liver or lungs. No changes were observed in cytochrome P450 contents in lungs or liver following inhalation exposure or i.p. treatment. Direct intratracheal administration of a dichloromethane DPM extract required doses greater than 6 mg/kg body weight before the activity of induced AHH in the lung was barely doubled; liver AHH activity remained unchanged (Chen, 1986).

In related studies, Navarro et al. (1981) evaluated the effect of exposure to DE on rat hepatic and pulmonary microsomal enzyme activities. The same exposure regimen was employed (20 h/day, 5.5 days/week, for up to 1 year), and the exhaust was diluted to achieve concentrations of 0.25 and 1.5 mg/m^3 DPM (a few studies were also conducted at 0.75 mg/m^3). After 8 weeks of exposure, there was no evidence for the induction of cytochrome P450, cytochrome P448, or NADPH-dependent cytochrome c reductase in rat liver microsomes. One year of exposure had little, if any, effect on the hepatic metabolism of B[*a*]P. However, 1 year of exposure to 0.25 and 1.5 mg/m^3 significantly impaired the ability of lung microsomes to metabolize B[*a*]P (0.15 and 0.02 nmole/30 min/mg protein, respectively, versus 0.32 nmole/30 min/mg protein for the controls).

There are conflicting results regarding the induction of microsomal AHH activities in the lungs and liver of rodents exposed to DE. One study reported induction of AHH activity in the lungs, liver, and prostate of rats exposed to DE containing 6.32 mg/m^3 DPM for 20 h/day for 42 days; however, no induction of AHH was observed in the lungs of rats and mice exposed to 6 mg/m^3 DPM for 8 h/day, 7 days/week for up to 8 mo or to 0.25 to 2 mg/m^3 for periods up to 2 years. Exposure to DE has not been shown to produce adverse effects on microsomal cytochrome P450 in the lungs or liver of rats or mice. The weight of evidence suggests that the absence of enzyme induction in the rodent lung exposed to DE is caused either by the unavailability of the adsorbed hydrocarbons or by their presence in quantities insufficient for enzyme induction.

5.1.3.3.11. ***Effects on behavior and neurophysiology***. Studies on the effects of exposure to DE on the behavior and neurophysiology of laboratory animals are summarized in Table 5-14. Laurie et al. (1978) and Laurie et al. (1980) examined behavioral alterations in adult and neonatal rats exposed to DE. Exposure for 20 h/day, 7 days/week, for 6 weeks to exhaust containing 6 mg/m^3 DPM produced a significant reduction in adult spontaneous locomotor activity (SLA) and in neonatal pivoting (Laurie et al., 1978). In a follow-up study, Laurie et al. (1980) found that shorter exposure (8 h/day) to 6 mg/m^3 DPM also resulted in a reduction of SLA in adult rats. Laurie et al. (1980) conducted additional behavioral tests on adult rats exposed during their neonatal period. For two of three exposure situations (20 h/day for 17 days postparturition, or 8 h/day for the first 28 or 42 days postparturition), significantly lower SLA was observed in the majority of the tests conducted on the adults after week 5 of measurement. When compared with control rats, adult 15-month-old rats that had been exposed as neonates (20 h/day for 17 days) also exhibited a significantly slower rate of acquisition of a bar-pressing task to obtain food. The investigators noted that the evidence was insufficient to determine whether the differences were the result of a learning deficit or due to some other cause (e.g., motivational or arousal differences).

These data are difficult to interpret in terms of health hazards to humans under ambient environmental conditions because of the high concentration of DE to which the laboratory rats were exposed. Additionally, there are no further concentration-response studies to assess at what exposure levels these observed results persist or abate. A permanent alteration in both learning ability and activity resulting from exposures early in life is a health hazard whose significance to humans should be pursued further.

Neurophysiological effects from exposure to DE were investigated in rats by Laurie and Boyes (1980, 1981). Rats were exposed to diluted DE containing 6 mg/m^3 DPM for 8 h/day, 7 days/week from birth up until 28 days of age. Somatosensory evoked potential, as elicited by a 1 mA electrical pulse to the tibial nerve in the left hind limb, and visual evoked potential, as elicited by a flash of light, were the endpoints tested. An increased pulse latency was reported for the rats exposed to DE, and this was thought to be caused by a reduction in the degree of

Table 5-14. Effects of chronic exposures to diesel exhaust on behavior and neurophysiology

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg{\cdot}h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, Sprague-Dawley, M	8 h/day 7 days/week 1-4 weeks	6	336-1,344	19	2.5	1.8	Somatosensory and visual evoked potentials revealed longer pulse latencies in pups exposed neonatally	Laurie and Boyes (1980, 1981)
Rat, Sprague Dawley, F	20 h/day 7 days week 6 weeks	6	5,040	19	2.5	1.8	Reduction in adult SLA and in neonatal pivoting	Laurie et al. (1978)
Rat, Sprague-Dawley, F	8 or 20 h/day 7 days/week 3, 4, 6, or 16 weeks	6	1,008-13,440	19	2.5	1.8	Reduction in SLA in adults; neonatal exposures for 20 or 8 h/day caused reductions in SLA. Neonatal exposures for 20 h/day for 17 days resulted in a slower rate of a bar-pressing task to obtain food	Laurie et al. (1980)

SLA = Spontaneous locomotor activity.

nerve myelinization. There was no neuropathological examination, however, to confirm this supposition.

Based on the data presented, it is not possible to specify the particular neurological impairment(s) induced by the exposure to DE. Again, these results occurred following exposure to a high level of DE and no additional concentration-response studies were performed.

5.1.3.3.12. ***Effects on reproduction and development***. Studies of the effects of exposure to DE on reproduction and development are summarized in Table 5-15. Twenty rats were exposed 8 h/day on days 6 through 15 of gestation to diluted DE containing 6 mg/m^3 DPM (Werchowski et al., 1980a,b; Pepelko and Peirano, 1983). There were no signs of maternal toxicity or decreased fertility. No skeletal or visceral teratogenic effects were observed in 20-day-old fetuses (Werchowski et al., 1980a). In a second study, 42 rabbits were exposed to 6 mg/m^3 DPM for 8 h/day on gestation days 6 through 18. No adverse effects on body weight gain or fertility were seen in the does exposed to DE. No visceral or skeletal developmental abnormalities were observed in the fetuses (Werchowski et al., 1980b).

Pepelko and Peirano (1983) evaluated the potential for DE to affect reproductive performance in mice exposed from 100 days prior to exposure throughout maturity of the F_2 generation. The mice were exposed for 8 h/day, 7 days/week to 12 mg/m^3 DPM. In general, treatment-related effects were minimal. Some differences in organ and body weights were noted, but overall fertility and survival rates were not altered by exposure to DE. The only consistent change, an increase in lung weights, was accompanied by a gross pathological diagnosis of anthracosis. These data denoted that exposure to DE at a concentration of 12 mg/m^3 did not affect reproduction. See Section 5.3, which reports a lack of effects of exposure to DE on rat lung development (Mauderly et al., 1987b).

Several studies have evaluated the effect of exposure to DE on sperm. Lewis et al. (1989) found no adverse sperm effects (sperm motility, velocity, densities, morphology, or incidence of abnormal sperm) in monkeys exposed for 7 h/day, 5 days/week for 104 weeks to 2 mg/m^3 DPM. In another study in which A/Strong mice were exposed to DE containing 6 mg/m^3 DPM for 8 h/day for 31 or 38 weeks, no significant differences were observed in sperm morphology between exposed and control mice (Pereira et al., 1981). It was noted, however, that there was a high rate of spontaneous sperm abnormalities in this strain of mice, and this may have masked any small positive effect. Quinto and De Marinis (1984) reported a statistically significant and dose-related increase in sperm abnormalities in mice injected intraperitoneally for 5 days with 50, 100, or 200 mg/kg of DPM suspended in corn oil. A significant decrease in sperm number was seen at the highest dose, but testicular weight was unaffected by the treatment.

Table 5-15. Effects of chronic exposures to diesel exhaust on reproduction and development in laboratory animals

Species/sex	Exposure period	Particles (mg/m^3)	C × T ($mg \cdot h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Mouse, [C57BL]/ 6XC3H]F_1, M	5 days	50, 100, or 200 mg/kg in corn oil; i.p. injection	—	—	—	—	Dose-related increase in sperm abnormalities; decrease in sperm number at highest dose; testicular weights unaffected	Quinto and De Marinis (1984)
Rat, Sprague-Dawley, F	8 h/day 7 days/week 1.7 weeks	6	571	20	2.7	2.1	No signs of maternal toxicity or decreased fertility; no skeletal or visceral teratogenic effects in 20-day-old fetuses	Werchowski et al. (1980a) Pepelko and Peirano (1983)
Rabbit, New Zealand Albino, F	8 h/day 7 days/week 1.9 weeks	6	638	20	2.7	2.1	No adverse effects on maternal weight gain or fertility; no skeletal or visceral teratogenic effects in the fetuses	Werchowski et al. (1980a) Pepelko and Peirano (1983)
Monkey, Cynomolgus, M	7 h/day 5 days/week 104 weeks	2	7,280	11.5	1.5	0.8	No effects on sperm motility, velocity, density, morphology, or incidence of abnormalities	Lewis et al. (1989)
Mouse, A/Strong, M	8 h/day 7 days/week 31 or 38 weeks	6	10,416-12,768	20	2.7	2.1	No effect on sperm morphology; high rate of spontaneous sperm abnormalities may have masked small effects	Pereira et al. (1981)
Mouse, CD-1, M, F	8 h/day 7 days/week 6 to 28 weeks	12	4,032-18,816	33	4.4	5.0	Overall fertility and survival rates were unaffected in the three-generation reproductive study; only consistent change noted, an increase in lung weights, was diagnosed as anthracosis	Pepelko and Peirano (1983)

Watanabe and Oonuki (1999) investigated the effects of diesel engine exhaust on reproductive endocrine function in growing rats. The rats were exposed to whole diesel engine exhaust (5.63 mg/m^3 DPM, 4.10 ppm NO_2, and 8.10 ppm NO_x); a group was exposed to filtered exhaust without DPM, and a group was exposed to clean air. Exposures were for 3 mo beginning at birth (6 hrs/day for 5 days/week).

Serum levels of testosterone and estradiol were significantly higher and follicle-stimulating hormone significantly lower in animals exposed to whole DE and filtered exhaust compared to controls. Luteinizing hormone was significantly decreased in the whole-exhaust-exposed group as compared to the control and filtered groups. Sperm production and activity of testicular hyaluronidase were significantly reduced in both exhaust-exposed groups as compared to the control group. This study suggests that DE stimulates hormonal secretion of the adrenal cortex, depresses gonadotropin-releasing hormone, and inhibits spermatogenesis in rats. Because these effects were not inhibited by filtration, the gaseous phase of the exhaust appears more responsible than particulate matter for disrupting the endocrine system.

The effects of freshly generated DE particles on the reproductive system of male Fischer 344 rats were investigated by Tsukue et al. (2001). Groups (n=25) of 13-mo. old male rats were exposed to whole DE diluted to 0.33, 0.99 or 3.24 mg/m^3 (MMAD = 0.4 μm) for 8 months 12 hrs/day, 7 days/week. Subsequent to this exposure, evaluation of potential reproductive effect was performed, including measurement of reproductive organ weights, sperm characteristics and number, gonadotrophins, testosterone, and inhibin. Results showed either no effect or effects with an inconsistent dose-response character that typically were not different from controls even at the highest exposure concentration.

No teratogenic, embryotoxic, fetotoxic, or female reproductive effects were observed in mice, rats, or rabbits at exposure levels up to 12 mg/m^3 DPM. Effects on sperm morphology and number were reported in hamsters and mice exposed to high doses of DPM; however, no adverse effects were observed in sperm obtained from monkeys exposed at 2 mg/m^3 for 7 hrs/day, 5 days/week for 104 weeks. Concentrations of 12 mg/m^3 DPM did not affect male rat reproductive fertility in the F_0 and F_1 generation breeders. Thus, exposure to DE would not appear to be a reproductive or developmental hazard.

5.2. MODE OF ACTION OF DIESEL EXHAUST-INDUCED NONCANCER EFFECTS

5.2.1. Comparison of Health Effects of Filtered and Unfiltered Diesel Exhaust

There exist a total of four chronic toxicity studies of DE, in which the experimental protocol included exposing test animals to exhaust containing no particles. Comparisons were then made between the effects caused by whole, unfiltered exhaust and those caused by the gaseous components of the exhaust. Concentrations of components of the exposure atmospheres in these four studies are given in Table 5-16.

Heinrich et al. (1982) compared the toxic effects of whole and filtered DE on hamsters and rats. Exposures were at 3.9 mg/m^3 for 7 to 8 hrs/day and 5 days/week. Rats exposed for 24 mo to either whole or filtered exhaust exhibited no significant changes in respiratory frequency, respiratory minute volume, compliance or resistance as measured by a whole-body plethysmography, or heart rate. In the hamsters, histological changes (adenomatous proliferations) were seen in the lungs of animals exposed to either whole or filtered exhaust; however, in all groups exposed to the whole exhaust the number of hamsters exhibiting such lesions was significantly higher than for the corresponding groups exposed to filtered exhaust or clean air. Severity of the lesions was, however, not reported.

In a second study, Heinrich et al. (1986a, see also Stöber, 1986) compared the toxic effects of whole and filtered DE on hamsters, rats, and mice. The test animals (96 per test group) were exposed to 4.24 mg DPM/m^3 for 19 hrs/day, 5 days/week for 120 (hamsters and mice) or 140 (rats) weeks. Body weights of hamsters were unaffected by either exposure. Body weights of rats and mice were reduced by the whole exhaust but not by the filtered exhaust. Exposure-related higher mortality rates occurred in mice after 2 years of exposure to whole exhaust. After 1 year of exposure to the whole exhaust, hamsters exhibited increased lung weights, a significant increase in airway resistance, and a nonsignificant reduction in lung compliance. For the same time period, rats exhibited increased lung weights, a significant decrease in dynamic lung compliance, and a significant increase in airway resistance. Test animals exposed to filtered exhaust did not exhibit such effects. Histopathological examination indicated that different levels of response occurred in the three species. In hamsters, filtered exhaust caused no significant histopathological effects in the lung; whole exhaust caused thickened alveolar septa, bronchioloalveolar hyperplasia, and emphysematous lesions. In mice, whole exhaust, but not filtered exhaust, caused multifocal bronchioloalveolar hyperplasia, multifocal alveolar lipoproteinosis, and multifocal interstitial fibrosis. In rats, there were no significant morphological changes in the lungs following exposure to filtered exhaust. In rats exposed to whole exhaust, there were severe inflammatory changes in the lungs, thickened alveolar septa, foci of macrophages, crystals of cholesterol, and hyperplastic and metaplastic lesions. Biochemical studies of lung lavage fluids of hamsters and mice indicated that exposure to filtered exhaust caused fewer changes than did exposure to whole exhaust. The latter produced significant increases in lactate dehydrogenase, alkaline phosphatase, glucose-6-phosphate dehydrogenase (G6PDH), total protein, protease (pH 5.1), and collagen. The filtered exhaust had a slight but nonsignificant effect on G6PDH, total protein, and collagen. Similarly, cytological studies showed that while the filtered exhaust had no effect on differential cell

Table 5-16. Composition of exposure atmospheres in studies comparing unfiltered and filtered diesel exhaust[a]

Species/sex	Exposure[b] period		Particles (mg/m^3)	C × t ($mg{\cdot}h/m^3$)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	Effects	Study
Rat, Wistar, F; Hamster, Syrian	7 h/day 5 days/week 104 weeks	Uf F C	3.9 — —	14,196	18.5 18.0 —	1.2 1.0 —	3.1 2.8 —	No effect on pulmonary function or heart rate in rats; increases in pulmonary adenomatous proliferations in hamsters, UF significantly higher than F or C	Heinrich et al. (1982)
Rat, F344, F	8 h/day 7 days/week 104 weeks	Uf F[c] C	4.9 — —	28,538	7.0 — —	1.8 — —	13.1 — —	Body weight decrease after 6 mo in UF, 18 mo in f; lung/body rate weight rate higher in both groups at 24 mo; at 2 years, fibrosis and epithelial hyperplasia in lungs of uf; nominal lung and spleen histologic changes	Iwai et al. (1986)
Rat, F344, M, F; Hamster, Syrian, M, F	16 h/day 5 days/week 104 weeks	Uf Uf Uf F[d] C	0.7 2.2 6.6 — —	5,824 18,304 54,912	— — 32.0 32.0 1.0	— — — — —	— — — — —	Uf: elevated red and white cell counts, hematocrit and hemoglobin; increased heart/body weight and right ventricular/heart weight ratios; lower left ventricular contractility; changes in blood chemistry; obstructive and restrictive lung disease; F: no effects	Brightwell et al. (1986)
Rat, Wistar, F; Hamster, Syrian, F; Mouse NMRI, F	19 h/day 5 days/week 120 to 140 weeks	Uf F[d] C	4.24 — —	48,336 56,392	12.5 11.1 0.16	1.5 1.2 —	3.1 1.02 —	Uf: decreased body wt in rats and mice but not hamsters; increased mortality, mice only; decreased lung compliance and increased airway resistance, rats and hamsters; species differences in lung lavage enzymes and cell counts and lung histopathology and collagen content, most pronounced in rats; F: no effect on glucose-6-phosphate dehydrogenase, total protein, and lung collagen	Heinrich et al. (1986a)
Mouse, NMRI, F, C57BL/6N, F	18 h/day 5 days/week 23 mo (NMRI) 24 mo (C57BL/6N)	Uf F C	4.5 0.01 0.01	40,365	14.2 14.2 0.2	2.3 2.9 0.01	2.8 2.4 0.1	Uf: increased lung wet weight starting at 3 mo F: no noncancer effects reported	Heinrich et al. (1995)

[a]Man values.
[b]UF= unfiltered whole exhaust, F = filtered exhaust, C = control.
[c]Reported to have the same component concentrations as the unfiltered, except particles were present in undetectable amounts.
[d]Concentrations reported for high concentration level only.

counts, the whole exhaust resulted in an increase in leukocytes (161 ± 43.3/μL versus 55.7 ± 12.8/μL controls), a decrease in AMs (30.0 ± 12.5 versus 51.3 ± 12.5/μL in the controls), and an increase in granulocytes (125 ± 39.7 versus 1.23 ± 1.14/μL in the controls). All values presented for this study are the mean with its standard deviation. The differences were significant for each cell type. There was also a small increase in lymphocytes (5.81 ± 4.72 versus 3.01 ± 1.23 μL in the controls).

Iwai et al. (1986) exposed rats (24 per group) to whole or filtered DE 8 h/day, 7 days/week for 24 mo. The whole exhaust was diluted to achieve a concentration of 4.9 ± 1.6 mg/m^3 DPM. Body weights in the whole exhaust group began to decrease after 6 mo and in both exposed groups began to decrease after 18 mo when compared with controls. Lung-to-body weight ratios of the rats exposed to the whole exhaust showed a significant increase (p<0.01) after 12 mo in comparison with control values. Spleen-to-body weight ratios of both exposed groups were higher than control values after 24 mo. After 6 mo of exposure to whole exhaust, DPM accumulated in AMs, and Type II cell hyperplasia was observed. After 2 years of exposure, the alveolar walls had become fibrotic with mast cell infiltration and epithelial hyperplasia. In rats exposed to filtered exhaust, after 2 years there were only minimal histologic changes in the lungs, with slight hyperplasia and stratification of bronchiolar epithelium and infiltration of atypical lymphocytic cells in the spleen.

Brightwell et al. (1986) evaluated the toxic effects of whole and filtered DE on rats and hamsters. Three exhaust dilutions were tested, producing concentrations of 0.7, 2.2, and 6.6 mg/m^3 DPM. The test animals (144 rats and 312 hamsters per exposure group) were exposed for five 16-h periods per week for 2 years. The four exposure types were gasoline, gasoline catalyst, diesel, and filtered diesel. The results presented were limited to statistically significant differences between exhaust-exposed and control animals. The inference from the discussion section of the paper was that there was a minimum of toxicity in the animals exposed to filtered DE: "It is clear from the results presented that statistically significant differences between exhaust-exposed and control animals are almost exclusively limited to animals exposed to either gasoline or unfiltered diesel exhaust." Additional results are described in Section 5.1.3.3.

Heinrich et al. (1995) exposed female NMRI and C57BL/6N mice to a DE dilution that resulted in a DPM concentration of 4.5 mg/m^3 and to the same dilution after filtering to remove the particles. This study is focused on the carcinogenic effects of DPM exposure, and inadequate information was presented to compare noncancer effects in filtered versus unfiltered exhaust.

A comparison of the toxic responses in laboratory animals exposed to whole exhaust or filtered exhaust containing no particles demonstrates across studies that when the exhaust is sufficiently diluted to limit the concentrations of gaseous irritants (NO_2 and SO_2), irritant vapors (aldehydes), CO, or other systemic toxicants, the diesel particles are the prime etiologic agents of noncancer health effects, although additivity or synergism with the gases cannot be ruled out. These toxic responses are both functional and pathological and represent cascading sequelae of lung pathology based on concentration and species. The diesel particles plus gas exposures produced biochemical and cytological changes in the lung that are much more prominent than those evoked by the gas phase alone. Such marked differences between whole and filtered DE are also evident from general toxicological indices, such as decreases in body weight and increases in lung weights, pulmonary function measurements, and pulmonary histopathology (e.g., proliferative changes in Type II cells and respiratory bronchiolar epithelium, fibrosis). Hamsters, under equivalent exposure regimens, have lower levels of retained DPM in their lungs than rats and mice do and, consequently, less pulmonary function impairment and pulmonary pathology. These differences may result from lower DPM inspiration and deposition during exposure, greater DPM clearance, or lung tissue less susceptible to the cytotoxicity of deposited DPM.

5.2.2. Mode of Action for the Noncarcinogenic Effects of DPM

As noted in Chapter 2, diesel emissions are a complex mixture that includes both a vapor phase and a particle phase. The particle phase consists of poorly soluble carbon particles on the surfaces of which are adsorbed a large number of organic and inorganic compounds. Although the effects to be discussed are considered attributable to the particle phase (termed diesel particulate matter or DPM), additive or synergistic effects due to the vapor phase cannot be totally discounted. This may be especially so in the human studies and the animal toxicology studies where exposure is to various dilutions of diesel emissions, or in the in vitro studies in which the test material was captured by filtration.

The mechanisms by which DPM is inhaled, deposited, and cleared from the respiratory tract are discussed in Chapter 3. DPM deposited upon airway surfaces may be cleared from the respiratory tract completely, or may be translocated to other sites within the respiratory system. In rats, the pathogenic sequence following the deposition of inhaled DPM begins with the interaction of DPM with airway epithelial cells and phagocytosis by AMs. The airway epithelial cells and activated AMs release chemotactic factors that attract neutrophils and additional AMs. As the lung burden of DPM increases, there is an aggregation of particle-laden AMs in alveoli adjacent to terminal bronchioles, increases in the number of Type II cells lining particle-laden alveoli, and the presence of particles within alveolar and peribronchial interstitial tissues and associated lymph nodes.

The macrophages engulfing the DPM may release cytokines, growth factors, and proteases, which may cause inflammation, cell injury, cell proliferation, hyperplasia, and fibrosis. This is especially true under lung overload conditions occurring in laboratory rats when the rate of deposition exceeds the rate of alveolar clearance. This phenomenon is described in

Chapter 3. The mechanisms leading to the generation of oxygen radicals and subsequent lung injury are described in Chapter 7, Section 7.4.3.

DPM is a poorly soluble particle whose rate of clearance by dissolution is likely insignificant compared to its rate of clearance as an intact particle. The organic material adsorbed to the surface is desorbed from the DPM and may enter into metabolic reactions and be activated and enter into reactions with other macromolecules or be detoxified and excreted (Figure 7-1). The diesel particle may be cleared directly by the clearance mechanisms described in Chapter 3.

The organic material desorbed from the particle (described in Chapter 7, Section 7.4.7) appears to be associated with the immunological changes described above. The potential adjuvant effects of DPM have also been studied. The results indicate that the nonextractable particle core and the organic matter adsorbed to the core both contribute to the adjuvant activity of DPM. Further, it is possible that any of the plethora of compounds present in the organic fraction of DPM, including various PAH, may elicit this response.

Thus, the available evidence indicates that DPM has the potential to produce pathological and immunological changes in the respiratory tract. Moreover, the magnitude of these responses is determined by the dose delivered to the respiratory tract and is attributable to both the carbon core and the adsorbed organic materials.

5.3. INTERACTIVE EFFECTS OF DIESEL EXHAUST

A multitude of factors may influence the susceptibility to exposure to DE as well as the resulting response. Some of these have already been discussed in detail (e.g., the composition of DE and concentration-response data); others will be addressed in this section (e.g., the interaction of DE with factors particular to the exposed individual and the interaction of DE components with other airborne contaminants).

In a study discussed already in this chapter, Mauderly et al. (1990a) compared the susceptibility of normal rats and rats with preexisting laboratory-induced pulmonary emphysema exposed for 7 h/day, 5 days/week for 24 mo to DE containing 3.5 mg/m^3 DPM or to clean air (controls). Emphysema was induced in one-half of the rats by intratracheal instillation of elastase 6 weeks before exhaust exposure. Measurements included lung burdens of DPM, respiratory function, bronchoalveolar lavage, clearance of radiolabeled particles, pulmonary immune responses, lung collagen, excised lung weight and volume, histopathology, and mean linear intercept of terminal air spaces. None of the data for the 63 parameters measured suggest that rats with emphysematous lungs were more susceptible than rats with normal lungs to the effects of DE exposure. In fact, each of the 14 emphysema-exhaust interactions detected by statistical analysis of variance indicated that emphysema acted to reduce the effects of DE exposure. DPM accumulated much less rapidly in the lungs of emphysematous rats than in those of normal rats. The mean lung burdens of DPM in the emphysematous rats were 39%, 36%, and 37% of the lung burdens of normal rats at 12, 18, and 24 mo, respectively. No significant interactions were observed among lung morphometric parameters. Emphysema prevented the exhaust-induced increase for three respiratory indices of expiratory flow rate at low lung volumes, reduced the exhaust-induced increase in nine lavage fluid indicators of lung damage, prevented the expression of an exhaust-induced increase in lung collagen, and reduced the exhaust-induced delay in DPM clearance.

Mauderly et al. (1987b) evaluated the relative susceptibility of developing and adult rat lungs to damage by exposure to DE. Rats (48 per test group) were exposed to DE containing 3.5 mg/m^3 DPM and about 0.8 ppm NO_2. Exposures were for 7 h/day, 5 days/week through gestation to the age of 6 mo, or from the age of 6 to 12 mo. Comparative studies were conducted on respiratory function, immune response, lung clearance, airway fluid enzymes, protein and cytology, lung tissue collagen, and proteinases in both age groups. After the 6-mo exposure, adult rats, compared with controls, exhibited (1) more focal aggregates of particle-containing AMs in the alveolar ducts near the terminal bronchioles, (2) a sixfold increase in the neutrophils (as a percentage of total leukocytes) in the airway fluids, (3) a significantly higher number of total lymphoid cells in the pulmonary lymph nodes, (4) delayed clearance of DPM and radiolabeled particles ($t_{1/2}$ = 90 days versus 47 days for controls), and (5) increased lung weights. These effects were not seen in the developing rats. On a weight-for-weight (milligrams of DPM per gram of lung) basis, DPM accumulation in the lungs was similar in developing and adult rats immediately after the exposure. During the 6-mo postexposure period, DPM clearance was much more rapid in the developing rats, approximately 2.5-fold. During postexposure, diesel particle-laden macrophages became aggregated in the developing rats, but these aggregations were located primarily in a subpleural position. The authors concluded that exposure to DE, using pulmonary function, structural (qualitative or quantitative) biochemistry as the indices, did not affect the developing rat lung more severely than the adult rat lung.

As a result of the increasing trend of using diesel-powered equipment in coal mining operations and the concern for adverse health effects in coal miners exposed to both coal dust or coal mine dust and DE, Lewis et al. (1989) and Karagianes et al. (1981) investigated the interaction of coal dust and DE. Lewis et al. (1989) exposed rats, mice, and cynomolgus monkeys to (1) filtered ambient air, (2) 2 mg/m^3 DPM, (3) 2 mg/m^3 respirable coal dust, and (4) 1 mg/m^3 of both DPM and respirable coal dust. Gaseous and vapor concentrations were identical in both DE exposures. Exposures were for 7 h/day, 5 days/week for up to 24 mo. Synergistic effects between DE and coal dust were not demonstrated; additive toxic effects were the predominant effects noted.

Karagianes et al. (1981) exposed rats (24 per group) to DE containing 8.3 mg/m^3 of DPM alone or in combination with about 6 mg/m^3 of coal dust. No synergistic effects were found between DE and coal dust; additive effects in terms of visual dust burdens in necropsied lungs were related to dose (i.e., length of exposure and airborne particulate concentrations).

The health effects of airborne contaminants from sources other than diesel engines may be altered in the presence of DPM by their adsorption onto the diesel particles. When adsorbed onto diesel particles, the gases and vapors can be transported and deposited deeper into the lungs, and because they are more concentrated on the particle surface, the resultant cytotoxic effects or physiological responses may be enhanced. Nitrogen dioxide adsorbed onto carbon particles caused pulmonary parenchymal lesions in mice, whereas NO_2 alone produced edema and inflammation but no lesions (Boren, 1964). Exposure to formaldehyde and acrolein adsorbed onto carbon particles (1 to 4 μm) resulted in the recruitment of PMNs to tracheal and intrapulmonary epithelial tissues but not when the aldehydes were tested alone (Kilburn and McKenzie, 1978).

Madden et al. (2000) observed that O_3 exposure increased the bioactivity of DPM. DPM, preexposed to O_3 for 48 h or nonozone-exposed DPM (1 to 500 μg), was instilled into the lungs of laboratory rats. Lung inflammation and injury were examined 24 h after instillation by lung lavage. DPM pre-exposed to 0.1 PPM O_3 was more potent in increasing neutrophilia, lavage total protein, and LDH compared to unexposed DPM. Treatment of DPM with higher concentrations of O_3 (1.0 PPM) decreased the bioactivity of the particles.

There is no direct evidence that DE, at concentrations found in the ambient environment, interacts with other substances in the exposure environment or the physiological status of the exposed subject other than impaired resistance to respiratory tract infections. Although there is experimental evidence that gases and vapors can be adsorbed onto carbonaceous particles, enhancing the toxicity of these particles when deposited in the lung, there is no evidence for an increased health risk from such interactions with DPM under urban atmospheric conditions. Likewise, there is no experimental evidence in laboratory animals that the youth or preexisting emphysema of an exposed individual enhances the risk of exposure to DE.

5.4. COMPARATIVE RESPONSIVENESS AMONG SPECIES TO THE HISTOPATHOLOGIC EFFECTS OF DIESEL EXHAUST

There is some evidence indicating that species may differ in pulmonary responses to DE. Mauderly (1994) compared the pulmonary histopathology of rats and mice after 18 mo of exposure to DE. There was less aggregation of macrophages in mice. Diffuse septal thickening was noted in the mice, but there were few inflammatory cells, no focal fibrosis, little epithelial hyperplasia, and no epithelial metaplasia, as was observed in rats. Heinrich et al. (1986a) reported that wet lung weight of hamsters increased only 1.8-fold following chronic exposure to DE, compared with an increase of 3.4-fold in rats. Smaller increases in neutrophils, lactic acid dehydrogenase, collagen, and protein supported the conclusion of a lesser inflammatory response in Syrian hamsters. The histopathologic changes in the lungs of Chinese hamsters after 6 mo exposure to DE, on the other hand, was similar to that of rats (Pepelko and Peirano, 1983). Guinea pigs respond to chronic DE exposure with a well-defined epithelial proliferation, but it is based on an eosinophilic response in contrast to the neutrophil-based responses in other species. Epithelial hyperplasia and metaplasia were quite striking in the terminal and respiratory bronchioles of cats exposed for 27 mo to DE (Plopper et al., 1983). This study is of particular interest because the terminal airways of cats are more similar to those of humans than rodent species are. It should be noted, however, that exposure concentrations were very high (12 mg/m^3) for most of the period. Lewis et al. (1989) exposed rats and cynomolgus monkeys 8 h per day, 5 days per week for 2 years to DE at a particle concentration of 2 mg/m^3. Unfortunately, this exposure rate was sufficiently low that few effects were noted in either species other than focal accumulations of particles, primarily in the alveolar macrophages, interstitium, and lymphoid tissue. It is apparent that species do vary in their pulmonary responses to DE exposure, despite the difficulty in making direct comparisons because of differences in exposure regimes, lifespans, and pulmonary anatomy. Most species do respond, however, suggesting that humans are likely to be susceptible to induction of pulmonary pathology during chronic exposure to DE at some level.

5.5. DOSE-RATE AND PARTICULATE CAUSATIVE ISSUES

The purpose of animal toxicological experimentation is to elucidate mechanisms of action and identify the hazards and dose-response effects posed by a chemical substance or complex mixture and to extrapolate these effects to humans for subsequent health assessments. The cardinal principle in such a process is that the intensity and character of the toxic action are a function of the dose of the toxic agent(s) that reaches the critical site of action. The considerable body of evidence reviewed clearly denotes that major noncancerous health hazards may be presented to the lung following the inhalation of DE. Based on pulmonary function and histopathological and histochemical effects, a determination can be made concerning which dose/exposure rates of DE (expressed in terms of the DPM concentration) result in injury to the lung and which appear to elicit no effect. The inhalation of poorly soluble particles, such as those found in DE, increases the pulmonary particulate burden. When the dosing rate exceeds the ability of the pulmonary defense mechanisms to achieve a steady-state lung burden of particles, there is a slowing of clearance and the progressive retention of particles in the lung that can ultimately approach a complete cessation of lung clearance (Morrow, 1988). This phenomenon, which is reviewed in Chapter 3, has practical significance both for the interpretation of experimental inhalation data and for the prevention of disease in humans exposed to airborne particles.

The data for exposure intensities that cause adverse pulmonary effects demonstrate that they are less than the exposure intensities reported to be necessary to induce lung tumors. Using the most widely studied laboratory animal species and the one reported to be the most sensitive to tumor induction, the laboratory rat, the no-adverse-effect exposure intensity for adverse pulmonary effects was 56 $mg \cdot h \cdot m^{-3}$/week (Brightwell et al., 1986). The lowest-observed-effect level for adverse pulmonary effects (noncancer) in rats was 70 $mg \cdot h \cdot m^{-3}$/week (Lewis et al., 1989), and for pulmonary tumors, 122.5 $mg \cdot h \cdot m^{-3}$/week (Mauderly et al., 1987a). The results clearly show that noncancerous pulmonary effects are produced at lower exposure intensities than are pulmonary tumors. Such data support the position that inflammatory and proliferative changes in the lung may play a key role in the etiology of pulmonary tumors in exposed rats (Mauderly et al., 1990b).

The effects of DE on the developing lung and on a model of a preexisting disease state have been studied in rats (Mauderly et al., 1990a, 1987b). Mauderly et al. (1987b) showed that diesel did not affect the developing lung more severely than the adult rat lung, and in fact, that clearance was faster in the younger lung. Mauderly et al. (1990a) compared the pulmonary response to inhalation of DE in rats with elastase-induced emphysema with normal rats. They found that respiratory tract effects were not more severe in emphysematous rats and that the lung burden of particles was less in the compromised rat. These studies provide limited evidence that some factors that are often considered to result in a wider distribution of sensitivity among members of the population may not have this effect with diesel exposure. However, these studies have no counterpart in human studies and extrapolation to humans remains uncertain.

There is also the issue of whether the noncancerous health effects related to exposure to DE are caused by the carbonaceous core of the particle or substances adsorbed onto the core, or both.

Current understanding, derived primarily from studies in rats, suggests that much of the toxicity resulting from the inhalation of DE relates to the carbonaceous core of the particles. Several studies on inhaled aerosols demonstrate that lung reactions characterized by an appearance of particle-laden AMs and their infiltration into the alveolar ducts, adjoining alveoli, and tracheobronchial lymph nodes; hyperplasia of Type II cells; and the impairment of pulmonary clearance mechanisms are not limited to exposure to diesel particles. Such responses have also been observed in rats following the inhalation of coal dust (Lewis et al., 1989; Karagianes et al., 1981), titanium dioxide (Heinrich et al., 1995; Lee et al., 1985), CB (Nikula et al., 1995; Heinrich et al., 1995), titanium tetrachloride hydrolysis products (Lee et al., 1986), quartz (Klosterkötter and Bünemann, 1961), volcanic ash (Wehner et al., 1986), amosite (Bolton et al., 1983), and manmade mineral fibers (Lee et al., 1988) among others. In more recent studies, animals have been exposed to CB that is similar to the carbon core of the DE particle. Nikula et al. (1995) exposed rats for 24 mo to CB or DE at target exposure concentrations of 2.5

and 6 mg/m^3 (exposure rates of 200 or 520 mg·h·m^{-3}/week). Both concentrations induced AM accumulation, epithelial proliferation, inflammation, and fibrosis. They observed essentially no difference in potency of nonneoplastic or in tumor responses based on a regression analysis.

Dungworth et al. (1994) reported moderate to severe inflammation characterized by multifocal bronchoalveolar hyperplasia, alveolar histiocytosis, and focal segmental fibrosis in rats exposed to CB for up to 20 mo at exposure rates of 510 to 540 mg·h·m^{-3}/week. The observed lung pathology reflects notable dose-response relationships and usually evolves in a similar manner. With increasing dose, there is an increased accumulation and aggregation of particle-laden AMs, Type II cell hyperplasia, a foamy (degenerative) macrophage response, alveolar proteinosis, alveolar bronchiolization, cholesterol granulomas, and often squamous cell carcinomas and bronchioalveolar adenomas derived from metaplastic squamous cells in the areas of alveolar bronchiolization.

Heinrich et al. (1995) compared effects of diesel exposure in rats and mice with exposure to titanium dioxide or carbon black. Exposures to TiO_2 and carbon black were adjusted during the exposure to result in a similar lung burden for the three types of particles. At similar lung burdens in the rat, DPM, TiO_2, and CB had nearly identical effects on lung weights and on the incidence of lesions, both noncancer and cancer. Also, a similar effect on clearance of a labeled test aerosol was measured for the different particles. A comparison of the effect of DPM, TiO_2, and carbon black exposures in mice also showed a similar effect on lung weight, but noncancer effects were not reported and no significant increase in tumors was observed.

Murphy et al. (1998) compared the toxicological effects of DPM with three other particles chosen for their differing morphology and surface chemistry. One mg each of well-characterized crystalline quartz, amorphous silica, CB, and DPM was administered to laboratory rats by a single intratracheal instillation. The laboratory rats were sacrificed at 48 h, and 1, 6, and 12 weeks after instillation. Crystalline quartz produced significant increases in lung permeability, persistent surface inflammation, progressive increases in pulmonary surfactant and activities of epithelial marker enzymes up to 12 wk after primary exposure. Amorphous silica did not cause progressive effects but did produce initial epithelial damage with permeability changes that regressed with time after exposure. By contrast, CB had little if any effect on lung permeability, epithelial markers, or inflammation. Similarly, DPM produced only minimal changes, although the individual particles were smaller and differed in surface chemistry from CB. The authors concluded that DPM is less damaging to the respiratory epithelium than is silicon dioxide, and that the surface chemistry of the particle is more important than ultrafine size in explaining biological activity.

These experiments provide strong support for the idea that DE toxicity results from a mechanism that is analogous to that of other relatively inert particles in the lung. This qualitative similarity exists along with some apparent quantitative differences in the potency of various particles for producing effects on the lung or on particle clearance.

The exact relationship between toxicity and particle size within the ultrafine particle mode, including DPM (BéruBé et al., 1999), remains unresolved. Studies reviewed in the PM CD (U.S. EPA, 1996) suggest a greater inherent potential toxicity of inhaled ultrafine particles. Exposure to ultrafine particles may increase the release of proinflammatory mediators that could be involved in lung disease. For example, Driscoll and Maurer (1991) compared the effects of fine (0.3 μm) and ultrafine (0.02 μm) TiO_2 particles instilled into the lungs of laboratory rats. Although both size modes caused an increase in the numbers of AMs and PMNs in the lungs, and release of TNF and fibronectin by AMs, the responses were greater and more persistent with the ultrafine particles. While fine particle exposure resulted in a minimally increased prominence of particle-laden macrophages associated with alveolar ducts, ultrafine particle exposure produced a somewhat greater prominence of macrophages, some necrosis of macrophages, and slight interstitial inflammation of the alveolar duct region. Moreover, collagen increased only with exposure to ultrafine particles.

Oberdörster et al. (1992) compared the effects of fine (0.25 μm) and ultrafine (0.02 μm) TiO_2 particles instilled into the lungs of laboratory rats on various indicators of inflammation. Instillation of ultrafine particles increased the number of total cells recovered by lavage, decreased the percentage of AMs, and increased the percentage of PMNs and protein. Instillation with fine particles did not cause statistically significant effects. Thus, the ultrafine particles had greater pulmonary inflammatory potency than did larger sizes of this material. The investigators attributed the enhanced toxicity to greater interaction of the ultrafine particles with their large surface area, with alveolar and interstitial macrophages, which resulted in enhanced release of inflammatory mediators. They suggested that ultrafine particles of low in vitro solubility appear to enter the interstitium more readily than do larger sizes of the same material, which accounted for the increased contact with macrophages in this compartment of the lung. Driscoll and Maurer (1991) noted that the pulmonary retention of ultrafine TiO_2 particles instilled into rat lungs was greater than for the same mass of fine-mode TiO_2 particles. Thus, the available evidence tends to suggest a potentially greater toxicity for inhaled ultrafine particles.

Particle size, volume, surface area, and composition may be the critical elements in the overload phenomenon following exposure to particles, which could explain those quantitative differences. The overloaded AMs secrete a variety of cytokines, oxidants, and proteolytic enzymes that are responsible for inducing particle aggregation and damaging adjacent epithelial tissue (Oberdörster, 1994). For a more detailed discussion of mechanism, see Chapter 3.

On the basis of currently available laboratory animal data, the principal noncancerous health hazard to humans posed by exposure to DE is a structural or functional injury to the lung. Such effects are demonstrable at dose rates or cumulative doses of DPM lower than those reported to be necessary to induce lung tumors in rats. An emerging human health issue concerning short-term exposure to ambient DE/DPM is the potential for allergenic responses in several studies. Heightened allergenic responses including increased cytokine production as well as increased numbers of inflammatory cells have been detected in nasal lavage from humans exposed to inhaled or instilled DE/DPM. In individuals already allergic to ragweed, exposure to DE/DPM with the allergen was observed to result in an enhanced allergenic response, particularly IgE production. Current knowledge indicates that the carbonaceous core of diesel particles is the major causative factor in the injury to the lung and that other factors such as the cytotoxicity of adsorbed substances on the particles also may play a role. The lung injury appears to be mediated through effects on pulmonary AMs. Because noncancerous pulmonary effects occur at lower doses than tumor induction does in the rat, and because these effects may be cofactors in the etiology of DE-induced tumors, noncancerous pulmonary effects must be considered in the total evaluation of DE, notably the particulate component.

5.6. SUMMARY AND DISCUSSION

5.6.1. Effects of Diesel Exhaust on Humans

The most readily identified acute noncancer health effect of DE on humans is its ability to elicit subjective complaints of eye, throat, and bronchial irritation and neurophysiological symptoms such as headache, lightheadedness, nausea, vomiting, and numbness and tingling of the extremities. Studies of the perception and offensiveness of the odor of DE and a human volunteer study in an exposure chamber have demonstrated that the time of onset of the human subjective symptoms is inversely related to increasing concentrations of DE and the severity is directly related to increasing concentrations of DE. In one study in which a diesel engine was operated under varying load conditions, a dilution factor of 140 to 475 was needed to reduce the exhaust level to an odor-detection threshold level.

A public health issue is whether short-term exposure to DE might result in an acute decrement in ventilatory function and whether the frequent repetition of such acute respiratory effects could result in chronic lung function impairment. One convenient means of studying acute decrements in ventilatory function is to monitor differences in pulmonary function in occupationally exposed workers at the beginning and end of a workshift. In studies of underground miners, bus garage workers, dockworkers, and locomotive repairmen, increases in respiratory symptoms (cough, phlegm, and dyspnea) and decreases in lung function (FVC, FEV_1, PEFR, and FEF_{25-75}) over the course of a workshift were generally found to be minimal and not statistically significant. In a study of acute respiratory responses in diesel bus garage workers, there was an increased reporting of cough, labored breathing, chest tightness, and wheezing, but no reductions in pulmonary function were associated with exposure to DE. Pulmonary function was affected in stevedores over a workshift exposure to DE but normalized after a few days without exposure to DE fumes. In a third study, there was a trend toward greater ventilatory function changes during a workshift among coal miners, but the decrements were similar in miners exposed and not exposed to DE.

Smokers appeared to demonstrate larger workshift respiratory function decrements and increased incidence of respiratory symptoms. Acute sensory and respiratory symptoms were earlier and more sensitive indicators of potential health risks from diesel exposure than were decrements in pulmonary function. Studies on the acute health effects of exposure to DE in humans, experimental and epidemiologic, have failed to demonstrate a consistent pattern of adverse effects on respiratory morbidity; the majority of studies offer, at best, equivocal evidence for an exposure-response relationship. The environmental contaminants have frequently been below permissible workplace exposure limits; in those few cases where health effects have been reported, the authors have failed to identify conclusively the individual or collective causative agents in the DE.

Chronic effects of DE exposure have been evaluated in epidemiologic studies of occupationally exposed workers (metal and nonmetal miners, railroad yard workers, stevedores, and bus garage mechanics). Most of the epidemiologic data indicate an absence of an excess risk of chronic respiratory disease associated with exposure to DE. In a few studies, a higher prevalence of respiratory symptoms, primarily cough, phlegm, or chronic bronchitis, was observed among the exposed. These increased symptoms, however, were usually not accompanied by significant changes in pulmonary function. Reductions in FEV_1 and FVC and, to a lesser extent, FEF_{50} and FEF_{75}, also have been reported. Two studies detected statistically significant decrements in baseline pulmonary function consistent with obstructive airway disease. One study of stevedores had a limited sample size of 17 exposed and 11 controls. The second study in coal miners showed that both underground and surface workers at diesel-use mines had somewhat lower pulmonary performance than their matched controls. The proportion of workers in or at diesel-use mines, however, showed equivalent evidence of obstructive airway disease, and for this reason the authors of the second paper felt that factors other than diesel exposure might have been responsible. A doubling of the prevalence of minor restrictive airway disease was also observed in workers in or at diesel-use mines. These two studies, coupled with other reported nonsignificant trends in respiratory flow-volume measurements, suggest that exposure to DE may impair pulmonary function among occupational populations. Epidemiologic studies of the effects of DE on organ systems other than the pulmonary system are scant. Whereas a preliminary study of the association of cardiovascular mortality and exposure to DE found a fourfold higher risk ratio, a more comprehensive epidemiologic study by the same investigators found no significant difference between the observed and expected number of deaths caused by cardiovascular disease.

Caution is warranted in the interpretation of results from the epidemiologic studies that have addressed noncarcinogenic health effects from exposure to DE. These investigations suffer from myriad methodological problems, including (1) incomplete information on the extent of exposure to DE, necessitating in some studies estimations of exposures from job titles and resultant misclassification; (2) the presence of confounding variables such as smoking or occupational exposures to other toxic substances (e.g., mine dusts); and (3) the short duration and low intensity of exposures. These limitations restrict drawing definitive conclusions as to the cause of any noncarcinogenic DE effect, observed or reported.

It is also apparent that at some level of exposure DE as measured by DPM appears to have the potential to induce airway inflammation in humans without disease. Also, in one other study peripheral blood changes were noted. An emerging area of concern is the immunological changes that have been documented in response to DE exposure and the potential relationship of these changes to the explosive growth of asthma in human populations.

5.6.2. Effects of Diesel Exhaust on Laboratory Animals

Laboratory animal studies of the toxic effects of DE have involved acute, subchronic, and chronic exposure regimens. In acute exposure studies, toxic effects appear to have been associated primarily with high concentrations of carbon monoxide, nitrogen dioxide, and aliphatic aldehydes. In short- and long-term studies, toxic effects have been associated with exposure to the complex exhaust mixture. Effects of DE in various animal species are summarized in Tables 5-2 to 5-15. In short-term studies, health effects related to function, when found, are mild and result from extremely high DPM concentrations of about 6 mg/m^3 and extensive durations of exposure approximating 20 h/day. There is ample evidence, however, that other pathophysiological effects such as accumulation of DPM in pulmonary tissues, evidence of inflammatory response, AM aggregation and accumulation near the terminal bronchioles, Type II cell proliferation, and the thickening of alveolar walls adjacent to AM aggregation do occur under short-term exposures at lower levels of DE. Little evidence exists, however, from short-term studies that exposure to DE impairs lung function. Chronic exposures cause lung pathology that results in altered pulmonary function and increased DPM retention in the lung. Exposures to DE have also been associated with increased susceptibility to respiratory tract infection, neurological or behavioral changes, an increase in banded neutrophils, and morphological alterations in the liver.

5.6.2.1. *Effects on Survival and Growth*

The data presented in Table 5-3 show limited effects on survival in mice and rats and some evidence of reduced body weight in rats following chronic exposures to concentrations of 1.5 mg/m^3 DPM or higher and exposure durations of 16 to 20 h/day, 5 days/week for 104 to

130 weeks. Increased lung weights and lung to body-weight ratios in rats, mice, and hamsters; an increased heart to body weight ratio in rats; and decreased lung and kidney weights in cats have been reported following chronic exposure to DE. No evidence was found of an effect of DE on other body organs (Table 5-4). The lowest-observed-effect level in rats approximated 1 to 2 mg/m^3 DPM for 7 h/day, 5 days/week for 104 weeks.

5.6.2.2. *Effects on Pulmonary Function*

Pulmonary function impairment has been reported in rats, hamsters, cats, and monkeys exposed to DE and included lung mechanical properties (compliance and resistance), diffusing capacity, lung volumes, and ventilatory performance (Table 5-5). The effects generally appeared only after prolonged exposures. The lowest exposure levels (expressed in terms of DPM concentrations) that resulted in impairment of pulmonary function occurred at 2 mg/m^3 in cynomolgus monkeys (the only level tested), 1.5 and 3.5 mg/m^3 in rats, 4.24 and 6 mg/m^3 in hamsters, and 11.7 mg/m^3 in cats. Exposures in monkeys, cats, and rats (3.5 mg/m^3) were for 7 to 8 h/day, 5 days/week for 104 to 130 weeks. While this duration is considered to constitute a lifetime study in rodents, it is a small part of the lifetime of a monkey or cat. Exposures in hamsters and rats (1.5 mg/m^3) varied in hours per day (8 to 20) and weeks of exposure (26 to 130). In all species but the monkey, the testing results were consistent with restrictive lung disease; alteration in expiratory flow rates indicated that 1.5 mg/m^3 DPM was a LOAEL for a chronic exposure (Gross, 1981). Monkeys demonstrated evidence of obstructive airway disease. The nature of the pulmonary impairment is dependent on the dose of toxicants delivered to and retained in the lung, the site of deposition and effective clearance or repair, and the anatomy and physiology of the affected species; these variables appear to be factors in the disparity of the airway disease in monkey versus the other species tested.

5.6.2.3. *Histopathological and Histochemical Effects*

Histological studies have demonstrated that chronic exposure to DE can result in effects on respiratory tract tissue (Table 5-6). Typical findings include alveolar histiocytosis, AM aggregation, tissue inflammation, increase in PMNs, hyperplasia of bronchiolar and alveolar Type II cells, thickened alveolar septa, edema, fibrosis, and emphysema. Lesions in the trachea and bronchi were observed in some studies. Associated with these histopathological findings were various histochemical changes in the lung, including increases in lung DNA, total protein, alkaline and acid phosphatase, glucose-6-phosphate dehydrogenase; increased synthesis of collagen; and release of inflammatory mediators such as leukotriene LTB and prostaglandin $PGF_{2\alpha}$. Although the overall laboratory evidence is that prolonged exposure to DPM results in histopathological and histochemical changes in the lungs of exposed animals, some studies have also demonstrated that there may be a threshold of exposure to DPM below which pathologic changes do not occur. These no-observed-adverse-effect levels for histopathological effects were reported to be 2 mg/m^3 for cynomolgus monkeys (the only concentration tested), 0.11 to 0.35 mg/m^3 for rats, and 0.25 mg/m^3 DPM for guinea pigs exposed for 7 to 20 h/day, 5 to 5.5 days/week for 104 to 130 weeks.

5.6.2.4. *Effects on Airway Clearance*

The pathological effects of DPM appear to be strongly dependent on the relative rates of pulmonary deposition and clearance (Table 5-7). Clearance of particles from the alveolar region of the lungs is a multiphasic process involving phagocytosis by AMs. Chronic exposure to DPM concentrations of about 1 mg/m^3 or above, under varying exposure durations, causes pulmonary clearance to be reduced, with concomitant focal aggregations of particle-laden AMs, particularly in the peribronchiolar and alveolar regions, as well as in the hilar and mediastinal lymph nodes. The exposure concentration at which focal aggregates of particle-laden AMs occur may vary from species to species, depending on rate of uptake and pulmonary deposition, pulmonary clearance rates, the relative size of the AM population per unit of lung tissue, the rate of recruitment of AMs and leukocytes, and the relative efficiencies for removal of particles by the mucociliary and lymphatic transport system. The principal means by which PM clearance is reduced is through a decrease in the function of pulmonary AMs. Impairment of particle clearance seems to be nonspecific and applies primarily to dusts that are persistently retained in the lungs. Lung dust levels of approximately 0.1 to 1 mg/g lung tissue appear to produce this effect in the Fischer 344 rat (Health Effects Institute, 1995). Morrow (1988) suggested that the inability of particle-laden AMs to translocate to the mucociliary escalator is correlated to an average composite particle volume per AM in the lung. When this particle volume exceeds approximately 60 μm^3 per AM in the Fischer 344 rat, impairment of clearance appears to be initiated. When the particulate volume exceeds approximately 600 μm^3 per cell, evidence suggests that AM-mediated particulate clearance virtually ceases, agglomerated particle-laden macrophages remain in the alveolar region, and increasingly nonphagocytized dust particles translocate to the pulmonary interstitium. Data for other laboratory animal species and humans are, unfortunately, limited.

5.6.2.5. *Neurological and Behavioral Effects*

Behavioral effects have been observed in rats exposed to DE from birth to 28 days of age (Table 5-14). Exposure caused a decreased level of spontaneous locomotor activity and a detrimental effect on learning in adulthood. In agreement with the behavioral changes was physiological evidence for delayed neuronal maturation. Exposures were to 6 mg/m^3 DPM for 8 h/day, 7 days/week from birth to about 7, 14, 21, or 28 days of age.

5.6.2.6. *Effects on Immunity and Allergenicity*

Several laboratory animal studies have indicated that exposure to DPM can reduce an animal's resistance to respiratory infection. This effect, which can occur even after only 2 or 6 h of exposure to DE containing 5 to 8 mg/m^3 DPM, does not appear to be caused by direct impairment of the lymphoid or splenic immune systems; however, in one study of influenza virus infection, interferon levels and hemaglutinin antibody levels were adversely affected in the exposed mice.

As with humans, there are animal data suggesting that DPM is a possible factor in the increasing incidence of allergic hypersensitivity. The effects have been demonstrated primarily in acute human and laboratory animal studies and appear to be associated with both the nonextractable carbon core and the organic fraction of DPM. It also appears that synergies with DPM may increase the potency of known airborne allergens. Both animal and human cell culture studies indicate that DPM also has the potential to act as an adjuvant.

5.6.2.7. *Other Noncancer Effects*

Essentially no effects (based on the weight of evidence of a number of studies) were noted for reproductive and teratogenic effects in mice, rats, rabbits, and monkeys; clinical chemistry and hematology in the rat, cat, hamster, and monkeys; and enzyme induction in the rat and mouse (Tables 5-11 through 5-13 and 5-15).

5.6.3. Comparison of Filtered and Unfiltered Diesel Exhaust

The comparison of the toxic responses in laboratory animals exposed to whole DE or filtered exhaust containing no particles demonstrates across laboratories that diesel particles are the principal etiologic agent of noncancerous health effects in laboratory animals exposed to DE (Table 5-16). Whether the particles act additively or synergistically with the gases cannot be determined from the designs of the studies. Under equivalent exposure regimens, hamsters have lower levels of retained DPM in their lungs than rats and mice do and consequently less pulmonary function impairment and pulmonary pathology. These differences may result from a lower intake rate of DPM, lower deposition rate and/or more rapid clearance rate, or lung tissue that is less susceptible to the cytotoxicity of DPM. Observations of a decreased respiration in hamsters when exposed by inhalation favor lower intake and deposition rates.

5.6.4. Interactive Effects of Diesel Exhaust

There is no direct evidence that DE interacts with other substances in an exposure environment, other than an impaired resistance to respiratory tract infections. Young animals were not more susceptible. In several ways, animals with laboratory-induced emphysema were more resistant. There is experimental evidence that both inorganic and organic compounds can be adsorbed onto carbonaceous particles. When such substances become affiliated with particles, these substances can be carried deeper into the lungs where they might have a more direct and potent effect on epithelial cells or on AM ingesting the particles. Few specific studies to test interactive effects of DE with atmospheric contaminants, other than coal dust, have been conducted. Coal dust and DPM had an additive effect only.

5.6.5. Conclusions

Conclusions concerning the principal human hazard from exposure to DE are as follows:

- Allergenic inflammatory disorders of the airways to responses typical of asthma have been demonstrated under short-term exposure scenarios to either DE or DPM. The evidence indicates that the immunological changes appear to be due to the DPM component of DE and that the immunological changes are caused by both the nonextractable carbon core and the adsorbed organic fraction of the diesel particle. The toxicological significance of these effects has yet to be resolved.
- Some occupational studies of acute exposure to DE during work shifts suggest that increased acute sensory and respiratory symptoms (cough, phlegm, chest tightness, wheezing) are more sensitive indicators of possible health risks from exposure to DE than pulmonary function decrements (which were consistently found not to be significantly associated with DE exposure)
- Noncancer effects in humans from long-term chronic exposure to DPM are not evident. Noncancer effects from long-term exposure to DPM of several laboratory animal species, conducted to assess the pathophysiologic effects of DPM in humans showed pulmonary histopathology (principally fibrosis) and chronic inflammation.

Although the mode of action of DE is not clearly evident for any of the effects documented in this chapter, the respiratory tract effects observed under acute scenarios are suggestive of an irritant mechanism, while lung effects observed in chronic scenarios indicate an underlying inflammatory response. Current knowledge indicates that the carbonaceous core of the diesel particle is the causative agent of the lung effects, with the extent of the injury being mediated at least in part by a progressive impairment of AMs. It is noted that lung effects occur in response to DE exposure in several species and occur in rats at doses lower than those inducing particle overload and a tumorigenic response (see above); it follows that lung effects such as inflammation and fibrosis are relevant in the development of risk assessments for DE.

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6. ESTIMATING HUMAN NONCANCER HEALTH RISKS OF DIESEL EXHAUST

6.1. INTRODUCTION

As discussed earlier in this document (Chapter 2, Section 2.2.7, 2.2.8), diesel engine exhaust (DE) consists of a complex mixture of gaseous pollutants and particles. In attempting to estimate potential health risks associated with human exposure to DE, researchers have focused attention mostly on the particulate matter (PM) components. They have done so, in part, by comparing the relative toxicity of unfiltered versus filtered DE (with gaseous components removed), as discussed in Chapter 5.

Diesel particulate matter (DPM) consists mainly of: (a) elemental carbon (EC) particles having relatively large surface areas, (b) soluble organic carbon, including 5-ring or higher polycyclic aromatic hydrocarbons (PAHs) such as benzo(*a*)pyrene, and other 3- or 4-ring compounds distributed between gas and particle phases, and (c) metallic compounds. DPM also typically contains small amounts of sulfate/sulfuric acid and nitrates, trace elements, and water, plus some unidentified components. DPM is made up almost entirely of fine particles (i.e., all below 1–3 µm) with a significant subset of ultrafine particles (i.e., those with a mass median diameter below about 0.1 µm).

Health concerns have long focused on DPM. Toxicological data described in Chapter 5 (Section 5.2) indicate DPM to be the prime etiologic agent of noncancer health effects when DE is sufficiently diluted to limit the concentrations of gaseous irritants (NO_2 and SO_2), irritant vapors (aldehydes), CO, or other systemic toxicants. The large surface areas of DPM allow for adsorption of organics from the diesel combustion process and for adsorption of additional compounds during transport in ambient air. The small size of DPM, combined with their large surface area, likely enhance the potential for subcellular interactions with important cellular components of respiratory tissues once the particles are inhaled by humans or other species (Johnston et al., 2000; Oberdörster et al., 2000).

The content of DPM as described above and in Chapter 2 is of clear toxicological significance. The experimental evidence described in Chapter 5 concerning DPM's association with and etiology of noncancer effects is extensive and compelling. These points, along with the fact that DPM is easily and most frequently measured and reported in toxicological studies of diesel emissions, make DPM a reasonable choice as a measure of diesel emissions. As a surrogate, DPM is as valid as any other component of DE to show what is currently known—and probably what is not yet known—about diesel emissions. Therefore, DPM is the quantitative focus of this chapter.

The usual agency approach to evaluating noncancer risks from inhaled exposures to toxic air pollutants such as ambient DE has been documented by EPA in the methods for derivation of an inhalation reference concentration (RfC) (U.S. EPA, 1994). For DPM exposures, this means combining key elements derived from evaluations of specific DPM noncancer effects in animals and humans (described in Chapter 5) with the use of quantitative dosimetry models (described in Chapter 3). The goal is to estimate DPM concentrations to which humans might be exposed throughout their lives (i.e., chronically) without experiencing any untoward or adverse effects. Such an effort can be accomplished through analysis of dose-response relationships where the adverse response is considered as a function of a corresponding measure of dose. Chapter 5 is replete with dose-response information on adverse (but nonlethal) noncancer health effects observed in long-term (chronic/lifetime) exposure studies to DE in general and to DPM in particular, albeit mostly in animals. Chapter 3 analyzes available methods to convert external exposure concentrations of DPM in animal studies to estimates of a human-equivalent concentration (HEC). The following sections of this chapter (Sections 6.2, 6.3, and 6.5) assess and integrate this information to derive a chronic RfC, using the above-cited methodology in developing dose-response assessments of the noncancer effects of toxic air pollutants.

Yet another approach to consider in deriving quantitative estimates of potential human health risks associated with ambient (nonoccupational) DPM exposures is the extent to which DPM could contribute to the adverse health effects that have been associated with exposure to ambient fine PM, $PM_{2.5}$. Such associations with adverse health effects are based primarily on epidemiologic studies evaluated in EPA's Air Quality Criteria Document for Particulate Matter (PM CD) (U.S. EPA, 1996a).[1] This PM CD served as the scientific basis for the last periodic review of the national ambient air quality standards (NAAQS) for PM, which resulted in the establishment of revised PM standards in 1997, including standards for $PM_{2.5}$. DPM is a component of ambient fine PM (see Chapter 2) and should be considered as a toxicologically important component of ambient fine PM. Any guidelines established for DPM, then, should be concordant with information on fine PM in general, as presented in the PM CD. To more fully consider the implications of the relationship between ambient DPM and fine PM, the epidemiological evidence on fine PM and the basis for the $PM_{2.5}$ standards are summarized, and the relationship between ambient DPM and fine PM is discussed later in this chapter (Section 6.4). This relationship is of interest with respect to the noncancer assessment of DE. As is noted here , however, and reflected in Sections 6.2–6.4 below, the definitions, procedures, and statutory mandates that apply to criteria pollutants such as PM (regulated through the establishment of

[1]A new PM CD is now being prepared to reflect the latest scientific studies on ambient PM available since the last document was completed.

NAAQS under sections 108 and 109 of the Clean Air Act) are fundamentally different from those that apply to toxic air pollutants such as DE and to the derivation of RfCs for such pollutants. Thus, the ambient $PM_{2.5}$ concentrations that are specified as the levels of the $PM_{2.5}$ NAAQS should not be compared directly with any RfC that may be derived for DPM. It is reasonable to observe, however, that the annual $PM_{2.5}$ standard would be expected to provide a measure of protection from DPM, reflecting DPM's current approximate proportion to $PM_{2.5}$.

Estimates of DE levels associated with effects occurring under less than lifetime exposure scenarios (such as acute exposure) are not addressed in this chapter. Studies of acute exposure to DE are discussed in Chapter 5, but are accompanied by scant dose-response information, with single-exposure studies for various specialized endpoints (e.g., allergenicity/adjuvancy) and other multiple-exposure-level studies reporting data on mortality only. Based on currently available methodologies, these studies do not yet appear to provide a sufficient basis from which to derive a dose-response assessment for an acute DE exposure scenario.

6.2. THE INHALATION REFERENCE CONCENTRATION APPROACH

Historically, approaches such as the Acceptable Daily Intake (ADI) were developed whereby effect levels, such as no-observed-adverse-effect levels (NOAELs) or lowest-observed-adverse-effect levels (LOAELs) from human or animal data, were combined with certain "safety factors" to accommodate areas of uncertainty to make quantitative estimates of a safe dose, i.e., a level at which no adverse effect would be likely to occur. In response to the National Academy of Sciences (NAS) report entitled "Risk Assessment in the Federal Government: Managing the Process" (National Research Council, 1983), EPA developed two approaches similar to the ADI, i.e., the oral reference dose (RfD) (Barnes and Dourson, 1988) and the parallel inhalation reference concentration, the RfC, with its formal methodology (U.S. EPA, 1994). Similar to the ADI in intent, the RfD/C approach is used for dose-response assessment of noncancer effects, using an explicitly delineated, rigorous methodology that adheres to the principles set forth in the 1983 NRC report. The RfC methodology includes comprehensive guidance on a number of complex issues, including consistent application to effect levels of uncertainty factors (UFs) rather than the ADI safety factors for consideration of uncertainty. Basically, these approaches attempt to estimate a likely subthreshold concentration in the human population. Use of the RfD/C approach is one of the principal current agency methods for deriving dose-response assessments.

A chronic RfC is currently defined as:

An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime.

The RfC approach involves the following general steps:

- Identification of a critical effect relevant to humans, i.e., an adverse effect that occurs at the lowest exposure/dose in human or animal studies and whose prevention avoids the occurrence of all other adverse effects;
- Selection of appropriate dose-response data to derive a point of departure (POD) for extrapolation of a key study (or studies) that provides a NOAEL, LOAEL, or benchmark concentration ($BMCL_x$)[2];
- Estimation of HECs when animal exposure-response data are used (via use of PBPK/dosimetry models);
- Application of UFs to the point of departure (e.g., NOAEL, LOAEL, $BMCL_x$) to address extrapolation uncertainties (e.g., interindividual variability, interspecies differences, adequacy of database); and
- Characterization of the “confidence” in the dose-response assessment and resultant RfC.

The basic quantitative formula for derivation of an RfC, given in Equation 6-1, has as its basic components an effect level, here a NOAEL, expressed as an HEC, and UFs. The units of an RfC are typically mg/m^3 or $\mu g/m^3$.

Alternatively, the numerator in Equation 6-1 may be a LOAEL or $BMCL_x$. The

$$RfC = \frac{NOAEL_{HEC}}{UF} \qquad (6\text{-}1)$$

benchmark concentration (BMC) approach and its application in this assessment are documented in Appendix B and described further below. Also, a modifying factor (MF) may be used in the denominator of this equation to account for scientific uncertainties, usually relating to the study chosen as the basis for the RfC. Further specifics of RfC derivation procedures are discussed as

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[2]$BMCL_x$ is defined as the lower 95% confidence limit of the dose that will result in a level of “x” response (e.g., $BMCL_{10}$ is the lower 95% confidence limit of a dose for a 10% increase in a particular response). See Appendix B for further specifics.

they are used in the following sections. All such procedures are described in detail in the RfC Methodology (U.S. EPA, 1994).

6.3. CHRONIC REFERENCE CONCENTRATION FOR DIESEL EXHAUST

As concluded in Chapter 5, chronic respiratory effects are the principal noncancer hazard to humans from long-term environmental exposure to DE. Other effects (e.g., neurological, liver-related) are observed in animal studies at higher exposures than those producing the respiratory effects. The human and animal data for the immunological effects of DE are currently considered inadequate for dose-response evaluation. Thus, the respiratory effects are considered the "critical effect" for the derivation of a chronic RfC for DE.

The evidence for chronic respiratory effects is based mainly on animal studies showing consistent findings of inflammatory, histopathological (including fibrosis), and functional changes in the pulmonary and tracheobronchial regions of laboratory animals, including the rat, mouse, hamster, guinea pig, and monkey. Occupational studies of DE provide some corroborative evidence of possible respiratory effects (e.g., respiratory symptoms and possible lung function changes), although those studies are generally deficient in exposure information.

Mode-of-action information about respiratory effects from DE exposure indicates that, at least in rats, the pathogenic sequence following the inhalation of DPM begins with the phagocytosis of diesel particles by alveolar macrophages (AMs). These activated AMs release chemotactic factors that attract neutrophils and additional AMs. As the lung burden of DPM increases, there are aggregations of particle-laden AMs in alveoli adjacent to terminal bronchioles, increases in the number of Type II cells lining particle-laden alveoli, and the presence of particles within alveolar and peribronchial interstitial tissues and associated lymph nodes. The neutrophils and AMs release mediators of inflammation and oxygen radicals, and particle-laden macrophages are functionally altered, resulting in decreased viability and impaired phagocytosis and clearance of particles. This series of events may result in pulmonary inflammation, fibrosis, and eventually lesions like those described in the studies reviewed in Chapter 5. Although information describing the possible pathogenesis of respiratory effects in humans is not available, the effects reported in studies of humans exposed to DE are not inconsistent with the findings in controlled laboratory animal studies.

Several reasons explain why the dose-response data from rats are considered especially appropriate for use in characterizing noncancer health effects in humans and deriving a chronic RfC for DE. First, similar noncancer respiratory effects are seen in other species (mouse, hamster, guinea pig, and monkey). Second, rats and humans exhibit similar noncancer responses (macrophage response and interstitial fibrosis) to other particles such as coal mine dust, silica, and beryllium (Haschek and Witschi, 1991; Oberdörster, 1994). Third, relative to other species there exists a plethora of long-term, specialized, and mechanistic studies in rats. Fourth, an expert panel convened by the International Life Sciences Institute (ILSI) recommended that response data on persistent, inflammatory processes may be used to assess nonneoplastic responses of poorly soluble particles (PSP) such as DPM (ILSI, 2000).

6.3.1. Principal Studies for Dose-Response Analysis: Chronic, Multiple-Dose Level Rat Studies

The experimental protocols and results from the long-term, repeated-exposure chronic studies demonstrating and characterizing the critical effects of pulmonary fibrotic changes and inflammation are discussed in Chapter 5. Salient points of these studies, including species/sex of the test species, the exposure regime and concentrations reported in mg DPM/m^3, and effect levels, are abstracted in Table 6-1 for further consideration. The effect levels are designated as N for no-observed-adverse-effect level, A for adverse-effect level, and $BMCL_{10}$.

The purpose of many of the chronic studies listed in this table was not the elucidation of the concentration-response character of DPM. The studies of Heinrich et al. (1982, 1986) in hamsters, mice, and rats; of Iwai et al. (1986) in rats; of Lewis et al. (1989) in monkeys; and of Pepelko (1982a) in rats are all single-dose-level analyses that have as their genesis mechanistic or species-comparative purposes. As discussed in Chapter 5, many of these studies do provide valuable supporting information for designation of the critical effect of pulmonary histopathology. The lack of any clear dose-response data, however, precludes consideration of these studies as a basis for RfC derivation.

Likewise, studies of chronic, multiple-level exposure involving species other than rats, i.e., hamsters (Pepelko, 1982b), cats (Plopper et al., 1983), and guinea pigs (Barnhart et al., 1981, 1982), provide cross-species corroboration of the critical effects of pulmonary histopathology and inflammatory alteration.

The remaining studies showing exposure-response relationships in rats for the critical effects include those of Ishinishi et al. (1986, 1988), Mauderly et al. (1987a), Heinrich et al. (1995), and Nikula et al. (1995). As described in Chapter 5, all of these studies were conducted and reported in a thorough, exhaustive manner on the critical effects and little, if any, basis exists for choosing one over another for purposes of RfC derivation. One way of taking advantage of this high degree of methodological and scientific merit would be to array data from all these studies and their effect levels (NOAEL, LOAEL, $BMCL_x$) subsequent to normalization of the exposure conditions, i.e., conversion of the exposure regimes to yield an HEC. This exercise would result in an interstudy concentration-response continuum normalized to a continuous human exposure to DPM that would facilitate the choice of a concentration to use as a point of departure in deriving an RfC.

Table 6-1. Histopathological effects of diesel exhaust in the lungs of laboratory animals

Study	Species/sex	Exposure period	Particles (mg/m^3)	Effect level[a]	Effects[b]
Lewis et al. (1989)	Monkey, Cynomolgus, M	7 h/day 5 days/wk 104 wks	2.0	N	AM aggregation; no fibrosis, inflammation, or emphysema
Bhatnagar et al. (1980) Pepelko (1982a)	Rat, F344, M, F	7 h/day 5 days/wk 104 wks	2.0		Multifocal histiocytosis; inflammatory changes; Type II cell proliferation; fibrosis
Pepelko (1982b)	Hamster, Chinese, M	8 h/day 5 days/wk 26 wks	6.0 12.0	A	Inflammatory changes; AM accumulation; thickened alveolar lining; Type II cell hyperplasia; edema; increase in collagen
Heinrich et al. (1982)	Hamster, Syrian, M, F	7-8 h/day 5 days/wk 120 wks	3.9	A	Inflammatory changes, 60% adenomatous cell proliferation
Iwai et al. (1986)	Rat, F344, F	8 h/day 7 days/wk 104 wks	4.9	A	Type II cell proliferation; inflammatory changes; bronchial hyperplasia; fibrosis
Mauderly et al. (1987a) Henderson et al. (1988)	Rat, F344, M, F; Mouse, CD-1, M, F	7 h/day 5 days/wk 130 wks	0.35 3.5 7.1	N A A	Alveolar and bronchiolar epithelial metaplasia in rats at 3.5 and 7.0 mg/m^3; fibrosis at 7.0 mg/m^3 in rats and mice; inflammatory changes; few quantitative data given
Heinrich et al. (1995)	Rat, Wistar, F; Mouse, NMRI, F (7 mg/m^3 only)	18 h/day 5 days/wk 24 mo	0.8 2.5 7.0	A A A	Bronchioalveolar hyperplasia, interstitial fibrosis in all groups; severity and incidence increase with exposure concentration; text given only
	Mouse, NMRI, F; C57BL/6N, F	18 h/day 5 days/wk 13.5 mo (NMRI) 24 mo (C57BL/N)	7.0	A	No increase in tumors; noncancer effects not discussed

Table 6-1. Histopathological effects of diesel exhaust in the lungs of laboratory animals (continued)

Study	Species/sex	Exposure period	Particles (mg/m^3)	Effect level[a]	Effects[b]
Ishnishi et al. (1986, 1988)	Rat, M, F, F344, /Jcl.	16 h/day 6 days/wk 130 wks	0.11[c] 0.41[c] 1.08[c] 2.32[c] 0.46[d] 0.96[d] 1.84[d] 3.72[d]	N N A A N A A A	Inflammatory changes; Type II cell hyperplasia and lung tumors seen at >0.4 mg/m^3; shortening and loss of cilia in trachea and bronchi; data given in text only
Heinrich et al. (1986)	Hamster, Syrian, M, F; Mouse, NMRI, F; Rat, Wistar, F	19 h/day 5 days/wk 120 wks	4.24	A	Inflammatory changes; thickened alveolar septa; bronchioloalveolar hyperplasia; alveolar lipo-proteinosis; emphysema (diagnostic methodology not described); hyperplasia; lung tumors
Barnhart et al. (1981, 1982); Vostal et al. (1981)	Guinea pig, Hartley, M	20 h/day 5.5 days/wk 104 wks	0.25 0.75 1.5 6.0	N A A A	Minimal response at 0.25 and ultrastructural changes at 0.75 mg/m^3; thickened alveolar membranes; cell proliferation; fibrosis at 6.0 mg/m^3; increase in PMN at 0.75 mg/m^3 and 1.5 mg/m^3
Plopper et al. (1983) Hyde et al. (1985)	Cat, inbred, M	8 h/day 7 days/wk 124 wks	6.0[c] 12.0[d]	A A	Inflammatory changes; AM aggregation; bronchiolar epithelial metaplasia; Type II cell hyperplasia; peribronchiolar fibrosis
Nikula et al. (1995)	Rat, F344, M	16 h/day 5 days/wk 23 mo	2.44 6.33	A, A $BMCL_{10}$	AM hyperplasia, epithelial hyperplasia, inflammation, septal fibrosis, bronchoalveolar metaplasia

[a]N= no-observed-adverse-effect level; A = adverse-effect level; $BMCL_{10}$ = benchmark concentration, lower limit, at a 10% response level (for incidence); see Appendix A for further specifics.
[b]AM = Alveolar macrophage; PMN = Polymorphonuclear leukocyte
[c]Light-duty engine.
[d]Heavy-duty engine.
[c]1 to 61 weeks exposure.
[d]62 to 124 weeks of exposure.
[e]See Appendix A.

6.3.2. Derivation of Human Continuous Equivalent Concentrations, HECs

Pharmacokinetic, or PK, models can be used to estimate across species the external concentrations of a toxicant that would result in equivalent internal doses. When used for these purposes, PK models may be termed comparative dosimetric models. Chapter 3 reviewed and evaluated a number of dosimetric models applicable to DPM. This analysis indicated that outputs from the human component of the model developed by Yu et al. (1991) specifically for DPM, such as deposition and estimated lung burden, were not substantially different from other available models. The analysis also demonstrated that the Yu model accounted for several diesel-specific phenomena, including particle overload lung clearance rates and interspecies kinetics of desorption of organics from the carbonaceous core of DPM, both slow- and fast-cleared. Of importance, the Yu model was parameterized for deposition and clearance in both animals and humans. Also, the animal component of the model was based on data from rats actually exposed to DPM, whereas other models analyzed used data based only on generic particles in the size range of DPM. It was concluded from this analysis that the Yu model could be used to estimate disposition of DPM both in animals and in humans and would therefore be an acceptable choice in performing animal-to-human extrapolation in deriving a continuous human-equivalent concentration. Note, however, that use of this or any other available PK model would address species differences in dose (i.e., pharmacokinetics, PK), and not necessarily pharmacodynamics (PD), the other component of uncertainty in animal-to-human or interspecies extrapolation (U.S. EPA, 1994).

Guidance on choosing measures of exposure for poorly soluble particles such as DPM (ILSI, 2000) states that some measures of external dose (e.g., the aerosol exposure parameters of MMAD, σ_g, particle surface area, and density) should be characterized. Likewise, some indication of internal dose resulting from the external exposure (e.g., lung burden) should be measured so that differences in dose metrics may be considered as new mechanistic insights are developed. The whole particle, as characterized in this assessment and used in the model of Yu et al. (1991), meets this recommended guidance, and DPM, in $\mu g/m^3$, is used as the measure of external exposure. Internal measures of exposure or dose were also considered in Chapter 3 (Section 3.3.1.1) with the conclusion that the dose metric of lung burden of DPM in terms of surface area (mg/cm^2) at the termination of the exposure period appears to be the most defensible and appropriate measure of internal dose, especially where clearance is involved. More detailed specifics are available in Chapter 3 and in Appendix A.

The logical and operational sequence of deriving a HEC using the Yu model and these metrics, i.e. external air concentration (in $\mu g/m^3$) and lung burden (in mg/cm^2), is demonstrated in Figure 6-1. First, the experimental animal exposures, including external concentration and

Figure 6-1. Flow diagram of procedure for calculating HECs.

daily and weekly duration, are entered into the animal component of the Yu model to estimate the animal lung burden, in mg DPM/cm^2, for the specific exposure scenario. The human component of the Yu model is then used by setting desired exposure conditions (continuous for 70 years) and running the model to find an external exposure DPM concentration that would result in this same lung burden. The human external DPM concentration matching this lung burden is the human-equivalent concentration. The step-by-step specifics and results of this procedure as applied to the various studies in Table 6-1 are shown in Table A-4 and fully explained in Appendix A.

The foregoing discussion does not address the variability in outcomes that may be estimated from the Yu et al. (1991) model from deposition of DPM. The model comparison exercises in Chapter 3 showed relatively minor differences among the various human models for one measure, deposition, and indicated that human lung burdens estimated by the human component of the Yu and ICRP66 models were nearly identical at low-exposure concentrations. Variability in output of their model (lung burden) was also examined by Yu and Yoon (1990), who studied dependency on tidal volume, respiration rate, and clearance (in terms of the overall particle transport rate from the alveolar region, λ_A). Analysis indicated that the model output is sensitive, but not overly so, for these determinative parameters. A ± 20% change in values for λ_A, for example, was estimated to result in a 16%–26% change in soot burden at a 0.1 mg/m^3 continuous diesel exposure for 10 years. For a ± 10% change in tidal volume, the model projected changes in soot burden ranging from 14% to 22% for this same exposure scenario. The fact that the changes in the model outcome were comparable to changes in the input parameters, such as tidal volume, indicates that the variability of the model when applied to the human population would reflect the variability of these physiological parameters across that population. In sum, at low concentrations of DPM (< 0.5 mg/m^3), relatively minor differences exist among the models currently available, and the input parameters in the human population may be a major source of variability. As discussed below, variability within the human population often is addressed by applying safety or uncertainty factors, usually in the range of 10 (Renwick and Lazarus, 1998; U.S. EPA, 1994).

6.3.3. Dose-Response Analysis—Choice of an Effect Level

HECs were obtained for the dose levels and exposure scenarios presented in the studies of Mauderly et al. (1987b), Ishinishi et al. (1986, 1988), Nikula et al. (1995), and Heinrich et al. (1995), the specifics of which are presented in Appendix A, specifically Table A-4. The HECs, along with the corresponding specific lung burdens in terms of $\mu g/cm^2$, were transcribed from Table A-4 and, along with the accompanying effect level (NOAEL, LOAEL or $BMCL_{10}$), are arrayed ordinally in Table 6-2. It is acknowledged that Table 6-2 is by no means a full portrayal of the dose-response relationship that may exist for DPM and health effects.

As indicated by the $BMCL_{10}$ values listed for the Nikula et al. (1995) study in Table 6-2, the BMC analysis was carried out on the DPM database and is documented in Appendix B. The chronic rat studies identified in this chapter were analyzed for information suitable for BMC analysis. Results yielded only a few datasets of pulmonary toxicity data from a single study, that of Nikula et al. (1995), that could be used for BMC analysis. These pulmonary data (histopathology incidence data) were extracted, HEC concentrations were calculated using the model of Yu, and the BMCs were generated. The results yielded a complex array of $BMCL_{10}$s from three different effects in two sexes (both separate and combined) with nine different models that were evaluated based on the nature of the dataset, on the goodness-of-fit parameters, and on visual inspection of the graphical outputs. From among all the benchmark data generated, the $BMCL_{10}$ of 0.37 mg/m^3 calculated from combined male and female rat pulmonary histopathology was judged as the most defensible choice. However, further characterization of this same benchmark value indicates that it is not a suitable candidate for use as a point of departure for development of a dose-response assessment such as the RfC. Limitations included the excessive extent of extrapolation from the observed experimental range (see Figure B-1 in Appendix B) and the paucity of data points (there were only two exposure groups) overall. Another serious limitation is that the high experimental concentrations used (and their $C \times t$ product) are well in the range where the problematic phenomenon of pulmonary overload in rats occurs (Section 5.1.3.3.4).

Inspection of Table 6-2 shows that calculating and ordering the HECs created a partial concentration-response continuum reflected in the estimated internal lung burden also given in this table. The continuum extends from HECs with no observed adverse effects at concentrations as low as 0.032 mg/m^3 to as high as 0.144 mg/m^3 to HECs with an adverse effect level that first appears definitively in the continuum probably at 0.33 mg/m^3 and extends out to 1.95 mg/m^3.

It should be noted that the relationship between HEC and lung burden is not consistently proportional. For example, at the lowest HEC listed, 0.032 mg/m^3, a lifetime (70 years) of continuous exposure to this concentration is estimated to result in a specific burden to the lung of 0.0587 $\mu g/cm^2$. At the other end of this spectrum, a lifetime of continuous exposure to 4.4

Table 6-2. Human equivalent continuous concentrations: 70-year HECs calculated with the model of Yu et al. (1991) from long-term studies of rats repeatedly exposed to DPM[a]

Study	Exposure concentration (mg/m^3)	Effect level[a]	Lung burden (modeled) (µg DPM /cm^2)[b]	HEC (mg/m^3)
Ishinishi et al. (1988) (LD[c])	0.11	NOAEL	0.0587	0.032
Mauderly et al. (1987a)	0.35	NOAEL	0.0685	0.038
Ishinishi et al. (1988) (LD[c])	0.41	NOAEL	0.245	0.128
Ishinishi et al. (1988) (HD[c])	0.46	NOAEL	0.281	0.144
Heinrich et al. (1995)	0.84	LOAEL	0.94	0.33
Nikula et al. (1995)	2.44 & 6.3[d]	$BMCL_{10}$ -inflam	1.34	0.37
Ishinishi et al. (1988) (HD[c])	0.96	LOAEL	3.16	0.883
Ishinishi et al. (1988) (LD[c])	1.18	LOAEL	4.50	1.25
Nikula et al. (1995)	2.44 & 6.3[d]	$BMCL_{10}$ - fibrosis	4.70	1.3
Mauderly et al. (1987a)	3.47	LOAEL	4.95	1.375
Nikula et al. (1995)	2.44	LOAEL	7.00	1.95
Ishinishi et al. (1988) (HD[c])	1.84	AEL	7.63	2.15
Heinrich et al. (1995)	2.5	AEL	8.40	2.35
Ishinishi et al. (1988) (LD[c])	2.32	AEL	9.75	2.75
Mauderly et al. (1987a)	7.08	AEL	10.9	3.05
Ishinishi et al. (1988) (HD[c])	3.72	AEL	15.8	4.4

[a]Effect levels are based on the critical effects of pulmonary histopathology and inflammation as reported in the individual studies. NOAEL: no-observed-adverse-effect level; LOAEL: lowest-observed-adverse-effect level; AEL: adverse-effect level; $BMCL_{10}$: lower 95% confidence estimate of the concentration of DPM associated with a 10% incidence of chronic pulmonary inflammation (inflam) or fibrosis (see Appendices A and B for more specifics).
[b]Lung burdens were derived from data generated from the animal portion of the Yu model using the concentration and duration scenario of each study. The human portion of the Yu model was then used to estimate the continuous, 70-year exposures that would result in this same lung burden, i.e., the HEC. See Table A-4 in Appendix A and accompanying text for further specifics on derivation.
[c]LD/HD = light-duty/heavy-duty diesel engine.
[d]These values are the actual exposure levels used in the Nikula study. These values were converted into HEC and entered into BMC equations to obtain the estimate of the $BMCL_{10}$ listed. The lung burdens for the two $BMCL_{10}$s listed here were derived by interpolation.

mg/m^3 is estimated to result in a specific lung burden of 15.8 µg/cm^2. This latter lung burden is disproportionally elevated compared with the burden estimated to result from exposure to the lowest concentration. Applying the absolute ratio of lung burden/HEC at the lowest HEC exposure (i.e., 0.0587/ 0.032 = 1.8) to the highest concentration would result in a lower lung burden, 4.4 × 1.8 = 7.9 µg/cm^2, which is much lower than the 15.8 µg/cm^2 indicated. This disproportionate increase in lung burden as a function of DPM concentration would be predicted from the assumption in the Yu model that the overload phenomena occurs in humans, as is demonstrated in Figure 3-9 in Chapter 3. Inspection of Table 6-2 shows that this disproportion between lung burden and HEC begins to be noticeable around 0.33 mg/m^3, at the HEC derived from the Heinrich et al. (1995) study. HECs below this value are not appreciably influenced by the overload/disproportionate lung burden phenomenon.

Inspection of the combined interstudy dose-response continuum in Table 6-2 to elucidate a point of departure for an RfC entails some interpretation. Exposures at the lower end of this table show that elevated chronic exposures to DPM consistently result in AELs. Conversely, entries in the upper portion of this table show that low-level chronic exposures to DPM have minimal, if any, effects within the capability of these studies to detect them. Intermediate chronic exposures, from 0.128 mg/m^3 to 0.9 mg/m^3, are, however, less clear and effect levels and exposures either have no or few observable effects, or effects that are minimally adverse.
In choosing from among levels (e.g., NOAELs, LOAELs, $BMCL_x$s) as a POD for derivation of an RfC, the methodology (U.S. EPA, 1994) provides guidance for choice of a highest no-effect level below an effect level; the interim guidance for the BMC suggests that for use as a point of departure, a benchmark (e.g., $BMCL_{10}$) should be within the range of the observable response data so as to avoid excessive extrapolation, and take the shape of the dose-response curve into consideration (Barnes et al., 1995; U.S. EPA, 1995). The highest no-effect HECs ($NOAEL_{HEC}$) in this table are 0.128 mg/m^3 and 0.144 mg/m^3 from the Ishinishi et al. (1988) study, nearly fivefold above other no-effect levels of 0.032 and 0.038 mg/m^3. The lower $BMCL_{10}$ (0.37 mg/m^3) is at nearly the same concentration as the lowest LOAEL of 0.33 mg/m^3 and thus may be too high an estimate for use as a POD based on these data. As discussed above, the limitations on this $BMCL_{10}$, including excessive extrapolation out of the observable range (see Appendix B for more specifics), make it a less than optimal candidate for consideration as a POD in the development of dose-response assessments and therefore was not used for this purpose in this assessment. However, this $BMCL_{10}$ (i.e., at a response rate of 0.1 or 10%) was generated directly from a modeled dose-response curve for chronic inflammation and lends credence to the other NOAELs in Table 6-2 as being associated with their respective dose-response curve at incidences of considerably less than 10%. Moreover, the HECs of less than 0.33 mg/m^3 are not appreciably influenced by the overload phenomenon (see above). Based on this analysis, the value of 0.144

mg/m^3 is chosen as the POD for development of the RfC, because it is the highest $NOAEL_{HEC}$ among those available.

6.3.4. Uncertainty Factors (UF) for the RfC—A Composite Factor of 30

Areas of uncertainty designated in the RfC that are relevant to the DPM assessment are interindividual variability and animal-to-human extrapolation. Each shall be addressed in this section.

Considerable qualitative but little, if any, quantitative information exists regarding subgroups that could be sensitive to any respiratory tract effects of DPM. It is acknowledged that exposure to DPM could be additive to many other daily or lifetime exposures to airborne organic compounds and nondiesel ambient PM. It is also likely that individuals who predispose their lungs to increased particle retention through smoking or other high particulate burdens, who have existing respiratory tract inflammation or infections, or who have chronic bronchitis, asthma, or fibrosis could be more susceptible to adverse impacts from DPM exposure (U.S. EPA, 1996a, Chapter 5 of this document). Also, infants and children could have a greater susceptibility to the acute/chronic toxicity of DPM because of their greater breathing frequency and consequent potential for greater particle deposition in the respiratory tract, which has not reached full development. Increased respiratory symptoms and decreased lung function in children versus ambient PM levels, of which DPM is a part, have been observed (U.S. EPA, 1996a). Thus, even though the limited evidence currently available (see Chapter 5) produces no clear evidence that children are especially sensitive to effects from breathing DPM, the possibility that they actually may be more susceptible because of their inherent physiology and anatomy should remain a consideration. Likewise, a number of factors may modify normal lung clearance, including, aging, gender, and disease. It should be noted that the results of Mauderly et al. (1989) discussed in Chapter 5 indicated that rats with diseased lungs (emphysematous) were no more susceptible than rats with normal lungs to the effects of DE exposure. Although the exact role of these factors is not resolved, all would influence the particle dose to the lung tissue from inhalation exposure. Activity patterns related to occupation and habitation in the proximity of major roadways are certain to be contributory for some subgroups in receiving higher DPM exposures (Chapter 2). In the absence of DE-specific data, this assessment relies on a default UF value of 10 to account for possible interindividual human variability (U.S. EPA, 1994; Renwick and Lazarus, 1998).

Application of an animal-to-human extrapolation or interspecies uncertainty factor to an assessment may be modified via a number of circumstances. When the assessment is based on human data, no such UF is necessary. When the assessment is based on animal data, as is the case with DPM, a default UF of 10 typically is applied to the animal effect level. This latter action implies that the effect observed in the animal study would occur in humans at a 10-fold lower concentration, ostensibly from some combination of pharmacokinetic and pharmacodynamic factors that would reflect greater dose (PK consideration) to the human target or greater sensitivity (PK consideration) of the human tissue.

The circumstances with DPM warrant modification away from application of the default UF for animal-to-human extrapolation. The first circumstance is the extensive effort in this assessment to address the pharmacokinetic component of the UF. The point of employing state-of-the-art lung dosimetry models with specific parameterization for DPM in conversion of animal exposures to human-equivalent exposures is to derive an estimate of interspecies pharmacokinetics; to know this aspect of interspecies difference with some degree of certainty. Having made this informed effort addresses a major portion of the PK component. It is acknowledged, however, that uncertainties about the model employed here (or any other model) persist. Although the model comparison shown in Chapter 3 indicates relatively minor variability in output among the various human models examined (see Table 3-3 and Figure 3-9) other sources of uncertainty and variability remain. These include, but are not limited to, matters such as the estimates if the model were applied to the general population or variability from the animal portion of the model(s). A second circumstance involves the pharmacodynamic or PD component of the interspecies UF, especially the aspect as to whether the experimental animal species used in the assessment is more or less sensitive than humans. In the consensus report of ILSI (2000) a specific recommendation is made concerning the PD aspect of the interspecies uncertainty factor for poorly soluble particles such as DPM. Because the pulmonary responses from DPM in the principal experimental species, the rat, are present under exposure conditions that do not appear to elicit any response in humans, the experimental species is considered more sensitive than humans. Accordingly, the report suggested that no accommodation be made for uncertainty concerning the pharmacodynamic component of the interspecies UF for DPM and presumably for any other PSP, as the rat appeared to be a sensitive species, more so even than the human. However, other information currently available on DPM suggests that, at least with regard to inflammatory effects, humans may indeed be as sensitive or even more so than rats. Section 5.1.1.1.3 discusses several studies where humans were exposed to airborne DPM and either precursors (Salvi et al., 2000; Nordenhall et al., 2000) or markers (Nightingale et al., 2000; Salvi et al.,1999) of inflammation were detected. These indicators of inflammation were in response to DPM levels of only 200–300 $\mu g/m^3$ of 1–2h duration. Note that in Table 6-2, NOAEL concentrations to which rats actually were exposed were only 100–400 $\mu g/m^3$, clearly within the range of the aforementioned human exposure levels. Thus, adverse effects (inflammation) have been shown to occur in humans at equivalent or possibly even lower levels of DPM than observed in rats, indicating that humans may indeed be at least as sensitive if not more so than rats.

The sum of these considerations on the animal-to-human UF is that, although major portions of uncertainty have been addressed, degrees of uncertainty persist in both the pharmacodynamic and pharmacokinetic components of the factor. In considering both this residual uncertainty and the information discussed above, it would be prudent to acknowledge partial degrees of uncertainty in both these areas with a partial uncertainty factor, i.e., $10^{0.5}$ vice 10^{1}, such that a factor of 3 would be applied for interspecies extrapolation.

In summary, the application of UFs for the two areas discussed above, interhuman and animal to human, would result in a composite uncertainty factor of 30, 10 for interhuman × 3 for animal to human. Use of other UFs, as discussed in the RfC methodology (U.S. EPA, 1994) for deficiencies in database or for duration extrapolation, is not considered necessary. It should be noted that, given the emerging research on DE-induced immunological effects, it may be necessary at a later date to reconsider the basis for selection of the critical effect and UFs and thus the entire derivation of the DE RfC.

6.3.5. Derivation of the RfC for Diesel Exhaust

On the basis of the above analysis, the value of 0.144 mg/m^3 DPM was selected as the point of departure for the RfC evaluation. This value was derived from concentrations in rat chronic studies that were modeled to obtain HECs. The pulmonary effects, histopathology and inflammation, were determined to be the critical noncancer effects. Response data on inflammation also were suggested by a specific scientific working group as a satisfactory surrogate for fibrogenic responses in assessing the pulmonary responses of poorly soluble particles such as DPM (ILSI, 2000). Sufficient documentation from other studies showed no effect in the portal-of-entry tissues, the extrathoracic (nasopharyngeal) region of the respiratory system, or in other organs at the lowest levels that produce pulmonary effects in chronic exposures. Application of the dosimetric model of Yu et al. (1991) to the exposure value from Ishinishi et al. (1988) of 0.46 mg/m^3 16 hr/day, 6 days/wk, a NOAEL, yielded a $NOAEL_{HEC}$ of 0.144 mg/m^3. Application of the composite UF yields the RfC:

$$NOAEL_{HEC} \div UF = RfC$$
$$0.144 \text{ mg/m}^3 \div 30 = 0.0048 \text{mg/m}^3 = 5\,\mu\text{g/m}^3.$$

6.4. EPIDEMIOLOGICAL EVIDENCE AND NAAQS FOR FINE PM

Historically, EPA has established primary NAAQS to protect sensitive human population groups against adverse health effects associated with ambient exposures to certain widespread air pollutants, including PM, ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and lead (Pb). The U.S. Clean Air Act (the Act) requires that EPA periodically review and revise as appropriate the criteria (scientific bases) and standards for each pollutant or class of pollutants (e.g., PM) for which NAAQS have been established. The primary, health-based NAAQS must be based on the latest scientific information useful in indicating the kind and extent of all effects on public health expected from the presence of the pollutant in the ambient air, which is evaluated in a "Criteria Document" (CD). The NAAQS are then set at levels that, in the judgment of the EPA Administrator, protect public health (as contrasted with the health of any individual) with an adequate margin of safety. In determining the degree of protection that will satisfy this mandate, EPA considers the nature and severity of the effects, the types of health evidence available, the kind and degree of scientific uncertainty that effects would in fact occur at any particular level of pollution, and the size and nature of sensitive populations at risk of experiencing exposures of concern. The EPA develops a staff paper to bridge the gap between the scientific criteria and the public health policy considerations the Administrator must take into account in reaching a final judgment. The EPA also must consider the recommendations of the Clean Air Scientific Advisory Committee (CASAC), an independent committee established by the Act specifically to advise the Administrator on air quality criteria and NAAQS. In contrast to an RfC, the NAAQS are not intended to identify a concentration that is protective against a hypothetical continuous lifetime exposure to a given level, but rather take into account expected actual exposure conditions of U.S. populations.

The original PM NAAQS were set in 1971 in terms of total suspended particulate matter (TSP) and included both inhalable and noninhalable particles, ranging in size up to 25–50 µm. A later periodic review of the PM criteria and NAAQS led to the setting in 1987 of PM_{10} NAAQS (150 µg/m^3, 24-h average; 50 µg/m^3, annual average) aimed at protecting against health effects associated with those inhalable particles capable of penetrating to lower (thoracic) regions of the human respiratory tract and depositing in tracheobronchial and alveolar tissue of the lung (≤10.0 µm) (52 FR 24634, July 1, 1987). The most recently completed PM NAAQS review was based on an assessment of the latest available scientific information characterized in the EPA PM CD (U.S. EPA, 1996a) and additional staff assessments contained in an associated PM Staff Paper (U.S. EPA, 1996b). In 1997, on the basis of this information and taking into account CASAC recommendations and extensive public comments, EPA established new $PM_{2.5}$ NAAQS (15 µg/m^3, annual average; 65 µg/m^3, 24-h average) to protect against adverse health effects associated with exposures to fine PM. At the same time, EPA retained, in modified form, the

PM_{10} NAAQS originally set in 1987 to protect against effects associated with coarse fraction PM (62 FR 38652, July 18, 1997).[3]

The 1997 PM NAAQS decisions were based, in part, on important distinctions already highlighted by information present in the PM CD between the fine and coarse fractions of PM_{10} with regard to size, chemical composition, sources, and transport. Also of key importance were the assessment and interpretation of new epidemiological findings on health effects associated with ambient PM. The epidemiological evidence and basis for the NAAQS for fine PM are summarized below, followed by a discussion of the relevance of this information for noncancer assessment of DE.

6.4.1. Epidemiological Evidence for Fine PM

The PM CD (U.S. EPA, 1996a) and Staff Paper (U.S. EPA, 1996b) highlighted more than 80 newly published community epidemiologic studies, of which more than 60 found significant associations between increased mortality and/or morbidity risks and various ambient PM indicators. The main findings of concern were community epidemiology results showing ambient PM exposures to be statistically associated with increased mortality (especially among people over 65 years of age and those with preexisting cardiopulmonary conditions) and morbidity (indexed by increased hospital admissions, respiratory symptom rates, and decrements in lung function).

Time-series mortality studies reviewed in the 1996 PM CD (U.S. EPA, 1996a) provide strong evidence that ambient PM air pollution is associated with increases in daily human mortality and morbidity (e.g., increased hospital admissions and respiratory symptoms). These studies provided evidence that such effects occur at routine ambient PM levels, extending to 24-h concentrations below the 150 $\mu g/m^3$ level of the PM_{10} NAAQS set in 1987. Overall, as shown in Table 6-3, the PM_{10} effects estimates derived from the recent PM_{10} total mortality studies suggest that an increase of 50 $\mu g/m^3$ in 24-h average PM_{10} is significantly associated with an increase in total mortality, with an RR on the order of 1.025 to 1.05 in the general population. Table 6-3 also shows higher relative risks for increased hospital admissions for the elderly and for those with preexisting respiratory conditions, both of which represent subpopulations at special risk for mortality implications of acute exposures to air pollution, including PM; higher relative risks are also shown for increased respiratory symptoms and decreased lung function in children. Results are very similar over a range of statistical models used in the analyses, and are not artifacts of the methods by which the data were analyzed. Further, these studies suggest a possible linear,

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[3]At present, the 1997 $PM_{2.5}$ standards are the subject of ongoing litigation, although they legally remain in effect, as do the 1987 PM_{10} standards.

Table 6-3. Effect estimates per 50 μg/m³ increase in 24-h PM_{10} concentrations from U.S. and Canadian studies

Study location	RR (± CI) only PM in model	RR (± CI) other pollutants in model	Reported PM_{10} levels mean (min/max)[†]
Increased total acute mortality			
Six Cities[a]		—	
Portage, WI	1.04 (0.98, 1.09)	—	18 (±11.7)
Boston, MA	1.06 (1.04, 1.09)	—	24 (±12.8)
Topeka, KS	0.98 (0.90, 1.05)	—	27 (±16.1)
St. Louis, MO	1.03 (1.00, 1.05)	—	31 (±16.2)
Kingston/Knoxville, TN	1.05 (1.00, 1.09)	—	32 (±14.5)
Steubenville, OH	1.05 (1.00, 1.08)	—	46 (±32.3)
St. Louis, MO[c]	1.08 (1.01, 1.12)	1.06 (0.98, 1.15)	28 (1/97)
Kingston, TN[c]	1.09 (0.94, 1.25)	1.09 (0.94, 1.26	30 (4/67)
Chicago, IL[h]	1.04 (1.00, 1.08)	—	37 (4/365)
Chicago, IL[g]	1.03 (1.02, 1.04)	1.02 (1.01, 1.04)	38 (NR/128)
Utah Valley, UT[b]	1.08 (1.05, 1.11)	1.19 (0.96, 1.47)	47 (11/297)
Birmingham, AL[d]	1.05 (1.01, 1.10)	—	48 (21, 80)
Los Angeles, CA[f]	1.03 (1.00, 1.055)	1.02 (0.99, 1.036)	58(15/177)
Increased hospital admissions (for elderly > 65 yrs.)			
Respiratory Disease			
Toronto, CAN[i]	1.23 (1.02, 1.43)[‡]	1.12 (0.88, 1.36)[‡]	30-39[*]
Tacoma, WA[j]	1.10 (1.03, 1.17)	1.11 (1.02, 1.20)	37 (14, 67)
New Haven, CT[j]	1.06 (1.00, 1.13)	1.07 (1.01, 1.14)	41 (19, 67)
Cleveland, OH[k]	1.06 (1.00, 1.11)	—	43 (19, 72)
Spokane, WA[l]	1.08 (1.04, 1.14)	—	46 (16, 83)
COPD			
Minneapolis, MN[n]	1.25 (1.10, 1.44)	—	36 (18, 58)
Birmingham, AL[m]	1.13 (1.04, 1.22)	—	45 (19, 77)
Spokane, WA[l]	1.17 (1.08, 1.27)	—	46 (16, 83)
Detroit, MI[o]	1.10 (1.02, 1.17)	—	48 (22, 82)
Pneumonia			
Minneapolis, MN[n]	1.08 (1.01, 1.15)	—	36 (18,58)
Birmingham, AL[m]	1.09 (1.03, 1.15)	—	45 (19, 77)

Table 6-3. Effect estimates per 50 μg/m³ increase in 24-h PM_{10} concentrations from U.S. and Canadian studies (continued)

Study location	RR (± CI) only PM in model	RR (± CI) other pollutants in model	Reported PM_{10} levels mean (min/max)[†]
Spokane, WA[l]	1.06 (0.98, 1.13)	—	46 (16, 83)
Detroit, MI[o]	—	1.06 (1.02, 1.10)	48 (22, 82)
Ischemic HD			
Detroit, MI[p]	1.02 (1.01, 1.03)	1.02 (1.00, 1.03)	48 (22, 82)
Increased respiratory symptoms			
Lower Respiratory			
Six Cities[q]	2.03 (1.36, 3.04)	Similar RR	30 (13,53)
Utah Valley, UT[r]	1.28 (1.06, 1.56)[τ]	—	46 (11/195)
	1.01 (0.81, 1.27)[π]		
Utah Valley, UT[s]	1.27 (1.08, 1.49)	—	76 (7/251)
Cough			
Denver, CO[x]	1.09 (0.57, 2.10)	—	22 (0.5/73)
Six Cities[q]	1.51 (1.12, 2.05)	Similar RR	30 (13, 53)
Utah Valley, UT[s]	1.29 (1.12, 1.48)	—	76 (7/251)
Decrease in Lung Function			
Utah Valley, UT[r]	55 (24, 86)[**]	—	46 (11/195)
Utah Valley, UT[s]	30 (10, 50)[**]	—	76 (7/251)
Utah Valley, UT[w]	29 (7,51)[***]	—	55 (1,181)

References:

[a]Schwartz et al. (1996a).
[b]Pope et al. (1992, 1994)/O_3.
[c]Dockery et al. (1992)/O_3.
[d]Schwartz (1993).
[f]Kinney et al. (1995)/O_3, CO.
[g]Ito and Thurston (1996)/O_3.
[h]Styer et al. (1995).
[i]Thurston et al. (1994)/O_3.
[j]Schwartz (1995)/SO_2.
[k]Schwartz et al. (1996b).
[l]Schwartz (1996).
[m]Schwartz (1994e).
[n]Schwartz (1994f).
[o]Schwartz (1994d).
[p]Schwartz and Morris (1995)/O_3, CO, SO_2.
[q]Schwartz et al. (1994).
[r]Pope et al. (1991).
[s]Pope and Dockery (1992).
[t]Schwartz (1994g)
[w]Pope and Kanner (1993).
[x]Ostro et al. (1991)
[†]Min/Max 24-h PM_{10} in parentheses unless noted otherwise as standard deviation (± S.D), 10 and 90 percentile (10, 90). NR = not reported.
[τ]Children.
[π]Asthmatic children and adults.
[*]Means of several cities.
[**]PEFR decrease in ml/sec.
[***]FEV_1 decrease.
[‡]RR refers to total population, not just>65 years.

Source: Adapted from U.S. EPA, 1996b, Tables V-3, V-6, and V-7. See U.S. EPA (1996a,b) for all reference citations.

non-threshold PM/mortality relationship, but the data do not rule out the existence of an underlying nonlinear, threshold relationship (U.S. EPA, 1996a, 12-310-311; 1996b, VI-16). Figure 6-2 illustrates the consistency and coherence of the PM_{10} epidemiology findings for increased total and cause-specific mortality and morbidity risks in adults and children. In addition, Table 6-4 summarizes results from a wide array of U.S. and Canadian studies that showed increased risks of mortality and morbidity to be related to changes in short-term (24-h) fine PM (indexed by $PM_{2.5}$ and other fine particle indicators).

As summarized below, long-term exposure studies reviewed in the 1996 PM CD (U.S. EPA, 1996a) also provide evidence of associations between indicators of PM, including fine particle indicators, and chronic mortality and morbidity. Table 6-5 shows the direct comparisons of two key prospective studies of long-term PM mortality: the Harvard Six Cities Study (Dockery et al., 1993) and the American Cancer Society (ACS) Study (Pope et al., 1995). These two studies agree in their findings of strong associations between fine particles and increased mortality. The RR estimates for total mortality are large and highly significant in the Six Cities study. With their 95% confidence intervals, the RR estimate for a 50 $\mu g/m^3$ increase in $PM_{15/10}$ is 1.42 (1.16, 2.01), the RR estimate for a 25 $\mu g/m^3$ increase in $PM_{2.5}$ is 1.31 (1.11, 1.68), and the RR estimate for a 15 $\mu g/m^3$ increase in SO_4 is 1.46 (1.16, 2.16). The ACS study estimates for total mortality are smaller, but also more precise: RR = 1.17 (1.09, 1.26) for a 25 $\mu g/m^3$ increase in $PM_{2.5}$, and RR = 1.10 (1.06, 1.16) for a 15 $\mu g/m^3$ increase in SO_4. Both studies used Cox regression models and were adjusted for similar sets of individual covariates. In each case, however, caution must be applied in use of the stated quantitative risk estimates, given that the lifelong cumulative exposures of the study cohorts (especially in the dirtiest cities) included distinctly higher past PM exposures than those indexed by the more current PM measurements used to estimate long-term PM exposures in the study. Thus, somewhat lower relative risk estimates than the published ones may well apply. A third study by Abbey et al. (1991, 1995) reported no association between long-term PM exposure (indexed by TSP and other estimated PM indices) after 10 years, although the PM CD (U.S. EPA, 1996a) noted TSP may have been an inadequate index for exposure to inhalable particles and that additional follow-up might still reveal chronic effects.

An additional line of evidence concerning long-term effects may be seen in comparing cause-specific deaths in the Six Cities and ACS studies. The relative risks for the most versus the least polluted cities in the two studies are very similar for mortality from cardiopulmonary causes (U.S. EPA, 1996b, V-17). These two long-term exposure studies, taken together, suggest that there may be increases in mortality for specific disease categories that are consistent with long-term exposure to ambient fine particles. Moreover, at least some fraction of these deaths is

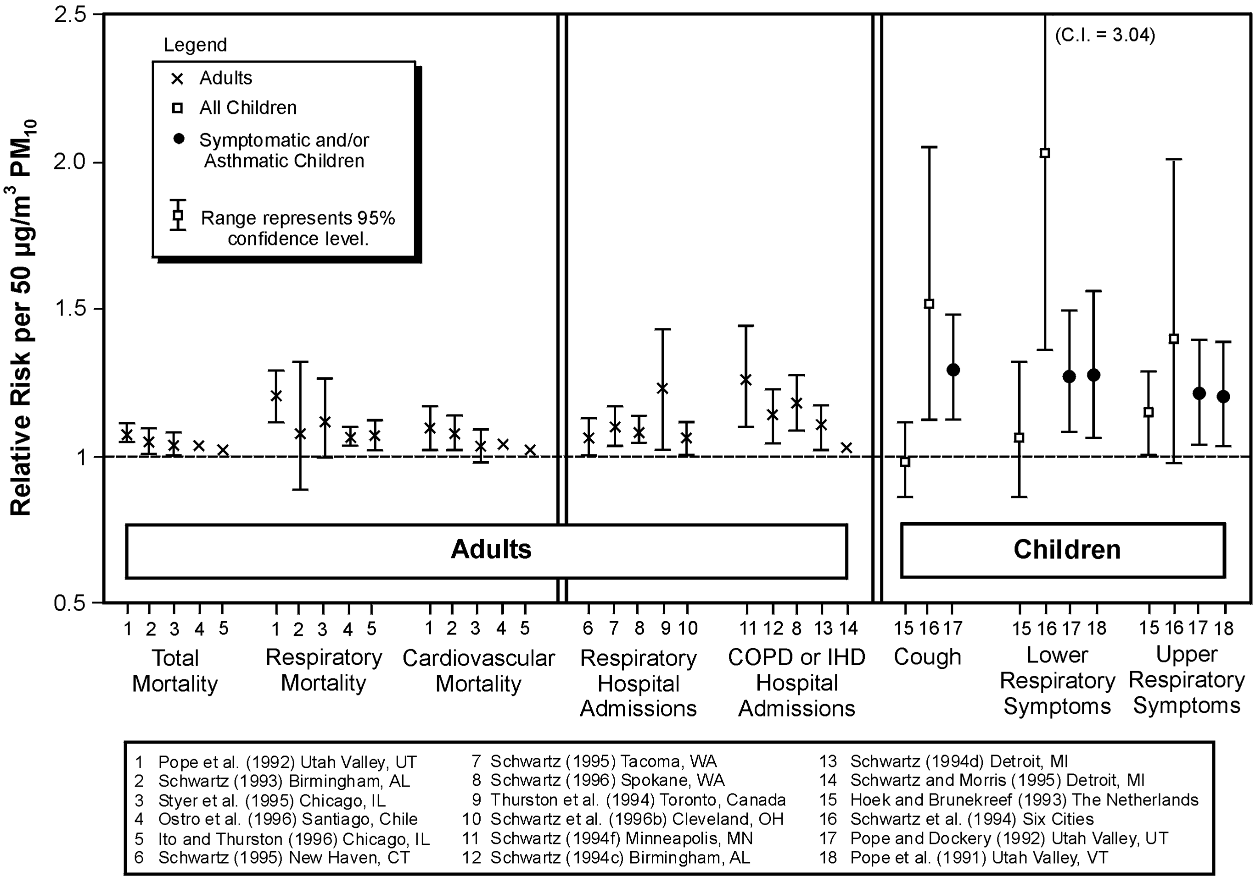

Figure 6-2. Relative risk (RR) estimates for increased mortality and morbidity endpoints associated with 50 µg/m³ increments in PM_{10} concentrations as derived from studies cited by numbers listed above each given type of health endpoint.

Note: Notice the consistency of RR elevations across studies for given endpoint and coherence of RR estimates across endpoints, e.g., higher RR values for symptoms versus hospital admissions and cause-specific mortality.

Source: PM Staff Paper (see U.S. EPA, 1996b for full reference citations for each study identified in figure.)

Table 6-4. Effect estimates per variable increments in 24-h concentrations of fine particle indicators ($PM_{2.5}$, $SO_4^=$, H^+) from U.S. and Canadian studies

Acute mortality	Indicator	RR (± CI) per 25 μg/m³ PM increase	Reported PM levels mean (min/max)†
Six Cities[a]			
Portage, WI	$PM_{2.5}$	1.030 (0.993, 1.071)	11.2 (±7.8)
Topeka, KS	$PM_{2.5}$	1.020 (0.951, 1.092)	12.2 (±7.4)
Boston, MA	$PM_{2.5}$	1.056 (1.038, 1.0711)	15.7 (±9.2)
St. Louis, MO	$PM_{2.5}$	1.028 (1.010, 1.043)	18.7 (±10.5)
Kingston/Knoxville, TN	$PM_{2.5}$	1.035 (1.005, 1.066)	20.8 (±9.6)
Steubenville, OH	$PM_{2.5}$	1.025 (0.998, 1.053)	29.6 (±21.9)
Increased hospitalization			
Ontario, CAN[b]	$SO_4^=$	1.03 (1.02, 1.04)	R = 3.1-8.2
Ontario, CAN[c]	$SO_4^=$ O_3	1.03 (1.02, 1.04) 1.03 (1.02, 1.05)	R = 2.0-7.7
NYC/Buffalo, NY[d]	$SO_4^=$	1.05 (1.01, 1.10)	NR
Toronto[d]	H^+ (Nmol/m³) $SO_4^=$ $PM_{2.5}$	1.16 (1.03, 1.30)* 1.12 (1.00, 1.24) 1.15 (1.02, 1.78)	28.8 (NR/391) 7.6 (NR, 48.7) 18.6 (NR, 66.0)
Increased respiratory symptoms			
Southern California[e]	$SO_4^=$	1.48 (1.14, 1.91)	R = 2-37
Six Cities[f] (Cough)	$PM_{2.5}$ $PM_{2.5}$ Sulfur H^+	1.19 (1.01, 1.42)** 1.23 (0.95, 1.59)** 1.06 (0.87, 1.29)**	18.0 (7.2, 37)*** 2.5 (3.1, 61)*** 18.1 (0.8, 5.9)***
Six Cities[f] (Lower Resp. Symp.)	$PM_{2.5}$ $PM_{2.5}$ Sulfur H^+	1.44 (1.15-1.82)** 1.82 (1.28-2.59)** 1.05 (0.25-1.30)**	18.0 (7.2, 37)*** 2.5 (0.8, 5.9)*** 18.1 (3.1, 61)***
Decreased lung function			
Uniontown, PA[g]	$PM_{2.5}$	PEFR 23.1 (-0.3, 36.9) (per 25 μg/m³)	25/88 (NR/88)

References:
[a]Schwartz et al. (1996a)
[b]Burnett et al. (1994)
[c]Burnett et al. (1995) O_3
[d]Thurston et al. (1992, 1994)
[e]Ostro et al (1993)
[f]Schwartz et al. (1994)
[g]Neas et al. (1995)

†Min/Max 24-h PM indicator level shown in parentheses unless otherwise noted as (± S.D.), 10 and 90 percentile (10,90) or R = range of values from min-max, no mean value reported.
*Change per 100 nmoles/m³.
**Change per 20 μg/m³ for $PM_{2.5}$; per 5 μg/m³ for $PM_{2.5}$ sulfur; per 25 nmoles/m³ for H^+.
***50th percentile value (10,90 percentile).

Source: Adapted from U.S. EPA, 1996b, Table V-12. See U.S. EPA (1996a,b) for all reference citations.

Table 6-5. Effect estimates per increments[a] in annual average levels of fine particle indicators from U.S. and Canadian studies

Type of health effect and location	Indicator	Change in health indicator per increment in PM[a]	Range of city PM levels mean ($\mu g/m^3$)
Increased total chronic mortality in adults		**Relative risk (95% CI)**	
Six City[b]	$PM_{15/10}$	1.42 (1.16-2.01)	18-47
	$PM_{2.5}$	1.31 (1.11-1.68)	11-30
	$SO_4^=$	1.46 (1.16-2.16)	5-13
ACS Study[c] (151 U.S. SMSA)	$PM_{2.5}$	1.17 (1.09-1.26)	9-34*
	$SO_4^=$	1.10 (1.06-1.16)	4-24
Increased bronchitis in children		**Odds ratio (95% CI)**	
Six City[d]	$PM_{15/10}$	3.26 (1.13, 10.28)	20-59
Six City[e]	TSP	2.80 (1.17, 7.03)	39-114
24 City[f]	H^+	2.65 (1.22, 5.74)	6.2-41.0
24 City[f]	$SO_4^=$	3.02 (1.28, 7.03)	18.1-67.3
24 City[f]	$PM_{2.1}$	1.97 (0.85, 4.51)	9.1-17.3
24 City[f]	PM_{10}	3.29 (0.81, 13.62)	22.0-28.6
Southern California[g]	$SO_4^=$	1.39 (0.99, 1.92)	—
Decreased lung function in children			
Six City[d,h]	$PM_{15/10}$	NS Changes	20-59
Six City[e]	TSP	NS Changes	39-114
24 City[i,j]	H^+ (52 nmoles/m^3)	−3.45% (-4.87, -2.01) FVC	—
24 City[i]	$PM_{2.1}$ (15 $\mu g/m^3$)	−3.21% (-4.98, -1.41) FVC	—
24 City[i]	$SO_4^=$ (7 $\mu g/m^3$)	−3.06% (-4.50, -1.60) FVC	—
24 City[i]	PM_{10} (17 $\mu g/m^3$)	−2.42% (-4.30, -.0.51) FVC	—

[a]Estimates calculated annual-average PM increments assume: a 100 $\mu g/m^3$ increase for TSP; a 50 $\mu g/m^3$ increase for PM_{10} and PM_{15}; a 25 $\mu g/m^3$ increase for $PM_{2.5}$; and a 15 $\mu g/m^3$ increase for $SO_4^=$, except where noted otherwise; a 100 nmole/m^3 increase for H^+.
[b]Dockery et al. (1993).
[c]Pope et al. (1995).
[d]Dockery et al. (1989).
[e]Ware et al. (1986).
[f]Dockery et al. (1996).
[g]Abbey et al. (1995a,b,c).
[h]NS Changes = No significant changes.
[i]Raizenne et al. (1996).
[j]Pollutant data same as for Dockery et al. (1996).
*Range of annual median values for subset of 50 cities.

Source: Adapted from U.S. EPA, 1996a, Table 12-6 and U.S. EPA, 1996b, Table V-8. See U.S. EPA (1996a,b) for all reference citations.

likely to be a consequence of cumulative, long-term exposure effects. These effects extend beyond the additive impacts of short-term exposure episodes, in terms of producing marked increases above the expected number of daily deaths among especially susceptible groups, such as the elderly and those with pulmonary disease.

The PM CD (U.S. EPA, 1996a) also highlighted a growing body of evidence directly comparing fine and coarse fraction PM effects that suggests that fine particles are more strongly related than coarse fraction particles to increased mortality and morbidity in both short- and long-term exposure studies. Such evidence notably includes the results of analyses of the type illustrated in Figure 6-3 through 6-5. More specifically, Figure 6-3 shows a stronger relationship between changes in short-term (24-h) concentrations of fine particles (indexed by $PM_{2.5}$) and increased mortality risks than for changes in short-term concentrations of coarse fraction particles (indexed by $PM_{15-2.5}$). Similarly, a stronger relationship is seen between chronic mortality and long-term exposure to fine particles (including both the sulfate and nonsulfate components) than exposure to coarse fraction particles (Figure 6-4), and a much stronger relationship between lung function decrements and long-term exposure to fine particles than to coarse fraction particles (Figure 6-5).

6.4.2. NAAQS for Fine PM

The health effects evidence discussed above is relevant to this current HAD, as both this document (Chapter 2) and the PM CD present information that clearly shows DPM to be a constituent of ambient fine particles. Therefore, it is reasonable to conclude that DPM is associated, but to an undetermined degree, with the health effects described above. Whereas broader public health factors are taken into account in setting NAAQS than are relevant for this noncancer assessment of lifetime exposure for DPM, the annual $PM_{2.5}$ NAAQS based primarily on this evidence is of interest in considering the extent to which the RfC for DE (as derived above in Section 6.3) is concordant with the information on fine particles.

As presented in the Federal Register final rule notice (62 FR 38652, July 18, 1997), EPA drew upon the quantitative epidemiology information concisely summarized above to derive a rationale for selection of an annual-average $PM_{2.5}$ standard.[4] First, to appropriately reflect the

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[4]As an initial matter, EPA concluded that the existing PM_{10} standards were not adequate to protect public health, that fine and coarse fraction particles should be considered separately, that $PM_{2.5}$ was the appropriate indicator to use for fine particles, and that an annual $PM_{2.5}$ standard could provide the requisite reduction in risk associated with both annual and 24-h averaging times in most areas of the United States. This annual standard, together with a 24-h standard, could provide supplemental protection against extreme peak fine particle levels that

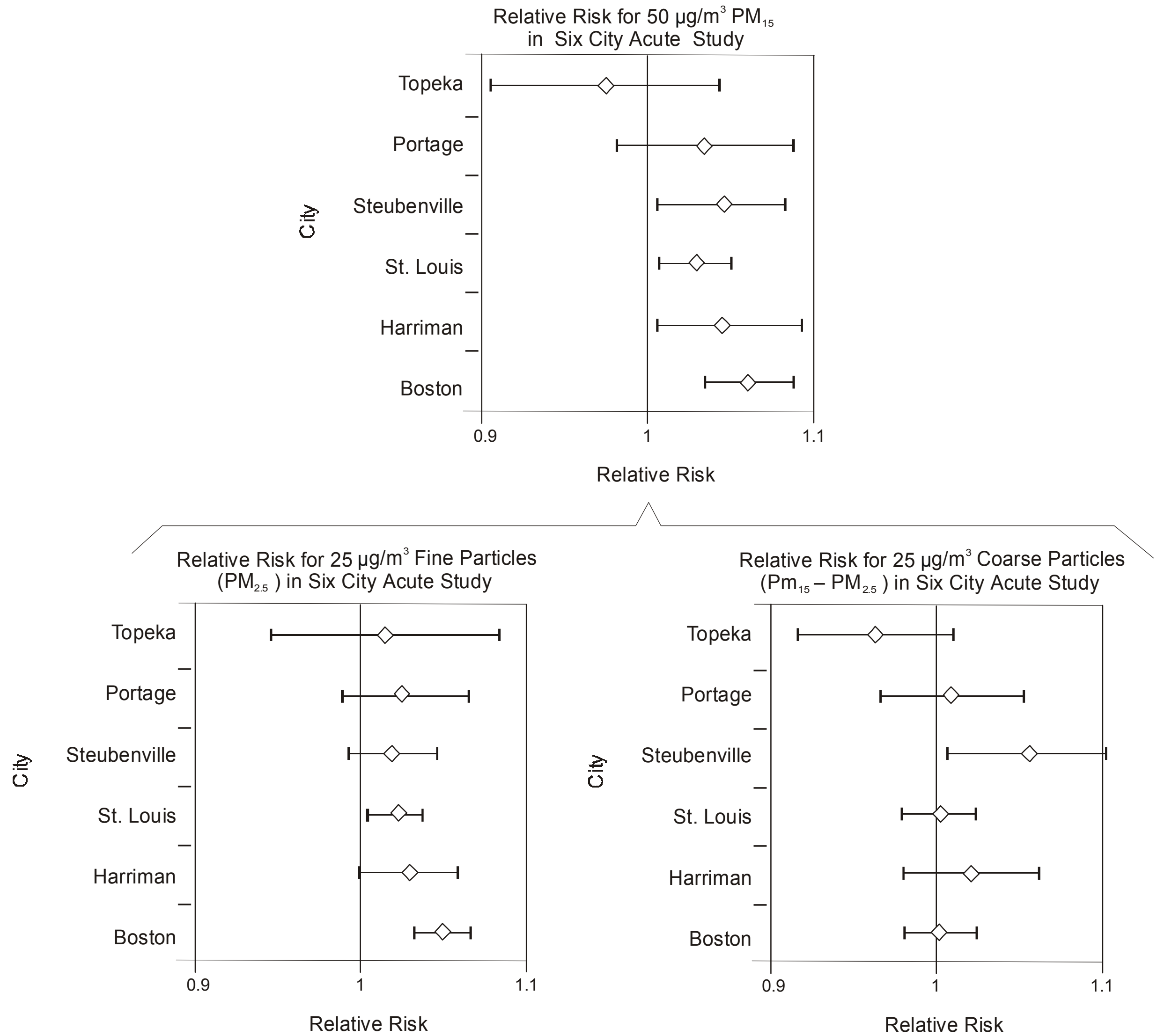

Figure 6-3. Relative risks of acute mortality in Harvard Six Cities Study, for inhalable thoracic particles (PM_{15}/PM_{10}), fine particles ($PM_{2.5}$), and coarse fraction particles (PM_{15}-$PM_{2.5}$).

Note: The coarse fraction effects are smaller and statistically nonsignificant (i.e., lower 95% confidence intervals do not exceed relative risk of 1.0), except in Steubenville where there is high correlation between fine and coarse particles ($R^2 = 0.69$).

Source: PM CD (U.S. EPA, 1996a) graphical depiction of results from Schwartz et al. (1996).

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might occur in some localized situations or in areas with distinct variations in seasonal fine particle levels (62 FR 38652).

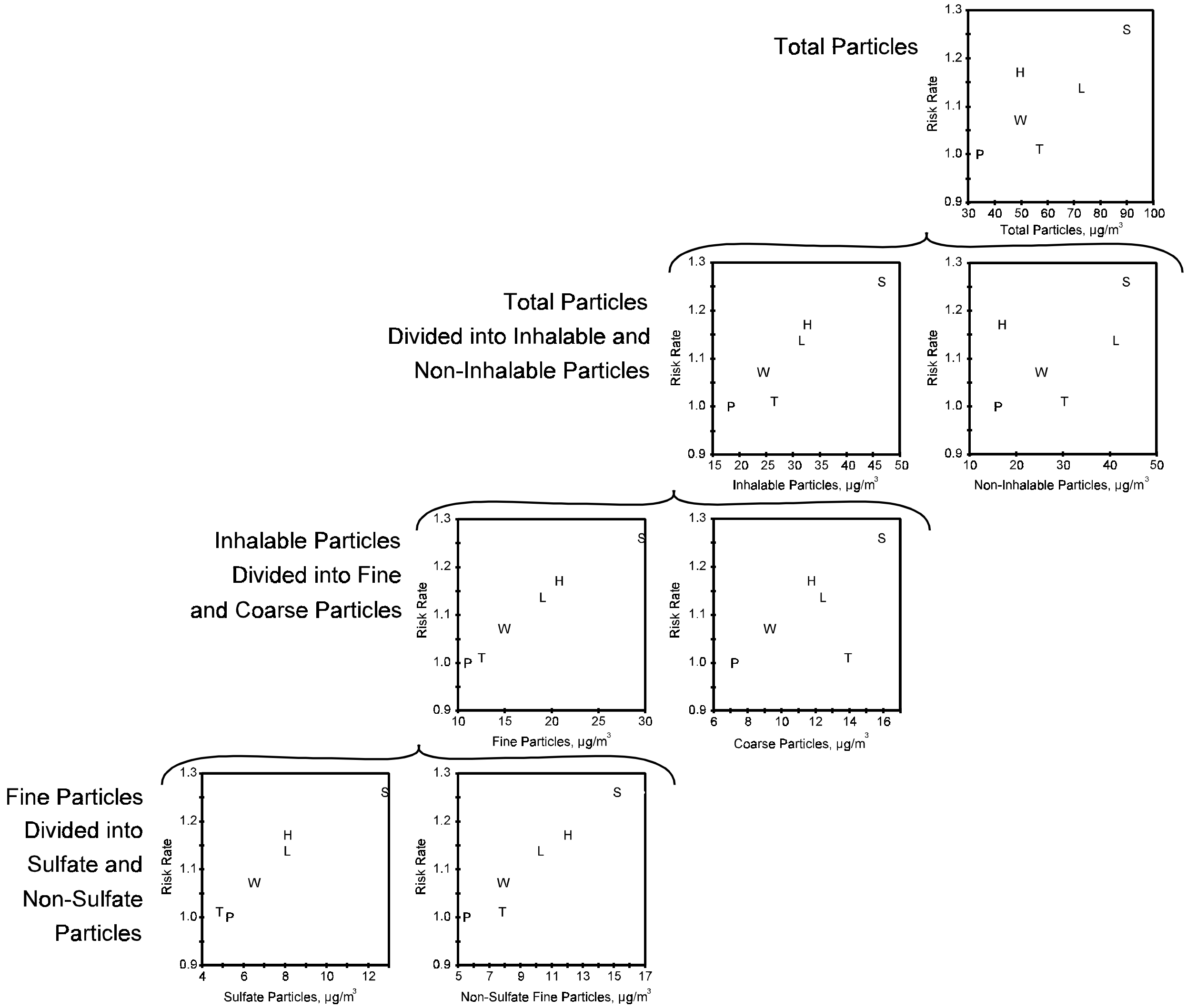

Figure 6-4. Adjusted relative risks for mortality are plotted against each of seven long-term average particle indices in the Harvard Six Cities Study, from largest range (total suspended particles, upper right) through sulfate and nonsulfate fine particle concentrations (lower left).

Note: A relatively strong linear relationship is seen for fine particles, and for sulfate and nonsulfate components. Topeka, which has a substantial coarse particle component of inhalable (thoracic) particle mass, stands apart from the linear relationship between relative risk and inhalable particle concentration.
Source: U.S. EPA (1996a) replotting of results from Dockery et al. (1993).

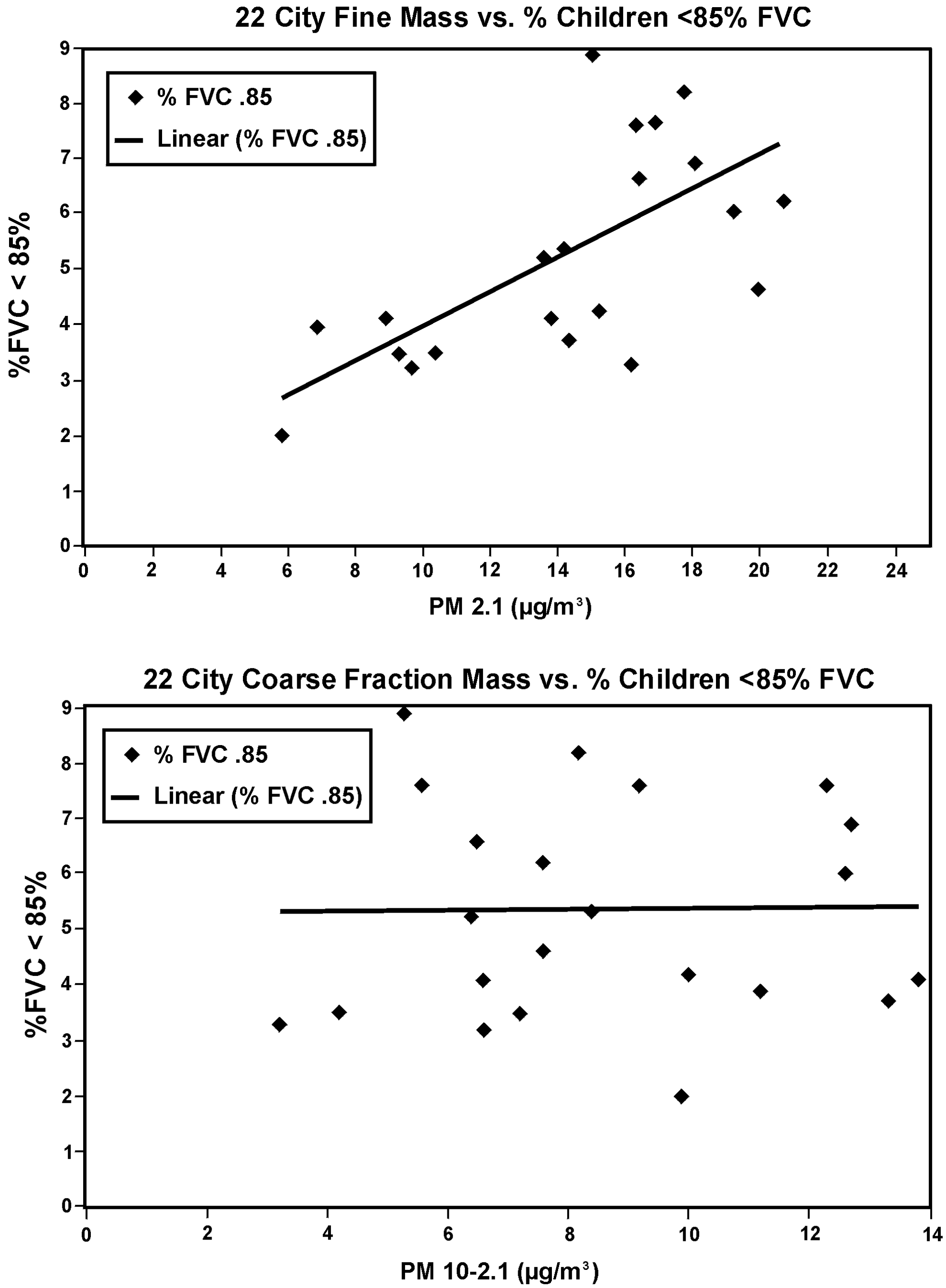

Figure 6-5. Percent of children with <85% normal FVC versus annual-average fine ($PM_{2.1}$) particle concentrations and coarse fraction ($PM_{10-2.1}$) levels for 22 North American cities.

Note: A much stronger connection appears between fine particles and lung function decrements (top panel) than for coarse fraction particles (bottom panel).
Source: PM Staff Paper (1996b) graphical depiction of results from Razienne et al. (1996).

weight of evidence as a whole, EPA concluded that it was appropriate to limit annual $PM_{2.5}$ concentrations to somewhat below those where the body of epidemiological evidence is most consistent and coherent, recognizing both the strengths and limitations of the full range of information on the health effects of PM, as well as associated uncertainties. In accordance with EPA staff and CASAC views on the relative strengths of the epidemiologic studies, major reliance was placed on several short-term (24-h) exposure studies showing significantly increased risks of daily mortality (Schwartz et al., 1996) and morbidity indexed by hospital admissions (Thurston et al., 1994) and respiratory symptoms/lung function decrements in children (Schwartz et al., 1994; Neas et al., 1995) in relationship to increased fine particle ($PM_{2.5}$) concentrations. Whereas it was recognized that health effects may occur over the full range of concentrations observed in these studies, it was concluded that the strongest evidence for short-term $PM_{2.5}$ effects occurs at concentrations near the long-term (e.g., annual) average. More specifically, the strength of the evidence of effects increases for concentrations of $PM_{2.5}$ that are at or above the long-term mean levels reported for these studies. Given the serious nature of the potential effects, EPA judged that it was both prudent and appropriate to select a level for an annual standard at or below such concentrations. More specifically, statistically significant increases in relative risks for daily mortality or morbidity were most clearly observed in these studies to be associated with 24-h fine particle concentrations in cities with long-term mean fine particle concentrations ranging from about 16 to about 21 $\mu g/m^3$, leading to the judgment that an annual standard level of 15 $\mu g/m^3$ would be appropriate.

Before reaching a final conclusion, the epidemiologic studies of long-term exposures to fine particles were also considered, which may reflect the accumulation of daily effects over time as well as potential effects uniquely associated with long-term exposures. Even subject to additional uncertainties, these studies were judged to provide important insights with respect to the overall protection afforded by an annual standard. In particular, the annual mean $PM_{2.5}$ concentrations for the multiple cities included in the two key long-term exposure mortality studies (Dockery et al., 1993; Pope et al., 1995) were 18 $\mu g/m^3$ and about 21–22 $\mu g/m^3$, respectively, with most of the 50 cities in the Pope, et al. (1995) having mean $PM_{2.5}$ concentrations above 15 $\mu g/m^3$. Taken together with other long-term exposure studies and considering other factors discussed in the final rule (62 FR 38676, July 18, 1997), EPA concluded that the concordance of evidence for PM effects and associated levels provides clear support for an annual standard set at 15 $\mu g/m^3$.

6.4.3. DPM as a Component of Fine PM

Chapter 2 of this document, as well as the PM CD (U.S. EPA, 1996a), report the extent to which DPM may contribute to ambient $PM_{2.5}$ concentrations. In some urban situations, the annual average fraction of $PM_{2.5}$ attributable to DPM (according to mass concentrations) is about 35% on the high end, although the proportion appears to be more typically in the range of about 10% (see Chapter 2, Table 2-23 and Section 2.4.2.1).

An approach to considering the relationship of toxicity between DPM and $PM_{2.5}$ would be simply to assume that, as DPM is contributory to the content of ambient $PM_{2.5}$, so too would it be contributory to toxicity of $PM_{2.5}$. This approach is qualitative only because no firm basis currently exists for apportioning toxicity among the various components of $PM_{2.5}$. Nevertheless, some qualitative information from laboratory animal studies does exist, showing that DPM is no more potent at eliciting pulmonary pathology than other poorly soluble particles such as talc, titanium dioxide, or carbon black in rats, or talc or titanium dioxide in mice. No data suggest that DPM is any more potent in eliciting pulmonary pathology than any other poorly soluble particle that typically may be present in ambient $PM_{2.5}$. It may be reasonable to suggest, then, that DPM is no more likely to be toxicologically potent than any other fine particle constituents that typically make up ambient $PM_{2.5}$.

Based on the foregoing aspects of such an approach, a conclusion could be drawn that as long as DPM constituted its current approximate proportion to $PM_{2.5}$, the annual $PM_{2.5}$ standard would also be expected to provide a measure of protection for DPM. Even if a basis did exist to apportion toxicity among the various components of ambient $PM_{2.5}$, such as DPM, use of such information in an approach to derive a safe air level for DPM would result in only a generalized, nonspecific estimate limited by a variety of factors including the accuracy of the apportionment of DPM from $PM_{2.5}$. The RfC derived in Section 6.3 was based on an approach that utilized toxicological information from actual DPM exposures, a more direct approach that would result in a more specific estimate not limited by any apportionment scheme.

6.5. CHARACTERIZATION OF THE NONCANCER ASSESSMENT FOR DIESEL EXHAUST

Adverse health effects from short-term acute (high-level) exposures to DE such as occupational reports of decreases in lung function, wheezing, chest tightness, increases in airway resistance, and reports in laboratory animals of inflammatory airway changes and lung function changes are acknowledged but are not assessed quantitatively. The focus of this dose-response assessment is on the adverse noncancer health consequences of a lifetime, low-level, continuous air exposure by humans to DE.

This assessment uses the whole particle, termed DPM, as the key index or measure of DE dose. DPM includes any and all adsorbed organics, among which are a large number of PAHs, heterocyclic compounds, and their derivatives (Chapter 2), as well as the carbon core. It is not possible to separate the carbon core of DPM from the adsorbed organics to compare the toxicity in exposures other than with limited in-vitro-type scenarios. The dosimetric model used in the derivation of the RfC (Yu et al., 1991) is consistent with this designation, as it considers DPM as well as the adsorbed organics as two types, slow-cleared and fast-cleared. Studies with diesel do occasionally report levels of accompanying gaseous components of DE (e.g., NO_x, CO), but nearly all report particle concentration and characteristics.

Adverse responses occurring in the rat lung have been used in this assessment as the basis for characterizing nonneoplastic human lung responses, yet use of these data in hazard evaluation for cancer is not considered relevant to humans. The basis for this use of these noncancer pulmonary effects in rats for derivation of an RfC includes the fact that humans and rats exhibit similar responses to other poorly soluble particles and also that similar noncancer effects are seen in other species (ILSI, 2000; Freedman and Robinson, 1988). Thus, when viewed across species (including humans), the nonneoplastic pulmonary effects of inflammation and fibrosis used in this assessment are dissociable from the cancer response and are of likely relevance to humans.

As a part of the RfC methodology (U.S. EPA, 1994), dose-response assessments are assigned levels of confidence that are intended to reflect the strengths and limitations of an assessment as well as to indicate the likelihood of the assessment changing with any additional information. Confidence levels of either low, medium, or high are assigned both to the study (or studies) used in the assessment to characterize the critical effects and to the overall toxicological database of the substance. An overall confidence level also is assigned to the entire assessment. Usually, it is the same, or in any case no higher than the level assigned to the database.

Compared with the databases of most other toxicants, the basic toxicological database for DE is substantial. The critical effects are characterized using not one but multiple long-term chronic studies conducted independently of one another (Tables 6-1 and 6-2). The exhaustive manner in which these studies were conducted and reported also imparts a high degree of confidence. Both developmental and reproductive areas are addressed. Also, ancillary studies that address mechanistic aspects of DE toxicity, either as the whole particle with adsorbed organics, or segregated as a poorly soluble particle and extracted organics, are available and used in this assessment. Although only limited human data are available, extensive consideration has been given to the relevancy of the animal studies to the human condition. On the other hand, data from related toxicants such as general ambient PM indicate effects in endpoints (e.g., cardiovascular measures) that have not been addressed in the DPM database. A major point to consider in assigning confidence in this assessment, and a reason that the value of the RfC may change in the future, is the emerging issue of allergenicity caused or exacerbated by DE. Although information to evaluate allergenicity in parallel to the present effects (pulmonary inflammation and histopathology) is currently lacking, future efforts to elucidate and characterize this effect may well be a driver to make a reevaluation of the noncancer RfC derivation for DE appropriate. With respect to the current RfC for DE, the confidence level is medium, both for the database and overall. The level reflects the relevance of (and information lacking on) allergenicity effects associated with DE in humans, and the possibility that the current RfC could change as a consequence of this information becoming available from the scientific community.

In the introductory portion of this chapter, DPM is acknowledged as a constituent of ambient PM (U.S. EPA, 1996a,b). A discussion of the quantitative epidemiology, particularly regarding fine PM, indicated that public health effects, including premature mortality, increased hospital admissions, respiratory symptoms, and decreased lung function, were observed in populations living in areas with long-term mean $PM_{2.5}$ levels generally ranging above 15 $\mu g/m^3$. Application of the RfC method, which involved critical consideration of the entirety of the disparate DE database with many chronic studies from several different species, evaluation of a myriad of possible DE-specific toxicological endpoints, and use of extrapolation models, produced a value of 5 $\mu g/m^3$. As the accuracy of the RfC is stated in the definition (*"...within an order of magnitude ..."*), this dose-response estimate could be considered to be not different from the level of 15 $\mu g/m^3$, the lower end of the range identified for $PM_{2.5}$. It is acknowledged here again that the levels of the $PM_{2.5}$ NAAQS should not be considered as indicative of the same degree of health protection for DE as intended by the RfC. Nevertheless, the congruence of these estimates tends to enhance the overall confidence that this range of levels is near or inclusive of those that would be expected to be protective of the human population against the health effects of DE.

6.6. SUMMARY

Table 6-6 summarizes the key data and factors used in the dose-response analysis leading to the derivation of the RfC for DE. The DE RfC of 5 μg DPM/m^3 is a chronic exposure likely to be without an appreciable risk of adverse human health effects.

The link between ambient fine PM and DPM with respect to origin, content, and possible health effects has been presented and discussed in this chapter, and the general congruence between the DE RfC and the level of the annual NAAQS for fine particles has been noted. Although these values should not be compared directly, it is reasonable to observe that the annual $PM_{2.5}$ standard would be expected to provide a measure of protection for DPM, reflecting DPM's

Table 6-6. Decision summary for the quantitative noncancer RfC assessment for continuous exposure to diesel particulate matter (DPM)

Quantitative assessment for noncancer effects from lifetime exposure to DPM	**5 µg/m³**
Critical effect	Pulmonary inflammation and histopathology in rats
Principal study	Array of four chronic rat studies
Designated basis for quantitation (exposures in rats)	0.46 mg DPM /m^3, 16 hr/day, 6 d/wk, 130 wks; a NOAEL
$NOAEL_{HEC}$ (HEC)	0.144 mg DPM / m^3
Adjustments for uncertainty factors (interspecies variability and intraspecies extrapolation)	30
$NOAEL_{HEC}$/UF = RfC	0.144 mg/m^3 / 30 = 5 µg/m^3

current approximate proportion to $PM_{2.5}$.

The estimated air concentration of 5 µg/m^3 (the RfC, a lifetime exposure to DE measured as DPM) is above the ambient air levels reported in most rural areas but could be below those levels reported under short-term conditions in some urban scenarios, such as at busy intersections or bus stops (see Chapter 2, Table 2-23). The RfC is intended to address lifetime chronic exposures and aspects of time-averaging for less than lifetime scenarios, such as, for example, acute exposures at busy intersections or bus stops, which are not addressed in this particular assessment.

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7. CARCINOGENICITY OF DIESEL EXHAUST

7.1. INTRODUCTION

Initial health hazard concerns regarding the potential carcinogenicity of diesel engine exhaust (DE) were based on the reported induction of skin papillomas by diesel particle extracts (Kotin et al., 1955), evidence for mutagenicity of extracts (Huisingh et al., 1978), evidence that components of diesel extract act as weak tumor promoters (Zamora et al., 1983), and the knowledge that diesel particles and their associated organics are respirable. During the 1980s, both human epidemiologic studies and long-term animal cancer bioassays were initiated. In 1981, Waller published the first epidemiologic investigation, a retrospective mortality study of London transport workers. Since then a large number of retrospective cohort and case-control studies have been carried out with railroad workers, dockworkers, truck drivers, construction workers, miners, and bus garage employees. During 1986 and 1987, several chronic animal cancer bioassays were published. These studies and numerous laboratory investigations carried out since then have been directed toward assessing the carcinogenic potential of whole exhaust, evaluating the importance of various exhaust components in the induction of cancer, and understanding the mode of action and implications of deposition, retention, and clearance of DE particles.

7.1.1. Overview

This chapter evaluates the carcinogenic potential of DE in both humans (Section 7.2) and animals (Section 7.3), discusses mode(s) of action (Section 7.4), and provides an overall weight-of-evidence evaluation (Section 7.5) for carcinogenicity in humans. This chapter also summarizes evaluations of DE conducted by other organizations (Section 7.6) and the final conclusions (Section 7.7) identify major uncertainties for which additional research is needed. This assessment focuses on DE, although it should be noted that diesel particles make up a portion of ambient particulate matter (PM) (Chapter 2, Section 2.2.3; Chapter 6, Section 6.4.3), and thus, the ambient PM data may have some relevance.

7.1.2. Ambient PM-Lung Cancer Relationships

A brief overview of the data regarding exposure to ambient PM and lung cancer is provided as background information and is based on analyses contained in the 1996 Air Quality Criteria for PM (PM CD) (U.S. EPA, 1996a).[1] With DE being part of ambient PM, the question

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[1]As noted in Chapter 6, a new PM CD is now being prepared to reflect the latest scientific studies on ambient PM available since the last document was completed.

of what is seen in the ambient PM data is of interest, as epidemiologic evidence for an effect of ambient PM on lung cancer mortality or incidence could possibly contribute to evaluation of DE-specific epidemiologic data.

Chapters 2 and 5 noted that DPM, consisting mostly of fine particles (<1.0 mm diameter), represents a toxicologically important component of typical ambient fine particle mixes. As discussed in Chapter 6, several large-scale prospective studies (Harvard Six Cities Study; American Cancer Society (ACS) Study; Adventist Health Study of Smog (AHSMOG) provide important evidence regarding associations between chronic exposures to ambient fine particles and increased risks of noncancer mortality/morbidity effects (e.g., cardiorespiratory-related deaths or hospital admissions) (U.S. EPA, 1996a). As summarized below, these same studies also evaluated relationships between chronic PM exposures and lung cancer mortality and/or incidence.

As an initial matter, both the Harvard Six Cities Study (Dockery et al., 1993), of approximately 8,000 adults in six cities comprising a transect across the northcentral and northeastern United States, and the ACS Study (Pope et al., 1995), of 550,000 adults in 151 cities across all U.S. geographic regions, found markedly increased relative risks (RR) of lung cancer mortality associated with smoking. More specifically, the Six City Study reported increased risks of smoking for current (RR = 8.00, 95% CI = 2.97-21.6) and former (RR = 2.54, CI = 0.90-7.18) smokers, with the ACS Study reporting striking similar increased risks for current smokers (RR = 9.73, 95% CI = 5.96-15.9).

After controlling for smoking and other risk factors, both the Six Cities Study and the ACS Study (using a subset of 50 of the 151 cities) evaluated relationships between long-term exposure to fine PM (indexed by $PM_{2.5}$), from the least to the most polluted of the cities in each study, and lung cancer mortality. In both studies, lung cancer mortality risks were not statistically significantly associated with ambient $PM_{2.5}$ concentrations in combined analyses of data for both males and females (RR = 1.37, 95% CI = 0.81-2.31, in the Six Cities Study; RR = 1.03, 95% CI = 0.80-1.33, in the ACS Study). Also, lung cancer mortality risks were not statistically significantly associated with ambient $PM_{2.5}$ concentrations in the ACS Study for smaller sample size subgroups broken out by sex and smoking status. In addition, analyses of data from the AHSMOG series of studies, of 6,338 nonsmoking long-term California adult residents, found no statistically significant associations between $PM_{2.5}$ (estimated from visibility data) and lung cancer mortality or total mortality (Abbey et al., 1995); further, no such associations were reported for PM_{10} (estimated from total suspended particulate matter [TSP] data) in the same study. Earlier AHSMOG analyses (Abbey et al., 1991) reported no statistically significant associations between TSP (which includes not only fine PM but also larger coarse-mode particles ranging up to 25-50 μm) and respiratory cancer for either sex (only respiratory symptoms and any-site female cancers were reported to be associated with TSP in this study).

The ACS Study and the later AHSMOG analyses (Abbey et al., 1995) also evaluated relationships between long-term exposures to sulfates (SO_4) (which are predominantly but not exclusively found in fine-mode particles, and can be considered an index for ambient fine particles) and lung cancer mortality. The ACS Study reported somewhat elevated and statistically significant lung cancer risk (RR = 1.36, 95% CI = 1.11-1.66) across 151 cities in combined analyses of data for both males and females. However, in further analyses of subgroups broken out by sex and smoking status (and thus having smaller sample sizes in each than for the above overall combined analyses), only the lung cancer mortality risks for male "ever-smokers" (RR = 1.44, 95% CI = 1.14-1.83) were statistically significant; no statistically significant relationships were reported for male "never-smokers" (RR = 1.36, 95% CI = 0.40 - 4.66), for female "ever-smokers" (RR = 1.10, 95% CI = 0.72-1.68), or for female "never-smokers" (RR = 1.61; 95% CI = 0.66 -3.92). In the later AHSMOG analyses, Abbey et al. (1995) found no statistically significant associations between sulfates and lung cancer or total mortality.

In summary, the three key prospective cohort studies summarized above, and discussed in more detail in the 1996 PM CD (U.S. EPA, 1996a), provide an equivocal array of results with regard to possible associations between chronic exposures to ambient PM and lung cancer mortality and/or incidence. None of the analyses of fine particles (as indexed by $PM_{2.5}$) in these three studies reported statistically significant relationships between long-term $PM_{2.5}$ concentrations and lung cancer mortality. Only the ACS Study found a statistically significant association of increased risk of lung cancer with one indicator of ambient fine particles (sulfates). Overall, then, these studies support a conclusion that there continues to be little epidemiologic evidence for an effect of ambient PM on lung cancer mortality or incidence. It is recognized, however, that subsequent AHSMOG analyses and other studies, published since completion of the 1996 PM CD, have further analyzed relationships between ambient PM and lung cancer. Results from these more recent studies are now being evaluated as part of the integrated assessment of ambient PM that will be part of the new PM CD targeted for completion in 2002.

7.2. EPIDEMIOLOGIC STUDIES OF THE CARCINOGENICITY OF EXPOSURE TO DIESEL EXHAUST

An increased risk from malignancies of the lung, bladder, and lymphatic tissue has been reported in populations potentially exposed to higher levels of DE than typically seen in the environment. A few authors have reported other malignancies, including testicular cancer

(Garland et al., 1988), gastrointestinal cancer (Balarajan and McDowall, 1988; Guberan et al., 1992), and prostate cancer (Aronsen et al., 1996). A detailed review of 22 lung cancer studies is presented in this section; a few more studies exist, but these 22 are judged to be the key ones. A detailed review of other health effect studies is not presented because findings are equivocal.

Excess risk of bladder cancer has been reported in several studies (Howe et al., 1980; Wynder et al., 1985; Hoar and Hoover et al., 1985; Silverman et al., 1983; Vineis and Magnani 1985; Silverman et al., 1986; Jensen et al., 1987; Steenland et al., 1987; Isocovich et al., 1987; Risch et al., 1988; Iyer et al., 1990; Steineck et al., 1990; Cordier et al., 1993; Notani et al., 1993). Very few studies found significant excesses after adjustment for cigarette smoking. Most studies failed to show any association between exposure to DE and occurrence of bladder cancer. Some authors have reported excess mortality from lymphohematopoietic system cancers in people potentially exposed to diesel fumes. Rushton and Alderson (1983) and Howe and Lindsay (1983) found increased mortality from lymphatic neoplasms. Balarajan and McDowall (1983) found raised mortality for malignant lymphomas. Flodin et al. (1987) observed increased risk for multiple myeloma, and Bender et al. (1989) reported excess mortality from leukemia. Because evidence for bladder cancer and lymphohematopoietic cancer was found to be equivocal, detailed reviews of these studies are not presented here.

The potential for elevated DE exposure in the occupational setting generally includes miners, railroad workers, truckers, bus and taxi drivers, heavy equipment operators, farm tractor drivers, and those involved with heavy duty marine engines. Regarding the mining industry some assert that excess lung cancer should be observed in the miners if exposure to DE is causally associated with the occurrence of lung cancer since DE is allegedly present in the mines. Our review of the mining industry data dose not support this assertion for the following reasons. In the United States, the introduction of diesel engines into metal mines dates from the early to the mid 1960s. Currently, there are approximately 265 underground metal/nonmetal mines in the United States. Virtually all of these mines use diesel powered equipment for various tasks, such as haulage, roof bolting etc. (Department of Labor, Mine Safety and Health Administration, 2001). Introduction of diesel equipment into coal mines was even later. Of 910 existing underground coal mines in the United States, only 145 currently use diesel-powered equipment. Of these 145 mines, 32 mines are currently using diesel equipment for face coal haulage. The remaining mines use diesel equipment for transportation, materials handling, and other support operations (Department of Labor, Mine Safety and Health Administration, 2001). It should be noted that there is a paucity of epidemiologic studies in miners where exposure to DE and health effects are explored. Furthermore, the majority of epidemiologic studies in miners do not mention exposure to diesel equipment use. Thus, it is impossible to know how many miners were exposed to DE and for how long and at what concentrations in a given study, if any. Hence the studies in miners (coal, metal, and nonmetal with the exception of potash miners) are not reviewed in this chapter, because the available studies are uninformative relative to DE.

In this section, various mortality and morbidity studies of lung cancer from potential exposure to diesel engine emissions are reviewed. Although an attempt was made to cover all the relevant studies, a number of studies are not included for several reasons. In the United States the change from steam to diesel engines in locomotives began after World War II. By 1946 about 10% of the locomotives in service were diesel, by 1952 55% were diesel, and dieselization was about 95% complete by 1959 (Garshick et al., 1988). Therefore, exposure to DE was less common, and the follow-up period for studies conducted prior to 1960 (Raffle, 1957; Commins et al., 1957; Kaplan, 1959) was not long enough to cover the long latency period of lung cancer. The usefulness of these studies in evaluating the carcinogenicity of DE is greatly reduced; thus, they are not considered here.

On the other hand, the trucking industry changed to diesel trucks by the 1960s. In the 1960s sales of diesel-powered Class 8 trucks (long-haul trucks) were 48% of the market, and by the 1970s sales had risen to 85%. Thus, studies conducted among truck drivers prior to the 1970s may reflect exposures to gasoline exhaust as well as DE. Hence, studies with ambiguous exposures or studies that examined several occupational risk factors were excluded because they would have contributed little to the evaluation of the carcinogenicity of DE (Waxweiler et al., 1973; Williams et al., 1977; Ahlberg et al., 1981; Stern et al., 1981; Buiatti et al., 1985; Gustafsson et al., 1986; Siemiatycki et al., 1988). A study by Coggon et al. (1984) was excluded because occupational information abstracted from death certificates had not been validated; this would have resulted in limited information.

Several types of studies of the health effects of exposure to diesel engine emissions are reviewed in this chapter, such as cohort studies, case-control studies, and studies that conducted meta-analysis. In the cohort studies, cohorts of heavy construction equipment operators, railroad and locomotive workers, bus garage employees, and miners were studied retrospectively to determine increased mortality and morbidity resulting from exposures to varying levels of diesel emissions in the workplace. The evaluation of each study presents the study population, methodology used for the study, i.e., data collection and verification, analysis, results, and a critique of the study. There are some methodologic limitations that are common to studies with similar design. The total evidence, including limitations, is discussed at the end of the chapter in the summary and discussion section.

7.2.1. Cohort Studies

7.2.1.1. *Waller (1981): Trends in Lung Cancer in London in Relation to Exposure to Diesel Fumes*

A retrospective mortality study of a cohort of London transport workers was conducted to determine if there was an excess of deaths from lung cancer that could be attributed to DE exposure. From nearly 20,000 male employees in the early years, those aged 45 to 64 were followed for the 25-year period between 1950 and 1974 (the actual number of employees is not given in the paper), constituting a total of 420,700 man-years at risk. These workers were distributed among five job categories: drivers, garage engineers, conductors, motormen or guards, and engineers (works). Lung cancer were ascertained from death certificates of individuals who died while still employed, or if retired, following diagnosis. Expected death rates were calculated by applying greater London death rates to the population at risk within each job category. Data were calculated in 5-year periods and 5-year age ranges, and the results were combined to obtain the total expected deaths in the required age range for the calendar period. A total of 667 cases of lung cancer was reported, compared with 849 expected, to give a cancer mortality ratio of 79%. In each of the five job categories, the observed numbers were below those expected. Engineers in garages had the highest mortality ratio, 90%, motormen and guards had a mortality ratio of 87%, and both the bus drivers and conductors had mortality ratios of 75%. The engineers in the central works had a mortality ratio of 66%. These mortality ratios did not differ significantly from each other. Environmental sampling was done at one garage, on one day in 1979, for benzo[*a*]pyrene (B[*a*]P) concentrations and was compared with corresponding values recorded in 1957. Concentrations of B[*a*]P recorded in 1957 were at least 10 times greater than those measured in 1979.

This study failed to find any association between DE and occurrence of lung cancer, which may be due to several methodologic limitations. The lung cancer deaths were ascertained while the workers were employed (the worker either died of lung cancer or retired after lung cancer was diagnosed). Although man-years at risk were based on the entire cohort, no attempt was made to trace or evaluate the individuals who had resigned from the London transport company for any other reason. Hence, information on resignees who may have had significant exposure to DE, and on lung cancer deaths among them, was not available for analysis. This may have led to a dilution effect, resulting in underascertainment of observed lung cancer deaths and underestimation of mortality ratios. Eligibility criteria for inclusion in the cohort, such as starting date and length of service with the company, were not specified. Therefore, there may not have been sufficient latency for the development of lung cancer. Use of greater London population death rates to obtain expected number of deaths may have resulted in a deficit in mortality ratios reflecting the "healthy worker effect." Investigators did not categorize the five job categories either by qualitative or quantitative levels of DE exposure; neither did they use an internal comparison group to derive risk estimates.

The age range considered for this study was limited (45 to 64 years of age) for the period between 1950 and 1974. It is not clear whether this age range was applied to calendar year 1950 or 1974, or at the midpoint of the 25-year follow-up period. No analyses were presented either by latency or by duration of employment (surrogate for exposure). The environmental survey based on B[*a*]P concentrations suggests that the cohort in its earlier years was exposed to much higher concentrations of environmental contaminants than currently exist. It is not clear when the reduction in B[*a*]P concentration occurred, because there are no environmental readings available between 1957 and 1979. It is also important to note that the concentrations of B[*a*]P inside the garage in 1957 were not very different from those outside the garage, thus indicating that exposure for garage workers was not much different from that of the general population. Thus, this study fails to provide either positive or negative association between the DE exposure and the occurrence of lung cancer.

7.2.1.2. *Howe et al. (1983): Cancer Mortality (1965 to 1977) in Relation to Diesel Fumes and Coal Exposure in a Cohort of Retired Railroad Workers*

This is a retrospective cohort study of the mortality experience of 43,826 male pensioners of the Canadian National Railroad (CNR) between 1965 and 1977. Members of this cohort consisted of male CNR pensioners who had retired before 1965 and who were known to be alive at the start of that year, as well as those who retired between 1965 and 1977. The records were obtained from a computer file that is regularly updated and used by the company for payment of pensions. To receive a pension, each pensioner must provide, on a yearly basis, evidence that he is alive. Specific cause of death among members of this cohort was ascertained by linking these records to the Canadian Mortality Data Base, which contains records of all deaths registered in Canada since 1950. Of the 17,838 deaths among members of the cohort between 1965 and 1977, 16,812 (94.4%) were successfully linked to a record in the mortality file. A random sample manual check on unlinked data revealed that failure to link was due mainly to some missing information on the death records.

Occupation at time of retirement was used by the Department of Industrial Relations to classify workers into three diesel fume and coal dust exposure categories: (1) nonexposed, (2) possibly exposed, and (3) probably exposed. Person-years of observation were calculated and classified by age at observation in 5-year age groups (35 to 39, 40 to 44, . . . , 80 to 84, and ≥85 years). The observed deaths were classified by age at death for different cancers, for all cancers combined, and for all causes of death combined. Standard mortality ratios (SMRs) were then calculated using rates of the Canadian population for the period between 1965 and 1977. The relative risks were calculated using the three exposure categories: nonexposed, possibly exposed, and probably exposed.

Both total mortality (SMR = 95, $p<0.001$) and all cancer deaths (SMR = 99, $p>0.05$) were close to that expected for the entire cohort. Analysis by exposure to diesel fume levels in the three categories (nonexposed, possibly exposed, and probably exposed) revealed an increased relative risk for lung cancer among workers with increasing exposure to diesel fumes. The relative risk for nonexposed workers was presumed to be 1.0; for those possibly exposed, the relative risk was significantly elevated to 1.2 (p=0.013); and for those probably exposed, it was significantly elevated to 1.35 (p=0.001). The corresponding rates for exposure to varying levels of coal dust were very similar at 1.00, 1.21 (p=0.012), and 1.35 (p=0.001), respectively. The trend tests were highly significant for both exposures ($p<0.001$). Analysis performed after the exclusion of individuals who worked in the maintenance of steam engines, and hence were exposed to high levels of asbestos, yielded a risk of lung cancer of 1.00, 1.21, and 1.33 for those nonexposed, possibly exposed, and probably exposed to DE, respectively, with a highly significant trend ($p<0.001$).

An analysis done on individuals who retired prior to 1950 showed the relative risk of lung cancer among nonexposed, possibly exposed, and probably exposed to be 1.00, 0.70, and 0.44, respectively, based on fewer than 15 deaths in each category. A similar analysis of individuals who retired after 1950 found the results in the same categories to be 1.00, 1.23, and 1.40, respectively. Although retirement prior to 1950 indicated exposure to coal combustion fumes alone, retirement after 1950 shows the results of mixed exposure to coal combustion fumes and diesel fumes. As there was considerable overlap between occupations involving probable exposure to diesel fumes and probable exposure to coal, and as most members of the cohort were employed during the years in which the transition from coal to diesel occurred, it was difficult to distinguish whether lung cancer was associated with exposure to coal combustion fumes or diesel fumes or a mixture of both.

Although this study showed a highly significant dose-response relationship between diesel fumes and lung cancer, it has some methodological limitations. There were concurrent exposures to both diesel fumes and coal combustion fumes during the transition period; therefore, misclassification of exposure may have occurred, because only occupation at retirement was available for analysis. It is possible that the elevated response observed for lung cancer was due to the combined effects of exposure to both coal dust/coal combustion products and diesel fumes and not just one or the other. However, deaths due to lung cancer were not elevated among workers who retired prior to the 1950s and thus would have been primarily exposed to coal dust/coal combustion products. Furthermore, it should be noted that so far coal dust has not been demonstrated to be a pulmonary carcinogen in studies of coal miners. This study was restricted to deaths among retired workers; therefore, it is unclear if a worker who developed lung cancer when actively employed and filed for a disability claim instead of retirement claim would be included in the study or not. Thus, it is possible that workers with heavy exposure might have been excluded from the study. Neither information on duration of employment in diesel work, nor coal dust-related jobs other than those held at retirement, nor details of how the exposure categories were created was provided. Therefore, it was not possible to evaluate whether this omission would have led to an under- or overestimate of the true relative risk. Although information on potential confounders such as smoking is lacking, the use of an internal comparison group to compute the relative risks minimizes the potential for confounding by smoking, as there is no reason to assume different smoking patterns among individuals exposed to DE versus those not exposed. Despite these limitations, this study provides suggestive evidence toward a causal association between exposure to DE and excess lung cancer.

7.2.1.3. *Rushton et al. (1983): Epidemiological Survey of Maintenance Workers in the London Transport Executive Bus Garages and Chiswick Works*

This is a retrospective mortality cohort study of male maintenance workers employed for at least 1 continuous year between January 1, 1967, and December 31, 1975, at 71 London transport bus (also known as rolling stock) garages and at Chiswick Works. The following information was obtained from computer listings: surname with initials, date of birth, date of joining company, last or present job, and location of work. For those individuals who left their job, date of and reason for leaving were also obtained. For those who died in service or after retirement, and for men who had resigned, full name and last known address were obtained from an alphabetical card index in the personnel department. Additional tracing of individuals who had left was carried out through social security records. The area of residence was assumed to be close to their work; therefore place of work was coded as residence. One hundred different job titles were coded into 20 broader groups. These 20 groups were not ranked for DE exposure, however. The reason for leaving was coded as died in service, retired, or other. The underlying cause of death was coded using the eighth revision of the International Classification of Diseases (ICD). Person-years were calculated from date of birth and dates of entry to and exit from the study using the man-years computer language program. The workers were then subdivided into 5-year age and calendar period groups. The expected number of deaths was calculated by applying the 5-year age and calendar period death rates of the comparison population with the person-years of corresponding groups. The mortality experience of the male population in England and Wales was used as the comparison population. Significance values were calculated for the difference between the observed and expected deaths, assuming a Poisson distribution.

The person-years of observation totaled 50,008 and were contributed by 8,490 individuals in the study, with a mean follow-up of 5.9 years. Only 2.2% (194) of the men were not traced. Observed deaths from all causes were significantly lower than expected (O = 495, $p<0.001$). Observed deaths from all neoplasms and cancer of the lung were approximately the same as those expected. The only significant excess observed, for cancer of the liver and gall bladder at Chiswick Works, was based on four deaths ($p<0.05$). A few job groups showed a significant excess of risks for various cancers. All the excess deaths observed for the various job groups, except for the general hand category, were based on very small numbers (usually fewer than five) and merited cautious interpretation. Only a notable excess in the general hand category for lung cancer was based on as many as 48 cases (SMR = 133, $p<0.03$).

This mortality study did not demonstrate any cancer excess. Details of work history were not obtained to permit any analysis by DE exposure. The study's limitations, including small sample size, short duration of follow-up (average of only 6 years), and lack of sufficient latency period, make it inadequate to draw any conclusions.

7.2.1.4. *Wong et al. (1985): Mortality Among Members of a Heavy Construction Equipment Operators Union With Potential Exposure to DE Emissions*

This retrospective mortality study was conducted on a cohort of 34,156 male members of a heavy construction equipment operators union with potential exposure to DE emissions. Study cohort members were identified from records maintained at Operating Engineers' Local Union No. 3-3A in San Francisco, CA. This union has maintained both work and death records on all its members since 1964. Individuals with at least 1 year of membership in this union between January 1, 1964, and December 31, 1978, were included in the study. Work histories of the cohort were obtained from job dispatch computer tapes. The study follow-up period was January 1964 to December 1978. Death information was obtained from a trust fund, which provided information on retirement dates, vital status, and date of death for those who were entitled to retirement and death benefits. Approximately 50% of the cohort had been union members for less than 15 years, whereas the other 50% had been union members for 15 years or more. The average duration of membership was 15 years. As of December 31, 1978, 29,046 (85%) cohort members were alive, 3,345 (9.8%) were dead, and 1,765 (5.2%) remained untraced. Vital status of 10,505 members who had left the union as of December 31, 1978, was ascertained from the Social Security Administration. Death certificates were obtained from appropriate State health departments. Altogether, 3,243 deaths (for whom death certificates were available) in the cohort were coded using the seventh revision of the ICD. For 102 individuals, death certificates could not be obtained, only the date of death; these individuals were included in the calculation of the SMR for all causes of death but were deleted from the cause-specific SMR analyses. Expected deaths and SMRs were calculated using the U.S. national age-sex-race cause-specific mortality rates for 5-year time periods between 1964 and 1978. The entire cohort population contributed to 372,525.6 person-years in this 15-year study period.

A total of 3,345 deaths was observed, compared with 4,109 expected. The corresponding SMR for all causes was 81 (p=0.01), which is consistent with the “healthy worker effect.” A total of 817 deaths was attributed to malignant neoplasms, slightly fewer than the 878 expected based on U.S. white male cancer mortality rates (SMR = 93, p=0.05). Mostly there were SMR deficits for cause-specific cancers, including lung cancer for the entire cohort (SMR = 99, O = 309). The only significant excess SMR was observed for cancer of the liver (SMR = 167, O = 23, p<0.05).

Analysis by length of union membership as a surrogate of duration for potential exposure showed statistically significant increases in SMRs of cancer of the liver (SMR = 424, p<0.01) in the 10- to 14-year membership group and of the stomach (SMR = 248, p<0.05) in the 5- to 9-year membership group. No cancer excesses were observed in the 15- to 19-year and 20+-year membership groups. Although the SMR for cancer of the lung had a statistically significant deficit in the less-than-5-year duration group, it showed a positive trend with increasing length of membership, which leveled off after 10 to 14 years.

Cause-specific mortality analysis by latency period showed a positive trend for SMRs of all causes of death, although all of them were statistically significant deficits, reflecting the diminishing “healthy worker effect.” This analysis also demonstrated a statistically significant SMR excess for cancer of the liver (10- to 19-year group, SMR = 258). The SMR for cancer of the lung showed a statistically significant deficit for a <10-year latency but showed a definite positive trend with increasing latency.

In addition to these analyses of the entire cohort, similar analyses were carried out in various subcohorts. Analyses of retirees, 6,678 individuals contributing to 32,670 person-years, showed statistically significant increases (p<0.01) in SMRs for all cancers; all causes of death; cancers of the digestive system, large intestine, respiratory system, and lung; emphysema; and cirrhosis of the liver. The other two significant excesses (p<0.01) were for lymphosarcoma and reticulosarcoma and nonmalignant respiratory diseases. Further analysis of the 4,075 retirees (18,678 person-years) who retired at age 65 or who retired earlier but had reached the age of 65 revealed statistically significant SMR increases (p<0.05) for all cancers, cancer of the lung, and lymphosarcoma and reticulosarcoma.

To analyze cause-specific mortality by job held (potential exposure to DE emissions), 20 functional job titles were used, which were further grouped into three potential categories: high exposure, low exposure, and unknown exposure. A person was classified in a job title if he ever worked on that job. Based on this classification system, if a person had ever worked in a high-exposure job title he was included in that group, even though he may have worked for a longer time in a low-exposure group or in an unknown exposure group. Information on length of work in any particular job, hence indirect information on potential length of exposure, was not available either.

For the high-exposure group a statistically significant excess was observed for cancer of the lung among bulldozer operators who had 15 to 19 years of membership and 20+ years of follow-up (SMR = 343, $p<0.05$). This excess was based on 5 out of 495 deaths observed in this group of 6,712 individuals, who contributed 80,328 person-years of observation.

The cause-specific mortality analysis in the low-exposure group revealed statistically significant SMR excesses in individuals who had ever worked as engineers. These excesses were for cancer of the large intestine (SMR = 807, O = 3, $p<0.05$) among those with 15 to 19 years of membership and length of follow-up of at least 20 years, and cancer of the liver (SMR = 872, O = 3, $p<0.05$) among those with 10 to 14 years of membership and length of follow-up of 10 to 19 years. There were 7,032 individuals who contributed to 78,403 person-years of observation in the low-exposure group.

For the unknown exposure group, a statistically significant SMR was observed for motor vehicle accidents only (SMR = 174, O = 21, $p<0.05$). There were 3,656 individuals who contributed to 33,388 person-years of observation in this category.

No work histories were available for those who started their jobs before 1967 and for those who held the same job prior to and after 1967. This group comprised 9,707 individuals (28% of the cohort) contributing to 104,448 person-years. Statistically significant SMR excesses were observed for all cancers (SMR = 112, O = 339, $p<0.05$) and cancer of the lung (SMR = 119, O = 141, $p<0.01$). A significant SMR elevation was also observed for cancer of the stomach (SMR = 199, O = 30, $p<0.01$).

This study demonstrates a statistically significant excess for cancer of the liver but also shows statistically significant deficits in cancers of the large intestine and rectum. It may be, as the authors suggested, that the liver cancer cases actually resulted from metastases from the large intestine and/or rectum, as tumors of these sites will frequently metastasize to the liver. The excess in liver cancer mortality and the deficits in mortality that are due to cancer of the large intestine and rectum could also, as the authors indicate, be due to misclassification. Both possibilities have been considered by the investigators in their discussion.

Cancer of the lung showed a positive trend with length of membership as well as with latency, although none of the SMRs were statistically significant except for workers without any work histories. The individuals without any work histories may have been the ones who were in their jobs for the longest period of time, because workers without job histories included those who had the same job before and after 1967 and thus may have worked 12 to 14 years or longer. If they had belonged to the category in which heavy exposure to DE emissions was very common for this prolonged time, then the increase in lung cancer, as well as stomach cancer, might be linked to DE. Further information on those without work histories should be obtained if possible, because such information may be quite informative with regard to the evaluation of the carcinogenicity of DE.

The study design is adequate, covers about a 15-year observation period, has a large enough population, and is appropriately analyzed; however, it has too many limitations to permit any conclusions. First, no exposure histories are available; one has to make do with job histories, which provide limited information on exposure level. Any person who ever worked at the job, or any person working at the same job over any period of time, is included in the same category; this would have a dilution effect, because extremely variable exposures were considered in the study. Second, the length of time worked in any particular job is not available. Third, work histories were not available for 9,707 individuals, who contributed 104,448 person-years, a large proportion of the study cohort (28%). These individuals happen to show the most evidence of a carcinogenic effect. Confounding by alcohol consumption for cancer of the liver and smoking for emphysema and cancer of the lung was not ruled out. Fourth, 15 years' follow-up may not provide sufficient latency to observe excess lung cancer. Last, although 34,156 members were eligible for the study, the vital status of 1,765 individuals was unknown. Nevertheless, they were still considered in the denominator of all the analyses. The investigators fail to mention how the person-year calculation for these individuals was handled. Also, some of the person-years might have been overestimated, as people may have paid the dues for a particular year and then left work. These two causes of overestimation of the denominator may have resulted in some or all the SMRs being underestimated.

7.2.1.5. *Edling et al. (1987): Mortality Among Personnel Exposed to DE*

This retrospective cohort mortality study of bus company employees investigated a possible increased mortality of cardiovascular diseases and cancers from DE exposure. The cohort comprised all males employed at five different bus companies in southeastern Sweden between 1950 and 1959. Based on information from personnel registers, individuals were classified into one or more categories and could have contributed person-years at risk in more than one exposure category. The study period was from 1951 to 1983; information was collected from the National Death Registry, and copies of death certificates were obtained from the National Bureau of Statistics. Workers who died after age 79 were excluded from the study because diagnostic procedures were likely to be more uncertain at higher ages (according to investigators). The cause-, sex-, and age-specific national death rates in Sweden were applied to the 5-year age categories of person-years of observation to determine expected deaths for all causes, malignant diseases, and cardiovascular diseases. A Poisson distribution was used to calculate *p*-values and confidence limits for the ratio of observed to expected deaths. The total cohort of 694 men (after loss of 5 men to follow-up) was divided into three exposure categories: (1) clerks with lowest exposure, (2) bus drivers with moderate exposure, and (3) bus garage workers with highest exposure.

The 694 men provided 20,304 person-years of observation, with 195 deaths compared with 237 expected. A deficit in cancer deaths largely accounted for this lower-than-expected mortality in the total cohort. Among subcohorts, no difference between observed and expected deaths for total mortality, total cancers, or cardiovascular causes was observed for clerks (lowest diesel exposure), bus drivers (moderate diesel exposure), and garage workers (high diesel exposure). The risk ratios for all three categories were less than 1 except for cardiovascular diseases among bus drivers, which was 1.1.

When the analysis was restricted to members who had at least a 10-year latency period and either any exposure or an exposure exceeding 10 years, similar results were obtained, with fewer neoplasms than expected, whereas cardiovascular diseases showed risk around or slightly above unity.

Five lung cancer deaths were observed among bus drivers who had moderate DE exposure, whereas seven were expected. The only other lung cancer death was observed among bus garage workers who had the highest DE exposure. This study's major limitations, including small size and poor data on DE exposure, make it inadequate to draw any conclusions.

7.2.1.6. *Boffetta and Stellman (1988): DE Exposure and Mortality Among Males in the American Cancer Society Prospective Study*

Boffetta and Stellman conducted a mortality analysis of 461,981 males with known smoking history and vital status at the end of the first 2 years of follow-up. The analysis was restricted to males aged 40 to 79 years in 1982 who enrolled in the American Cancer Society's prospective mortality study of cancer. Mortality was analyzed in relation to exposure to DE and to employment in selected occupations related to DE exposure. In 1982, more than 77,000 American Cancer Society volunteers enrolled more than 1.2 million men and women from all 50 States, the District of Columbia, and Puerto Rico in a long-term cohort study, the Cancer Prevention Study II (CPS-II). Enrollees were usually friends, neighbors, or relatives of the volunteers; enrollment was by family groups, with at least one person in the household 45 years of age or older. Subjects were asked to fill out a four-page confidential questionnaire and return it in a sealed envelope. The questionnaire included history of cancer and other diseases; use of medications and vitamins; menstrual and reproductive history; occupational history; and information on diet, drinking, smoking, and other habits. The questionnaire also included three questions on occupation: (1) current occupation, (2) last occupation, if retired, and (3) job held for the longest period of time, if different from the other two. Occupations were coded to an ad hoc two-digit classification in 70 categories. Exposures at work or in daily life to any of the 12 groups of substances were also ascertained. These included diesel engine exhausts, asbestos, chemicals/acids/solvents, dyes, formaldehyde, coal or stone dusts, and gasoline exhausts. Volunteers checked whether their enrollees were alive or dead and recorded the date and place of all deaths every other year during the study. Death certificates were then obtained from State health departments and coded by a trained nosologist according to a system based on the ninth revision of the ICD.

The data were analyzed to determine the mortality for all causes and lung cancer in relation to DE exposure, mortality for all causes and lung cancer in relation to employment in selected occupations with high DE exposure, and mortality from other causes in relation to DE exposure. The incidence-density ratio was used as a measure of association, and test-based confidence limits were calculated by the Miettinen method. For stratified analysis, the Mantel-Haenszel method was used for testing linear trends. Although data on 476,648 subjects comprising 939,817 person-years of risk were available for analysis, 3% of the subjects (14,667) had not given any smoking history, and 20% (98,026) did not give information on DE exposure and were therefore excluded from the main DE analysis. Among individuals who had provided DE exposure history, 62,800 were exposed and 307,143 were not exposed. Comparison of the population with known information on DE exposure with the excluded population with no information on DE exposure showed that the mean ages were 54.7 and 57.7 years, the nonsmokers were 72.4% and 73.2%, and the total mortality rates per 1,000 per year were 23.0% and 28.8%, respectively.

All-cause mortality was elevated among railroad workers (relative risk [RR] = 1.43, 95% confidence interval [CI] = 1.2, 1.72), heavy equipment operators (RR = 1.7, 95% CI = 1.19, 2.44), miners (RR = 1.34, 95% CI = 1.06, 1.68), and truck drivers (RR = 1.19, 95% CI = 1.07, 1.31). The age-adjusted lung cancer relative risk was elevated significantly (RR = 1.41, 95% CI = 1.19,1.66), which was slightly decreased to 1.31 (95% CI = 1.10, 1.54). For lung cancer mortality the age- and smoking-adjusted risks were significantly elevated for miners (RR = 2.67, 95% CI = 1.63, 4.37) and heavy equipment operators (RR = 2.60, 95% CI = 1.12, 6.06). Risks were also elevated, but not significantly, for railroad workers (RR = 1.59, 95% CI = 0.94, 2.69) and truck drivers (RR = 1.24, 95% CI = 0.93, 1.66). These risks were calculated with the Mantel-Haenszel method, controlling for age and smoking. Although the relative risk was nonsignificant for truck drivers, a small dose-response effect was observed when duration of DE exposure was examined. For drivers who worked for 1 to 15 years, the relative risk was 0.87, whereas for drivers who worked for more than 16 years, the relative risk was 1.33 (95% CI = 0.64, 2.75). Relative risks for lung cancer were not presented for other occupations. Mortality analysis for other causes and DE exposure showed a significant excess of deaths ($p<0.05$) in the following categories: cerebrovascular disease, arteriosclerosis, pneumonia, influenza, cirrhosis of the liver, and accidents.

The main strength of this study is detailed information on smoking. The two main methodologic concerns are the representativeness of the study population and the quality of information on exposure. The sample, though very large, was composed of volunteers. Thus, the cohort was healthier and less frequently exposed to important risk factors such as smoking and alcohol. Self-administered questionnaires were used to obtain data on occupation and DE exposure. None of this information was validated. Nearly 20% of the individuals had an unknown exposure status to DE, and they experienced a higher mortality for all causes and lung cancer than both the DE exposed and unexposed groups. This could have introduced a substantial bias in the estimate of the association. Given that all DE exposure occupations, such as heavy equipment operators, truck drivers, and railroad workers, showed elevated lung cancer risk, this study is suggestive of a causal association. It should be noted that after adjusting for smoking, the RR reduced slightly from 1.41 to 1.31 and remained significant, indicating that observed excess of lung cancer was associated mainly with DE exposure.

7.2.1.7. *Garshick et al. (1988): A Retrospective Cohort Study of Lung Cancer and DE Exposure in Railroad Workers*

An earlier case-control study of lung cancer and DE exposure in U.S. railroad workers by these investigators had demonstrated a relative odds of 1.41 (95% CI = 1.06, 1.88) for lung cancer with 20 years of work in jobs with DE exposure. To confirm these results, a large retrospective cohort mortality study was conducted by the same investigators. Data sources for the study were the work records of the U.S. Railroad Retirement Board (RRB). The cohort was selected based on job titles in 1959, which was the year by which 95% of the locomotives in the United States were diesel powered. DE exposure was considered to be a dichotomous variable depending on yearly job codes between 1959 and death or retirement through 1980. Industrial hygiene evaluations and descriptions of job activities were used to classify jobs as exposed or unexposed to diesel emissions. A questionnaire survey of 534 workers at one of the railroads where workers were asked to indicate the amount of time spent in railroad locations, either near or away from sources of DE, was used to validate this classification. Workers selected for this survey were actively employed at the time of the survey, 40 to 64 years of age, started work between 1939 and 1949 in the job codes sampled in 1959, and eligible for railroad benefits. To qualify for benefits, a worker must have had 10 years or more of service with the railroad and should not have worked for more than 2 years in a nonrailroad job after leaving railroad work. Workers with recognized asbestos exposure, such as repair of asbestos-insulated steam locomotive boilers, passenger cars, and steam pipes, or railroad building construction and repairs, were excluded from the job categories selected for study. However, a few jobs with some potential for asbestos exposure were included in the cohort, and the analysis was done both ways, with and without them.

The death certificates for all subjects identified in 1959 and reported by the RRB to have died through 1980 were searched. Twenty-five percent of them were obtained from the RRB and the remainder from the appropriate State departments of health. Coding of cause of death was done without knowledge of exposure history, according to the eighth revision of the ICD. If the underlying cause of death was not lung cancer, but was mentioned on the death certificate, it was assigned as a secondary cause of death, so that the ascertainment of all cases was complete. Workers not reported by the RRB to have died by December 31, 1980, were considered to be alive. Deceased workers for whom death certificates had not been obtained or, if obtained, did not indicate cause of death, were assumed to have died of unknown causes.

Proportional hazard models were fitted that provided estimates of relative risk for death caused by lung cancer using the partial likelihood method described by Cox, using the time dimension being the time since first entry into the cohort. The model also controlled for the birth year and the calendar time. The 95% confidence intervals were constructed using the asymptotic normality of the estimated regression coefficients of the proportional hazards model. Exposure was analyzed by DE-exposed jobs in 1959 and by cumulative number of years of DE exposure through 1980. Directly standardized rate ratios for deaths from lung cancer were calculated for DE exposed compared with unexposed for each 5-year age group in 1959. The standardized rates were based on the overall 5-year person-year time distribution of individuals in each age group starting in 1959. The only exception to this was between 1979 and 1980, when a 2-year person-year distribution was used. The Mantel-Haenszel analogue for person-year data was used to calculate 95% confidence intervals for the standardized rate ratios.

The cohort consisted of 55,407 workers, 19,396 of whom had died by the end of 1980. Death certificates were not available for 11.7% of all deaths. Of the 17,120 deaths for whom death certificates were obtained, 48.4% were attributable to diseases of the circulatory system, whereas 21% were attributable to all neoplasms. Of all neoplasms, 8.7% (1,694 deaths) were due to lung cancer. A higher proportion of workers in the younger age groups, mainly brakemen and conductors, were exposed to DE, while a higher proportion of workers in the older age groups were potentially exposed to asbestos. In a proportional hazards model, analyses by age in 1959 found a relative risk of 1.45 (95% CI = 1.11, 1.89) among the age group 40 to 44 years and a relative risk of 1.33 (95% CI = 1.03, 1.73) for the age group 45 to 49 years. Risk estimates in the older age groups 50 to 54, 55 to 59, and 60 to 64 years were 1.2, 1.18, and 0.99, respectively, and were not statistically significant. The two youngest age groups in 1959 had workers with the highest prevalence and longest duration of DE exposure and lowest exposure to asbestos. When potential asbestos exposure was considered as a confounding variable in a proportional hazards model, the estimates of relative risk for asbestos exposure were all near null value and not significant. Analysis of workers exposed to DE in 1959 (n = 42,535), excluding workers with potential past exposure to asbestos, yielded relative risks of 1.57 (95% CI = 1.19, 2.06) and 1.34 (95% CI = 1.02, 1.76) in the 1959 age groups 40 to 44 years and 45 to 49 years. Directly standardized rate ratios were also calculated for each 1959 age group based on DE exposure in 1959. The results confirmed those obtained by using the proportional hazards model.

Relative risk estimates were then obtained using duration of DE exposure as a surrogate for dose. In a model that used years of exposure up to and including exposure in the year of death, no exposure duration-response relationship was obtained. When analysis was done by disregarding exposure in the year of death and 4 years prior to death, the risk of dying from lung cancer increased with the number of years worked in a diesel-exhaust-exposed job. In this analysis, exposure to DE was analyzed by exposure duration groups and in a model entering age in 1959 as a continuous variable. The workers with greater than 15 years of exposure had a relative risk of lung cancer of 1.72 (95% CI = 1.27, 2.33). The risk for 1 to 4 years of cumulative exposure was 1.20 (95% CI = 1.01, 1.44); for 5 to 9 years of cumulative exposure, it was 1.24 (95% CI = 1.06, 1.44); and for 10 to 14 years of cumulative exposure, it was 1.32 (95% CI = 1.13, 1.56).

The results of this study, demonstrating a positive association between DE exposure and increased lung cancer, are consistent with the results of the case-control study conducted by the same investigators in railroad workers dying of lung cancer from March 1981 through February 1982. This cohort study has addressed many of the weaknesses of the other epidemiologic studies. The large sample size (55,400) allowed sufficient power to detect small risks and also permitted the exclusion of workers with potential past exposure to asbestos. The stability of job career paths in the cohort ensured that of the workers 40 to 44 years of age in 1959 classified as DE-exposed, 94% of the cases were still in DE-exposed jobs 20 years later.

The main limitation of the study is the lack of quantitative data on exposure to DE in either individual workers or overall job categories. This is one of the few studies in which industrial hygiene measurements of DE were done. These measurements were correlated with job titles to divide the cohort in dichotomous exposure groups of exposed and nonexposed. This may have led to an underestimation of the risk of lung cancer because exposed groups included individuals with low to high exposure. The number of years exposed to DE was used as a surrogate for dose. The dose, based on duration of employment, was inaccurate because individuals were working on steam and diesel locomotives during the transition period. It should be noted that the investigators only included exposures after 1959; the duration of exposure prior to 1959 was not known. If the categories of exposure to DE had been set up as no, low, moderate, and high exposure, the results would have been more meaningful, as would the dose-response relationship. Another limitation of this study was its inability to examine the effect of years of exposure prior to 1959 and latency. No adjustment for smoking was made in this study. However, an earlier case-control study done in the same cohort (Garshick et al., 1987) showed no significant difference in the risk estimate after adjusting for smoking. Despite these limitations, the results of this study indicate that occupational exposure to DE is associated with a modest risk (1.5) of lung cancer.

The data of this study were used by Crump et al. (1991) to explore the development of dose-response-based quantitative estimates of lung cancer associated with DE exposure by using diesel exposure estimate data from the industrial hygiene (IH) studies conducted by Hammond (1998) and Woskie et al. (1988a,b). These studies were conducted in conjunction with the Garshick et al. (1988) study. The Woskie et al. (1988a,b) IH studies were conducted in four small northern railroads where the workers were exposed to DE in the early 1980s, prior to the Garshick et al. (1988) epidemiologic study. A total of 39 job titles were identified by Woskie et al. (1988a,b), which were subsequently combined into 13 job groups and finally merged into 5 career exposure job codes as follows: brakers, conductors, and hostlers; clerks; engineers and firers; signal maintainers; and shop workers. The average exposure estimates were assigned to the cohort members by Crump et al. (1991) based on the job codes in 1959. Cumulative exposures were calculated using these average exposures for each job code. The exposures in the IH study by Hammond (1998) were defined as the concentrations of respirable-sized particles (RSP), the adjusted respirable particles (ARP) concentrations, and the adjusted extractable mass (AEM). The concentrations of ARP were estimated in the IH study by removing the particle contribution of environmental tobacco smoke (ETS). Crump et al. (1991) also used another index called total extractable material (TEX), which was the extractable RSP including the particle contribution of ETS. Using these four exposure indices and the regional climates for the United States, Crump et al. (1991) constructed various exposure metrics. They conducted more than 50 analyses based on calendar year, age in 1959, attained age, and five job codes identified in 1959: brakers, conductors, and hostlers; clerks; engineers and firers; signal maintainers; and shop workers; using the exposure metrics. Crump et al. (1991) used the U.S. general population age- and year-specific death rates for comparison and found that the relative risk can be positively or negatively related to the duration of exposure depending on how age was controlled in a model. Their use of the U.S. general population rates instead of the internal unexposed group of railroad workers that was used by Garshick et al. (1988) identified that the death ascertainment between 1977 and 1980 as incomplete. The Crump et al. (1991) analysis, limited to 1959 through 1976, found an excess lung cancer risk similar to the subsequent Garshick analysis (letter from Garshick, Harvard Medical School, to Chao Chen, U.S. EPA, dated August 15, 1991).

Garshick conducted some additional analyses after confirming the underascertainment of deaths by RRB identified by Crump et al. (1991). He reported that the relationship between years of exposure, when adjusted for attained age and calendar year, was flat to negative depending upon which model was used. He also found that in the years 1977-1980 the death ascertainment was incomplete; approximately 20% to 70% of deaths were missing depending upon the calendar year. Garshick's analysis, based on job titles in 1959 and limited to deaths occurring through 1976, showed that even though the relative risk for all exposure groups was elevated, the youngest workers still had the highest risk of dying of lung cancer.

Crump (1999), on the other hand, reported that the negative dose-response continued to be upheld in his latest analysis when age was controlled more carefully and years of exposure quantified more accurately. Crump (1999) asserted that the negative dose-response trends for lung cancer observed either with the cumulative exposure or with duration of exposure may be due to underascertainment of deaths in the last 4 years of follow-up of the Garshick et al. (1988) study as well as incomplete follow-up in earlier years.

California EPA's (Cal EPA, 1998) Office of Environmental Health Hazard Assessment (OEHHA) used the same railroad worker data for its quantitative risk assessment. The five job categories defined by Woskie et al. (1988a,b) and used by Crump et al. (1991) were combined into three exposure categories: exposed (engineers and firers; brakers, conductors, and hostlers; collectively known as "train workers"), unexposed (clerks and signalmen), and uncertain exposure (shop workers). In its analysis, OEHHA found a positive dose-response and a steadily increasing risk of lung cancer with increasing duration of exposure by using age in 1959 but allowing for an interaction term of age and calendar year in the model. This positive dose-response finding was contradictory to the negative to flat dose-response findings of both Crump et al. (1991) and Garshick (letter from Garshick, Harvard Medical School, to Chao Chen, U.S. EPA, dated August 15, 1991).

The Health Effects Institute (HEI, 1999) convened an expert panel specifically to evaluate strengths and limitations of two epidemiologic studies that had some exposure data, for quantitative risk estimation and to resolve the discrepancies in the dose-response results reported by Garshick et al. (1988), Crump et al. (1991), and OEHHA (Cal EPA, 1998). In their evaluation of the epidemiologic study of railroad worker data for quantitative risk assessment, the panel conducted their own analysis of the Garshick et al. (1988) data. They excluded the last 4 years of follow-up (1977-1980) because of underascertainment of deaths during these years.

The panel categorized the duration of exposure in 12 categories that were basically the duration of employment. The exposure was assumed to be linearly increasing for 15 years prior to 1959. Lags of 5 and 10 years were also considered in the analysis. The job categories based on job held in 1959 were classified as clerks, signalmen, engineers and firers, conductors and brakers, hostlers, and shop workers. For final analysis these were collapsed into three groups: clerks and signalmen, train workers (engineers and firers, conductors and brakers, and hostlers), and shop workers. Seven different models were used. The panel's analysis revealed consistently elevated lung cancer risk for train workers compared with clerks for each duration of employment (1-4, 5-9, 10-14, 15-17, 18+) in years and that shop workers had an intermediate risk of lung cancer. Their analysis also revealed decreasing risk of lung cancer with increasing duration of employment in all three job categories. These findings were similar to those of Garshick (letter from Garshick, Harvard Medical School, to Chao Chen, U.S. EPA, dated August 15, 1991) and Crump et al. (1991).

In addition to differences in adjusting the age (age in 1959 versus attained age) in their respective analyses, these three investigators made different assumptions in estimating exposure patterns in these railroad workers. Garshick et al. (1988) assumed that there was no exposure to DE prior to 1959 and that the exposure to DE was constant throughout the period of follow-up, i. e., 1959 to 1980 (block exposure pattern). Crump et al. (1991) assumed that the exposure to DE increased steadily from 1945 to 1959 to the same level as assumed in the block exposure pattern by Garshick et al. (1988) and then remained constant from 1959 through 1980 (ramp exposure pattern). OEHHA assumed that the exposure increased steeply from 1945 to 1959. The peak exposure attained in 1959 according to OEHHA was twice as high as assumed in the block and ramp exposure patterns by Garshick et al. (1988) and Crump et al. (1991), respectively. The exposures then declined steeply from 1959 to reach the levels assumed in the block and ramp exposure patterns in 1980 (roof exposure pattern). The roof exposure pattern was constructed on the assumption that diesel engines were "smokier" in the past. A detailed discussion of divergent results observed by Crump and Cal EPA can be found in Chapter 8.

The panel discussed various possibilities for the negative dose-response found among train workers and to a lesser extent among shop workers. They asserted that several types of biases could affect the data, alone or in combination, and mask a true positive association. The biases enumerated by the panel were: unmeasured confounding by smoking, exposure to other sources of pollution, previous occupational exposures, exposure misclassification, use of "duration of employment" as a surrogate measure for exposure, healthy worker survivor effect, and differential or incomplete ascertainment of lung cancer deaths (for detailed discussion of how an individual bias affects the results, please see HEI, 1999). The panel concluded, "However, despite the reason or reasons why the relative risks in these data decrease with duration of employment, the lack of a positive exposure-response association in the railroad worker cohort substantially weakens that study's potential to provide a reliable quantitative estimate of risk of exposure to diesel engine emissions." Thus, the panel recommended against using the current railroad worker data as the basis for quantitative risk assessment in ambient settings.

The panel also reported that the Garshick et al. study (1987, 1988) had several strengths, such as a large number of study subjects (55,407 subjects, including 1,694 lung cancer deaths in the cohort study and 1,256 lung cancer cases for the case-control study). The workers were employed in an industry where many of them were exposed to DE. Confounding by asbestos was handled by either excluding certain job categories from the analyses or controlling for it in the analyses. Confounding by smoking was controlled in the analyses of case-control study. The panel concluded that the overall results of the Garshick studies were generally consistent with findings of a weak association between exposure to DE and occurrence of lung cancer.

Thus, it should be noted that although the railroad worker data are unsuitable for quantitative risk assessment, they provide qualitative support for a positive association between exposure to DE and occurrence of lung cancer.

7.2.1.8. *Gustavsson et al. (1990): Lung Cancer and Exposure to DE Among Bus Garage Workers*

A retrospective mortality study (from 1952 to 1986), cancer incidence study (from 1958 to 1984), and nested case-control study were conducted among a cohort of 708 male workers from five bus garages in Stockholm, Sweden, who had worked for at least 6 months between 1945 and 1970. Thirteen individuals were lost to follow-up, reducing the cohort to 695.

Information was available on location of workplace, job type, and beginning and ending of work periods. Workers were traced through a computerized register of the living population, death and burial books, and data from the Stockholm city archives.

For the cohort mortality analyses, death rates of the general population of greater Stockholm were used. Death rates of occupationally active individuals, a subset of the general population of greater Stockholm, were used as a second comparison group to reduce the bias from "healthy worker effect." Mortality analysis was conducted using the "occupational mortality analysis program" (OCMAP-PC). For cancer incidence analysis, the "epidemiology in Linköping" (EPILIN) program was used, with the incidence rates obtained from the cancer registry.

For the nested case-control study, both dead and incident primary lung cancers identified in the register of cause of deaths and the cancer register were selected. Six controls matched on age ± 2 years, selected from the noncases at the time of the diagnosis of cases, were drawn at random without replacements. Matched analyses were done to calculate odds ratios using conditional logistic regression. The EGRET and Epilog programs were used for these analyses.

DE and asbestos exposure assessments were performed by industrial hygienists based on the intensity of exposure to DE and asbestos, specific for workplace, work task, and calendar time period. A DE exposure assessment was based on (1) amount of emission (number of buses, engine size, running time, and type of fuel), (2) ventilatory equipment and air volume of the garages, and (3) job types and work practices. Based on detailed historical data and very few actual measurements, relative exposures were estimated (these were not absolute exposure levels). The scale was set to 0 for unexposed and 1 for lowest exposure, with each additional unit increase corresponding to a 50% increase in successive intensity (i.e., 1.5, 2.25, 3.38, and 5.06).

Based on personal sampling of asbestos during 1987, exposures were estimated and time-weighted annual mean exposures were classified on a scale of three degrees (0, 1, and 2). Cumulative exposures for both DE and asbestos were calculated by multiplying the level of exposure by the duration of every work period. An exposure index was calculated by adding for every individual contribution from all work periods for both DE and asbestos. Four DE index classes were created: 0 to 10, 10 to 20, 20 to 30, and >30. The four asbestos index classes were 0 to 20, 20 to 40, 40 to 60, and >60. The cumulative exposure indices were used for the nested case-control study.

Excesses were observed for all cancers and some other site-specific cancers using both comparison populations for the cohort mortality study, but none of them was statistically significant. Based on 17 cases, SMRs for lung cancer were 122 and 115 using Stockholm occupationally active and general population, respectively. No dose-response was observed with increasing cumulative exposure in the mortality study. The cancer incidence study reportedly confirmed the mortality results (results not given).

The nested case-control study, on the other hand, showed increasing risk of lung cancer with increasing exposure. Using 0 to 10 DE exposure index as the comparison group yielded RRs of 1.34 (95% CI = 1.09 to 1.64), 1.81 (95% CI = 1.20 to 2.71), and 2.43 (95% CI = 1.32 to 4.47) for the DE indices 10 to 20, 20 to 30, and >30, respectively. The study was based on 17 cases and 6 controls for each case matched on age ± 2 years. Adjustment for asbestos exposure did not change the lung cancer risk for DE.

The main strength of this study is the detailed exposure matrices constructed for both DE and asbestos exposure, although they were based primarily on job tasks and very few actual measurements. There are a few methodological limitations to this study. The cohort is small and there were only 17 lung cancer deaths; thus the power is low. Exposure or outcome may be misclassified, although any resulting bias in the relative risk estimates is likely to be toward unity, because exposure classification was done independently of the outcome. Although the analysis by dose indices was done, no latency analysis was performed. Although data on smoking were missing, it is unlikely to confound the results because this is a nested case-control study; therefore, smoking is not likely to be different among the individuals irrespective of their exposure status to DE. Overall, this study provides some support to the excess lung cancer results found earlier among populations exposed to DE.

7.2.1.9. *Hansen (1993): A Follow-up Study on the Mortality of Truck Drivers*

This is a retrospective cohort mortality study of unskilled male laborers, ages 15 to 74 years, in Denmark, identified from a nationwide census file of November 9, 1970. The exposed group included all truck drivers employed in the road delivery or long-haul business (14,225). The unexposed group included all laborers in certain selected occupational groups considered to be unexposed to fossil fuel combustion products and to resemble truck drivers in terms of work-related physical demands and various personal background characteristics (43,024).

Through automatic record linkage between the 1970 census register (the Central Population Register 1970 to 1980) and the Death Certificate Register (1970 to 1980), the population was followed for cause-specific mortality or emigration up to November 9, 1980. Expected number of deaths among truck drivers was calculated by using the 5-year age group and 5-year time period death rates of the unexposed group and applying them to the person-years accumulated by truck drivers. ICD Revision 8 was used to code the underlying cause of death. Test-based CIs were calculated using Miettinen’s method. A Poisson distribution was assumed for the smaller numbers, and CI was calculated based on exact Poisson distribution (Ciba-Geigy). Total person-years accrued by truck drivers were 138,302, whereas for the unexposed population, they were 407,780. There were 627 deaths among truck drivers and 3,811 deaths in the unexposed group. Statistically significant excesses were observed for all cancer mortality (SMR = 121, 95% CI = 104 to 140); cancer of respiratory organs (SMR = 160, 95% CI = 128 to 198), which was due mainly to cancer of bronchus and lung (SMR = 160, 95% CI = 126 to 200); and multiple myeloma (SMR = 439, 95% CI = 142 to 1,024). When lung cancer mortality was further explored by age groups, excesses were observed in most age groups (30 to 39, 45 to 49, 50 to 54, 55 to 59, 60 to 64, and 65 to 74), but there were small numbers of deaths in each group when stratified by age, and the excesses were statistically significant for the 55 to 59 (SMR = 229, O = 19, 95% CI = 138 to 358) and 60 to 64 (SMR = 227, O = 22, 95% CI = 142 to 344) age groups only.

As acknowledged by the author, the study has quite a few methodologic limitations. The exposure to DE is assumed in truck drivers based on use of diesel-powered trucks, but no validation of qualitative or quantitative exposure is attempted. It is also not known whether any of these truck drivers or any other laborers had changed jobs after the census of November 9, 1970, thus creating potential misclassification bias in exposure to DE. The truck drivers and the unexposed laborers were from the same socioeconomic class and may have the same smoking habits. Still, the lack of information on smoking data and a 36% rural population (usually consuming less tobacco) in the unexposed group may potentially confound the lung cancer results. However, a population survey carried out in 1988 showed very little difference in smoking habits of residents of rural areas and the total Danish male population. The investigator reports that diesel trucks were introduced in Denmark after World War II, and since the late 1940s the majority of the Danish fleet has been composed of diesel trucks. Consequently, even though the follow-up period is relatively short, the truck drivers may have had exposure to DE for 20 to 30 years. Therefore, the finding of excess lung cancer in this study is consistent with the findings of other truck driver studies.

7.2.1.10. *Saverin et al. (1999): DE and Lung Cancer Mortality in Potash Mining*

This is a cohort mortality study conducted in male potash miners in Germany. The mines began using mobile diesel-powered vehicles in 1969 and 1970. Miners who had worked underground for at least 1 year after 1969 to 1991, when the mines were closed, were followed from 1970 to 1994. A total of 5,981 individuals were identified from the medical records by a team of medical personnel familiar with the mining technology. A total of 5,536 were eligible for follow-up after 5.5% were excluded due to implausible or incomplete work history and 1.9% were lost to follow-up. A subcohort of 3,258 miners who had worked for at least 10 years underground (80% had held a single job) was also identified. The miners' biannual medical examination records were used to extract the information about personal data, smoking data, and pre-mining occupation, and to reconstruct a chronology of workplaces occupied by the worker since hire for each person.

Exposure categories were defined as production, maintenance, and workshop, roughly corresponding to high, medium, and low. Concentrations of total carbon, including elemental and organics, were measured in the airborne fine dust in 1992. A total of 255 samples covering all workplaces was obtained. Most were personal dust samples; some were area dust samples. Cumulative exposure was calculated for each miner, for each year of observation, using the work chronology and the work category. For the workshop category years of employment were considered as exposure time; for production and maintenance years of employment was weighted by a factor of 5/8, since these workers for an 8-hour shift worked for only 5 hours underground. As neither the mining technology nor the type of machinery used had changed substantially from 1970 to 1992, the exposure measurements were considered to represent the exposures throughout the study period. Accrued person-years were classified into cumulative exposures and were expressed in intervals of 0.5 ymg/m^3. Both the exposure data and the smoking data obtained from the medical files were validated by personal interviews with 1,702 cohort members. Death certificates were obtained from local health centers for 94.4% of deceased members. Autopsy data were available for 13% of the deceased. Internal comparison was done between production and workshop categories. Using East German general male population rates, SMRs were computed for the total cohort as well as the subcohort. Analyses were done using Poisson and Cox regression models.

The concentrations of total carbon for production, maintenance, and workshop categories were 0.39 mg/m^3, 0.23 mg/m^3, and 0.12 mg/m^3, respectively. The cumulative exposure ranged from 0.25 ymg/m^3 to 6.25 ymg/m^3. The regression analysis showed that the cohort's smoking habits were homogenous and that smoking had an even distribution over cumulative exposure.

A total of 424 deaths were observed for the entire cohort (SMR = 54). The all-cancer deaths were 133, of which 38 were from lung cancer (SMR = 78). Analysis for the subcohort using the internal comparison group of low exposure (workshop category, mean cumulative exposure = 2.12 ymg/m^3) RR of 2.17 (95% CI = 0.79, 5.99) was found for the production category (mean cumulative exposure = 4.38 ymg/m^3). The relative risks for lung cancer for 20 years of exposure in the production category (highest exposure = cumulative exposure of 4.9 ymg/m^3) were calculated using Poisson and Cox regression methods. RRs of 1.16 and 1.68 were observed for the total cohort, while RRs of 1.89 and 2.7 were observed for the subcohort by Poisson and Cox regression methods respectively.

The main strengths of the study are the information available on DE exposure and smoking. Although these potash miners were exposed to salt dust and nitric gases, exposures to other confounders such as heavy metals and radon were absent. Smoking does not seem to be a confounder in this study but cannot be completely ruled out. Unfortunately, the age distribution of the cohort is not available. Since there were only 424 deaths in 25 years of follow-up in this cohort of 5,536, it appears that the cohort is young. Although lung cancer risk was elevated by twofold in the production category of the subcohort of miners who had worked for at least 10 years underground at the same job for 80% of their time and did not have more than 3 jobs, it was not statistically significant. The follow-up period for this study was 25 years, but the cohort members could have entered the cohort any time between 1970 and 1990, as long as they worked underground for a year, i.e., they could have worked in the mines for 1 year to 21 years. Thus, the authors may not have had enough follow-up or latency to observe the lung cancer excess. Despite these limitations, the results of this study provide suggestive evidence for the causal association between DE and excess lung cancer.

Table 7-1 summarizes the above cohort studies.

Table 7-1. Epidemiologic studies of the health effects of exposure to DE: cohort mortality studies

Authors	Population studied	DE exposure assessment	Results	Limitations
Waller (1981)	Approximately 20,000 male London transportation workers Aged 45 to 64 years 25 years follow-up (1950-1974)	Five job categories used to define exposure Environmental B[*a*]P concentrations measured in 1957 and 1979	SMR = 79 for lung cancer for the total cohort SMRs for all five job categories were less than 100 for lung cancer	Exposure measurement of B[*a*]P showed very little difference between inside and outside the garage Incomplete information on cohort members No adjustment for confounding such as other exposures, cigarette smoking, etc. No latency analysis
Howe et al. (1983)	43,826 male pensioners of the Canadian National Railway Company Mortality between 1965 and 1977 among these pensioners was compared with mortality of general Canadian population	Exposure groups classified by a group of experts based on occupation at the time of retirement Three exposure groups: Nonexposed Possibly exposed Probably exposed	RR = 1.2 (p=0.013) and RR = 1.3 (p=0.001) for lung cancer for possible and probable exposure, respectively A highly significant dose-response relationship demonstrated by trend test (p<0.001)	Incomplete exposure assessment due to lack of lifetime occupational history Mixed exposures to coal dust/combustion products and DE No validation of method was used to categorize exposure Lack of data on smoking but use of internal comparison group to compute RRs minimizes the potential confounding by smoking No latency analysis

Table 7-1. Epidemiologic studies of the health effects of exposure to DE: cohort mortality studies (continued)

Authors	Population studied	DE exposure assessment	Results	Limitations
Rushton et al. (1983)	8,490 male London transport maintenance workers Mortality of workers employed for 1 continuous year between January 1, 1967, and December 31, 1975, was compared with mortality of general population of England and Wales	100 different job titles were grouped in 20 broad categories The categories were not ranked for DE exposure	SMR = 133 ($p<0.03$) for lung cancer in the general hand job group Several other job categories showed SS increased SMRs for several other sites based on fewer than five cases	Ill-defined DE exposure without any ranking Average 6-year follow-up i.e., not enough time for lung cancer latency No adjustment for confounders
Wong et al. (1985)	34,156 male heavy construction equipment operators Members of the local union for at least 1 year between January 1, 1964, and December 1, 1978	20 functional job titles grouped into three job categories for potential exposure Exposure groups (high, low, and unknown) based on job description and proximity to source of DE emissions	SMR = 166 ($p<0.05$) for liver cancer for total cohort SMR = 343 (observed = 5, $p<0.05$) for lung cancer for high-exposure bulldozer operators with 15-19 years of membership, 20+ years of follow-up SMR = 119 (observed = 141, $p<0.01$) for workers with no work histories	No validation of exposure categories, which were based on surrogate information Incomplete employment records Employment history other than from the union not available 15 year follow-up may not provide sufficient time for lung cancer latency No data on confounders such as other exposures, alcohol, smoking, etc.
Edling et al. (1987)	694 male bus garage employees Follow-up from 1951 through 1983 Mortality of these men was compared with mortality of general population of Sweden	Three exposure groups based on job titles: High exposure, bus garage workers Intermediate exposure, bus drivers Low exposure, clerks	No SS differences were observed between observed and expected for any cancers by different exposure groups	Small sample size No validation of exposure No data on confounders such as other exposures, smoking, etc.

Table 7-1. Epidemiologic studies of the health effects of exposure to DE: cohort mortality studies (continued)

Authors	Population studied	DE exposure assessment	Results	Limitations
Boffetta and Stellman (1988)	46,981 male volunteers enrolled in the American Cancer Society's Prospective Mortality Study of Cancer in 1982 Aged 40 to 79 years at enrollment First 2-year follow-up	Self-reported occupations were coded into 70 job categories Employment in high DE exposure jobs were compared with nonexposed jobs	Total mortality (SS) elevated for railroad workers (RR=1.43), heavy equipment operators (RR=1.7), miners (RR=1.34), and truck drivers (RR=1.19) Lung cancer mortality (SS) adjusted for age & smoking, elevated for total cohort (RR=1.31), miners (RR=2.67), and heavy equipment operators (RR=2.6) Lung cancer mortality (SNS) elevated among railroad workers and truck drivers Truck drivers also showed a dose-response	Exposure information based on self-reported occupation for which no validation was done Volunteer population, probably healthy population

Table 7-1. Epidemiologic studies of the health effects of exposure to DE: cohort mortality studies (continued)

Authors	Population studied	DE exposure assessment	Results	Limitations
Garshick et al. (1988)	55,407 white male railroad workers Aged 40 to 64 years in 1959 Started work 10-20 years earlier than 1959	Industrial hygiene data correlated with job titles to dichotomize the jobs as "exposed" or "not exposed"	RR = 1.45 (40-44 year age group) RR = 1.33 (45-49 year age group) Both SS After exclusion of workers exposed to asbestos RR = 1.57 (40-44 year age group) RR = 1.34 (45-49 year age group) Both SS	Years of exposure used as surrogate for dose Not possible to separate the effect of time since first exposure and duration of exposure Lack of smoking data but case-control study showed very little difference between those exposed to DE versus those who were not
Garshick (ltr to Chao Chen, EPA, dtd 8/15/91			Dose response indicated by increasing lung cancer risk with increasing cumulative exposure Further analysis using attained age, limited through 1976 showed youngest workers still had the highest risk	
Crump et al. (1991)	Reanalysis of Garshick et al., 1988 data		Dose response found to be positive or negative depending upon how the age was controlled in the model	
Crump (1999)			Negative dose-response upheld in the latest analysis	
California EPA (1998)	Reanalysis of Garshick et al., 1988		Positive dose response using age at 1959 and interaction term of age & calendar year	

Table 7-1. Epidemiologic studies of the health effects of exposure to DE: cohort mortality studies (continued)

Authors	Population studied	DE exposure assessment	Results	Limitations
Gustavsson et al. (1990)	695 male workers from 5 bus garages in Stockholm, Sweden, who had worked for 6 months between 1945 and 1970 34 years follow-up (1952-1986) Nested case-control study 17 cases, six controls for each case matched on age ± 2 years	Four DE indices were created: 0 to 10, 10 to 20, 20-30, and >30 based on job tasks and duration of work	SNS SMRs of 122 and 115 (OA and GP), respectively Case-control study results showed dose response: RR = 1.34 (10 to 20) RR = 1.81 (20 to 30) RR = 2.43 (>30) All SS with 0-10 as comparison group	Exposure matrix based on job tasks (not on actual measurements) Small cohort, hence low power Lack of smoking data is unlikely to confound the results since it is a nested case-control study
Hansen (1993)	Cohort of 57,249 unskilled laborers, ages 15 to 74, in Denmark (nationwide census file) November 9, 1970 Follow-up through November 9, 1980	DE exposure assumed based on diesel-powered trucks	SS SMRs for lung cancer : SMR = 160 for total population SMR = 229 for age 55-59 years SMR = 227 for age 60-64 years	No actual exposure data available Lack of smoking data but population survey showed very little difference between rural and urban smoking habits Job changes may have occurred from laborer to driver Short follow-up period
Saverin et al. (1999)	Cohort of 5,536 potash miners who had worked underground for at least 1 year after 1969 Subcohort of 3,258 who had worked for at least 10 years underground Follow-up from 1970 to 1994	DE exposure categories defined as: production (high) maintenance (medium) workshop (low) 225 air samples obtained: for total carbon, organics, & fine dust in 1992	SNS increased RRs adjusted for smoking: 1.68 and 2.7 for total cohort & subcohort, respectively	Small, young cohort Few deaths No latency analysis

Abbreviations: RR = relative risk; SMR = standardized mortality ratio; SNS = statistically nonsignificant; SS = statistically significant; O = occupationally active; GP = general population.

7.2.2. Case-Control Studies of Lung Cancer

7.2.2.1. *Hall and Wynder (1984): A Case-Control Study of DE Exposure and Lung Cancer*

Hall and Wynder (1984) conducted a case-control study of 502 male lung cancer cases and 502 controls without tobacco-related diseases that examined an association between occupational DE exposure and lung cancer. Histologically confirmed primary lung cancer patients who were 20 to 80 years old were ascertained from 18 participating hospitals in 6 U.S. cities 12 months prior to the interview. Eligible controls, patients at the same hospitals without tobacco-related diseases, were matched to cases by age (± 5 years), race, hospital, and hospital room status. The number of male lung cancer cases interviewed totaled 502, which was 64% of those who met the study criteria for eligibility. Of the remaining 36%, 8% refused, 21% were too ill or had died, and 7% were unreliable. Seventy-five percent of eligible controls completed interviews. Of these interviewed controls, 49.9% were from the all-cancers category, whereas 50.1% were from the all-noncancers category. All interviews were obtained in hospitals to gather detailed information on smoking history, coffee consumption, artificial sweetener use, residential history, and abbreviated medical history as well as standard demographic variables. Occupational information was elicited by a question on the usual lifetime occupation and was coded by the abbreviated list of the U.S. Bureau of Census Codes. The odds ratios were calculated to evaluate the association between DE exposure and risk of lung cancer incidence. Summary odds ratios were computed by the Mantel-Haenszel method after adjusting for potential confounding by age, smoking, and socioeconomic class. Two-sided, 95% confidence intervals were computed by Woolf's method. Occupational exposure to DE was defined by two criteria. First, occupational titles were coded "probably high exposure" as defined by the industrial hygiene standards established for the various jobs. The job titles included under this category were warehousemen, bus and truck drivers, railroad workers, and heavy equipment operators and repairmen. The second method used the National Institute for Occupational Safety and Health (NIOSH) criteria to analyze occupations by diesel exposure. In this method, the estimated proportion of exposed workers was computed for each occupational category by using the NIOSH estimates of the exposed population as the numerator and the estimates of individuals employed in each occupational category from the 1970 census as the denominator. Occupations estimated to have at least 20% of their employees exposed to DE were defined as "high exposure," those with 10% to 19% of their employees exposed were defined as "moderate exposure," and those with less than 10% of their employees exposed were defined as "low exposure."

Cases and controls were compared with respect to exposure. The relative risk was 2.0 (95% CI = 1.2, 3.2) for those workers who were exposed to DE versus those who were not. The risk, however, decreased to a nonsignificant 1.4 when the data were adjusted for smoking.

Analysis by NIOSH criteria found a nonsignificant relative risk of 1.7 in the high- exposure group. There were no significantly increased cancer risks by occupation either by the first method or by the NIOSH method. To assess any possible synergism between DE exposure and smoking, the lung cancer risks were calculated for different smoking categories. The relative risks were 1.46 among nonsmokers and ex-smokers, 0.82 among current smokers of <20 cigarettes/day, and 1.3 among current smokers of 20+ cigarettes/day, indicating a lack of synergistic effects.

The major strength of this study is the availability of a detailed smoking history for all the study subjects. However, this is offset by lack of DE exposure measurements, use of a poor surrogate for exposure, and lack of consideration of latency period. Information was collected on only one major lifetime occupation, and it is likely that those workers who had more than one major job may not have reported the occupation with the heaviest DE exposures. Furthermore, the exposure categories based on job titles were broad, and thus would have made a true effect of DE difficult to detect.

7.2.2.2. *Damber and Larsson (1987): Occupation and Male Lung Cancer, a Case-Control Study in Northern Sweden*

A case-control study of lung cancer was conducted in northern Sweden to determine the occupational risk factors that could explain the large geographic variations of lung cancer incidence in that country. The study region comprised the three northernmost counties of Sweden, with a total male population of about 390,000. The rural municipalities, with 15% to 20% of the total population, have forestry and agriculture as dominating industries, and the urban areas have a variety of industrial activities (mines, smelters, steel factories, paper mills, and mechanical workshops). All male cases of lung cancer reported to the Swedish Cancer Registry during the 6-year period between 1972 and 1977 who had died before the start of the study were selected. Of 604 eligible cases, 5 did not have microscopic confirmation, and in another 5 the diagnosis was doubtful, but these cases were included nevertheless. Cases were classified as small-cell carcinomas, squamous cell carcinomas, adenocarcinomas, and other types. For each case a dead control was drawn from the National Death Registry matched by sex, year of death, age, and municipality. Deaths in controls classified as lung cancer and suicides were excluded. A living control matched to the case by sex, year of birth, and municipality was also drawn from the National Population Registry. Postal questionnaires were sent to close relatives of cases and dead controls, and to living controls themselves to collect data on occupation, employment, and smoking habits. Replies were received from 589 cases (98%), 582 surrogates of dead controls (96%), and 453 living controls (97%).

Occupational data were collected on occupations or employment held for at least 1 year and included type of industry, company name, task, and duration of employment. Supplementary telephone interviews were performed if occupational data were lacking for any period between age 20 and time of diagnosis. Data analysis involved calculation of the odds ratios by the exact method based on the hypergeometric distribution and the use of a linear logistic regression model to adjust for the potential confounding effects of smoking. Separate analyses were performed with dead and living controls, and on the whole there was good agreement between the two control groups. A person who had been active for at least 1 year in a specific occupation was in the analysis assigned to that occupation.

Using dead controls, the odds ratios adjusted for smoking were 1.0 (95% CI = 0.7, 1.5) and 2.7 (95% CI = 1.0, 8.1) for professional drivers ($\geq$1 year of employment) and underground miners ($\geq$1 year of employment), respectively. For 20 or more years of employment in those occupations, the odds ratios adjusted for smoking were 1.2 (95% CI = 0.9, 2.6) and 9.8 (95% CI = 1.5, 414). These were the only two occupations listed with potential DE exposure. An excess significant risk was detected for copper smelter workers, plumbers, electricians, and asbestos workers, as well as concrete and asphalt workers. All the odds ratios were calculated by adjusting for age, smoking, and municipality. A comparison with the live controls resulted in the odds ratios being lower than those observed with dead controls, and none were statistically significant in this comparison.

This study did not detect any excess risk of lung cancer for professional drivers, who, among all the occupations listed, had the most potential for exposure to motor vehicle exhaust. However, it is not known whether these drivers were exposed exclusively to gasoline exhaust, DE, or varying degrees of both. An excess risk was detected for underground miners, but it is not known if this was due to diesel emissions from engines or from radon daughters in poorly ventilated mines. Although a high response rate (98%) was obtained by the postal questionnaires, the use of surrogate respondents is known to lead to misclassification errors that can bias the results in either direction.

7.2.2.3. *Lerchen et al. (1987): Lung Cancer and Occupation in New Mexico*

This is a population-based case-control study conducted in New Mexico that examined the association between occupation and occurrence of lung cancer in Hispanic and non-Hispanic whites. Cases involved residents of New Mexico, 25 through 84 years of age, and diagnosed between January 1, 1980, and December 31, 1982, with primary lung cancer, excluding bronchioalveolar carcinoma. Cases were ascertained through the New Mexico Tumor Registry, which is a member of the Surveillance Epidemiology and End Results (SEER) Program of the National Cancer Institute. Controls were chosen by randomly selecting residential telephone numbers and, for those over 65 years of age, from the Health Care Financing Administration's roster of Medicare participants. They were frequency-matched to cases for sex, ethnicity, and 10-year age category with a ratio of 1.5 controls per case. The 506 cases (333 males and 173 females) and 771 controls (499 males and 272 females) were interviewed, with a nonresponse rate of 11% for cases. Next of kin provided interviews for 50% and 43% of male and female cases, respectively. Among controls, only 2% of the interviews were provided by next of kin for each sex. Data were collected by personal interviews conducted by bilingual interviewers in the participants' homes. A lifetime occupational history and a self-reported history of exposure to specific agents were obtained for each job held for at least 6 months since age 12. Questions were asked about the title of the position, duties performed, location and nature of industry, and time at each job title. A detailed smoking history was also obtained. The variables on occupational exposures were coded according to the Standard Industrial Classification scheme by a single person and reviewed by another. To test the hypothesis about high-risk jobs for lung cancer, the principal investigator created an a priori listing of suspected occupations and industries by a two-step process involving a literature review for implicated industries and occupations. The principal investigator also determined the appropriate Standard Industrial Classification and Standard Occupational Codes associated with job titles. For four agents—asbestos, wood dust, DE, and formaldehyde—the industries and occupations determined to have exposure were identified, and linking of specific industries and occupations was based on literature review and consultation with local industrial hygienists.

The relative odds were calculated for suspect occupations and industries, classifying individuals as ever employed for at least 1 year in an industry or occupation and defining the reference group as those subjects never employed in that particular industry or occupation. Multiple logistic regression models were used to control simultaneously for age, ethnicity, and smoking status. For occupations with potential DE exposure, the analysis showed no excess risks for diesel engine mechanics and auto mechanics. Similarly, when analyzed by exposure to specific agents, the odds ratio (OR) adjusted for age, smoking, and ethnicity was not elevated for DE fumes (OR = 0.6, 95% CI = 0.2, 1.6). Significantly elevated ORs were found for uranium miners (OR = 2.8), underground miners (OR = 2.4), construction workers, and welders (OR = 4.3). No excess risks were detected for the following industries: shipbuilding, petroleum refining, printing, blast furnace, and steel mills. No excess risks were detected for the following occupations: construction workers, painters, plumbers, paving equipment operators, roofers, engineers and firemen, woodworkers, and shipyard workers. Females were excluded from detailed analysis because none of the Hispanic female controls had been employed in high-risk jobs; among the non-Hispanic white controls, employment in a high-risk job was recorded for at least five controls for only two industries, construction and painting, for which the OR were not significantly elevated. Therefore, the analyses were presented for males only.

Among the many strengths of this study are its population-based design, high participation rate, detailed smoking history, and the separate analysis done for two ethnic groups, southwestern Hispanic and non-Hispanic white males. The major limitations pertain to the occupational exposure data. Job titles obtained from occupational histories were used as proxy for exposure status, but these were not validated. Further, for nearly half the cases, next of kin provided occupational histories. The authors acknowledge the above sources of bias but state without substantiation that these biases would not strongly affect their results. They also did not use a job exposure matrix to link occupations to exposures and did not provide details on the method they used to classify individuals as DE exposed based on reported occupations. The observed absence of an association for exposure to asbestos, a well-established lung carcinogen, may be explained by the misclassification errors in exposure status or by sample size constraints (not enough power). Likewise, the association for DE reported by only 7 cases and 17 controls also may have gone undetected because of low power. In conclusion, there is insufficient evidence from this study to confirm or refute an association between lung cancer and DE exposure.

7.2.2.4. *Garshick et al. (1987): A Case-Control Study of Lung Cancer and DE Exposure in Railroad Workers*

An earlier pilot study of the mortality of railroad workers by the same investigators (Schenker et al., 1984) found a moderately high risk of lung cancer among workers exposed to DE compared with those who were not. Based on these findings the investigators conducted a case-control study of lung cancer in the same population. The population base for this case-control study was approximately 650,000 active and retired male U.S. railroad workers with 10 years or more of railroad service who were born in 1900 or later. The U.S. Railroad Retirement Board (RRB), which operates the retirement system, is separate from the Social Security System, and to qualify for the retirement or survivor benefits the workers had to acquire 10 years or more of service. Information on deaths that occurred between March 1, 1981, and February 28, 1982, was obtained from the RRB. For 75% of the deceased population, death certificates were obtained from the RRB, and, for the remaining 25%, they were obtained from the appropriate State departments of health. Cause of death was coded according to the eighth revision of the ICD. The cases were selected from deaths with primary lung cancer, which was the underlying cause of death in most cases. Each case was matched to two deceased controls whose dates of birth were within 2.5 years of the date of birth of the case and whose dates of death were within 31 days of the date of death noted in the case. Controls were selected randomly from workers who did not have cancer noted anywhere on their death certificates and who did not die of suicide or of accidental or unknown causes.

Each subject's work history was determined from a yearly job report filed by his employer with the RRB from 1959 until death or retirement. The year 1959 was chosen as the effective start of DE exposure for this study since by this time 95% of the locomotives in the United States were diesel powered. Investigators acknowledge that because the transition to diesel-powered engines took place in the early 1950s, some workers had additional exposure prior to 1959; however, if a worker had died or retired prior to 1959, he was considered unexposed. Exposure to DE was considered to be dichotomous for this study, which was assigned based on an industrial hygiene evaluation of jobs and work areas. Selected jobs with and without regular DE exposure were identified by a review of job title and duties. Personal exposure was assessed in 39 job categories representative of workers with and without DE exposure. Those jobs for which no personal sampling was done were considered exposed or unexposed based on similarities in job activities and work locations and by degree of contact with diesel equipment. Asbestos exposure was categorized based on jobs held in 1959, or on the last job held if the subject retired before 1959. Asbestos exposure in railroads occurred primarily during the steam engine era and was related mostly to the repair of locomotive steam boilers that were insulated with asbestos. Smoking history information was obtained from the next of kin.

Death certificates were obtained for approximately 87% of the 15,059 deaths reported by the RRB, from which 1,374 cases of lung cancer were identified. Fifty-five cases of lung cancer were excluded from the study for either incomplete data (20) or refusal by two States to use information on death certificates to contact the next of kin. Successful matching to at least one control with work histories was achieved for 335 (96%) cases $\leq$64 years of age at death and 921 (95%) cases $\geq$65 years of age at death. In both age groups, 90% of the cases were matched with two controls. There were 2,385 controls in the study; 98% were matched within ± 31 days of the date of death, whereas the remaining 2% were matched within 100 days. Deaths from diseases of the circulatory system predominated among controls. Among the younger workers, approximately 60% had exposure to DE, whereas among older workers, only 47% were exposed to DE.

Analysis by a regression model, in which years of DE exposure were the sum total of the number of years in diesel-exposed jobs, used as a continuous exposure variable, yielded an odds ratio of lung cancer of 1.39 (95% CI = 1.05, 1.83) for >20 years of DE exposure in the $\leq$64 years of age group. After adjustment for asbestos exposure and lifetime smoking (pack-years), the odds ratio was 1.41 (95% CI = 1.06, 1.88). Both crude odds ratio and asbestos exposure as well as lifetime smoking-adjusted odds ratio for the $\geq$65 years of age group were not significant.

Increasing years of DE exposure, categorized as ≥20 diesel years and 5 to 19 diesel years, with 0 to 4 years as the referent group, showed significantly increased risk in the ≤64 years of age group after adjusting for asbestos exposure and pack-year category of smoking. For individuals who had ≥20 years of DE exposure, the odds ratio was 1.64 (95% CI = 1.18, 2.29), whereas among individuals who had 5 to 19 years of DE exposure, the odds ratio was 1.02 (95% CI = 0.72, 1.45). In the ≥65 years of age group, only 3% of the workers were exposed to DE for more than 20 years. Relative odds for 5 to 19 years and ≥20 years of diesel exposure were less than 1 (p>0.01) after adjusting for smoking and asbestos exposure.

Alternative models to explain past asbestos exposure were tested. These were variables for regular and intermittent exposure groups and an estimate of years of exposure based on estimated years worked prior to 1959. No differences in results were seen. The interactions between DE exposure and the three pack-year categories (<50, >50, and missing pack-years) were explored. The cross-product terms were not significant. A model was also tested that excluded recent DE exposure occurring within the 5 years before death and gave an odds ratio of 1.43 (95% CI = 1.06, 1.94), adjusted for cigarette smoking and asbestos exposure, for workers with 15 years of cumulative exposure. For workers with 5 to 14 years of cumulative exposure, the OR were not significant.

The many strengths of the study are consideration of confounding factors such as asbestos exposure and smoking; classification of DE exposures by job titles and industrial hygiene sampling; exploration of interactions between smoking, asbestos exposure, and DE exposure; and good ascertainment (87%) of death certificates from the 15,059 deaths reported by the RRB.

The investigators also recognized and reported the following limitations: overestimation of cigarette consumption by surrogate respondents, which may have exaggerated the contribution of smoking to lung cancer risk, and use of the Interstate Commerce Commission (ICC) job classification as a surrogate for exposure, which may have led to misclassification of DE exposure jobs with low intensity and intermittent exposure, such as railroad police and bus drivers, as unexposed. These two limitations would result in underestimation of the lung cancer risk. This source of error could have been avoided if DE exposures were categorized by a specific dose range associated with a job title that could have been classified as heavy, medium, low, and zero exposure instead of a dichotomous variable. The use of death certificates to identify cases and controls may have resulted in misclassification. Controls may have had undiagnosed primary lung cancer, and lung cancer cases might have been secondary lesions misdiagnosed as primary lung cancer. However, the investigators quote a third National Cancer Survey report in which the death certificates for lung cancer were coded appropriately in 95% of the cases. Last, as in all previous studies, there is a lack of data on the contribution of unknown occupational or environmental exposures and passive smoking. In conclusion, this study provides strong evidence that occupational DE emission exposure increases the risk of lung cancer.

7.2.2.5. *Benhamou et al. (1988): Occupational Risk Factors of Lung Cancer in a French Case-Control Study*

This is a case-control study of 1,625 histologically confirmed cases of lung cancer and 3,091 matched controls, conducted in France between 1976 and 1980. This study was part of an international study to investigate the role of smoking and lung cancer. Each case was matched with one or two controls, whose diseases were not related, to tobacco use, sex, age at diagnosis (± 5 years), hospital of admission, and interviewer. Information was obtained from both cases and controls on place of residence since birth, educational level, smoking, and drinking habits. A complete lifetime occupational history was obtained by asking participants to give their occupations from the most recent to the first. Women were excluded because most of them had listed no occupation. Men who smoked cigars and pipes were excluded because there were very few in this category. Thus, the study was restricted to nonsmokers and cigarette smokers. Cigarette smoking exposure was defined by age at the first cigarette (nonsmokers, ≤20 years, or >20 years), daily consumption of cigarettes (nonsmokers, <20 cigarettes a day, and ≥20 cigarettes a day), and duration of cigarette smoking (nonsmokers, <35 years, and ≥35 years). The data on occupations were coded by a panel of experts according to their own chemical or physical exposure determinations. Occupations were recorded blindly using the International Standard Classification of Occupations. Data on 1,260 cases and 2,084 controls were available for analysis. The remaining 365 cases and 1,007 controls were excluded because they did not satisfy the required smoking status criteria.

A matched logistic regression analysis was performed to estimate the effect of each occupational exposure after adjusting for cigarette status. Matched relative risk ratios were calculated for each occupation with the baseline category, which consisted of patients who had never been engaged in that particular occupation. The matched RR ratios, adjusted for cigarette smoking for the major groups of occupations, showed that the risks were significantly higher for production and related workers, transport equipment operators, and laborers (RR = 1.24, 95% CI = 1.04, 1.47). On further analysis of this group, for occupations with potential diesel emission exposure, significant excess risks were found for motor vehicle drivers (RR = 1.42, 95% CI = 1.07, 1.89) and transport equipment operators (RR = 1.35, 95% CI = 1.05, 1.75). No interaction with smoking status was found in any of the occupations. The only other significant excess was observed for miners and quarrymen (RR = 2.14, 95% CI = 1.07, 4.31). None of the significant associations showed a dose-response relationship with duration of exposure.

This study was designed primarily to investigate the relationship between smoking (not occupations or environmental exposures) and lung cancer. Although an attempt was made to obtain complete occupational histories, the authors did not clarify whether, in the logistic regression analysis, they used the subjects' first occupation, predominant occupation, last occupation, or ever worked in that occupation as the risk factor of interest. The most important limitation of this study is that the occupations were not coded into exposures for different chemical and physical agents, thus precluding the calculation of relative risks for diesel exposure. Using occupations as surrogate measures of diesel exposure, an excess significant risk was obtained for motor vehicle drivers and transport equipment operators, but not for motor mechanics. However, it is not known if subjects in these occupations worked with diesel engines or nondiesel engines.

7.2.2.6. *Hayes et al. (1989): Lung Cancer in Motor Exhaust-Related Occupations*

This study reports the findings from an analysis of pooled data from three lung cancer case-control studies that examine in detail the association between employment in motor exhaust-related (MER) occupations and lung cancer risk adjusted for confounding by smoking and other risk factors. The three studies were carried out by the National Cancer Institute in Florida (1976 to 1979), New Jersey (1980 to 1981), and Louisiana (1979 to 1983). These three studies were selected because the combined group would provide a sufficient sample to detect a risk of lung cancer in excess of 50% among workers in MER occupations. The analyses were restricted to males who had given occupational history. The Florida study was hospital based, with cases ascertained through death certificates. Controls were randomly selected from hospital records and death certificates, excluding psychiatric diseases, matched by age and county. The New Jersey study was population based, with cases ascertained through hospital records, cancer registry, and death certificates. Controls were selected from among the pool of New Jersey licensed drivers and death certificates. The Louisiana study was hospital based (it is not specified how the cases were ascertained), and controls were randomly selected from hospital patients, excluding those with lung diseases and tobacco-related cancers.

A total of 2,291 cases of male lung cancers and 2,570 controls were eligible, and the data on occupations were collected by next-of-kin interviews for all jobs held for 6 months or more, including the industry, occupation, and number of years employed. The proportion of next-of-kin interviews varied by site from 50% in Louisiana to 85% in Florida. The coding schemes were reviewed to identify MER occupations, which included truck drivers and heavy equipment operators (cranes, bulldozers, and graders); bus drivers, taxi drivers, chauffeurs, and other motor vehicle drivers; and automobile and truck mechanics. Truck drivers were classified as routemen and delivery men and other truck drivers. All jobs were also classified with respect to potential exposure to known and suspected lung carcinogens. ORs were calculated by the maximum likelihood method, adjusting for age by birth year, usual amount smoked, and study area. Logistic regression models were used to examine the interrelationship of multiple variables.

A statistically significant excess risk was detected for employment of 10 years or more for all MER occupations (except truck drivers) adjusted for birth cohort, usual daily cigarette use, and study area. The odds ratio for lung cancer using data gathered by direct interviews was 1.4 (95% CI = 1.1, 2.0), allowing for multiple MER employment, and 2.0 (95% CI = 1.3, 3.0), excluding individuals with multiple MER employment. ORs for all MER employment, except truck drivers who were employed for less than 10 years, were 1.3 (95% CI = 1.0, 1.7) and 1.3 (95% CI = 0.9, 1.8) including and excluding multiple MER employment, respectively. ORs were then derived for specific MER occupations and, to avoid the confounding effects of multiple MER job classifications, analyses were also done excluding subjects with multiple MER job exposures. Truck drivers employed for more than 10 years had an odds ratio of 1.5 (95% CI = 1.1, 1.9). A similar figure was obtained excluding subjects with multiple MER employment. An excess risk was not detected for truck drivers employed less than 10 years. The only other job category that showed a statistically significant excess for lung cancer included taxi drivers and chauffeurs who worked multiple MER jobs for less than 10 years (OR = 2.5, 95% CI = 1.4, 4.8). For the same category, the risk for individuals working in that job for more than 10 years was 1.2 (95% CI = 0.5, 2.6). A statistically significant positive trend ($p<0.05$) with increasing employment of <2 years, 2 to 9 years, 10 to 19 years, and 20+ years was observed for truck drivers but not for other MER occupations. A statistically nonsignificant excess risk was also observed for heavy equipment operators, bus drivers, taxi drivers and chauffeurs, and mechanics employed for 10 years or more. All of the above-mentioned ORs were derived, adjusted for birth cohort, usual daily cigarette use, and State of residence. Exposure to other occupational suspect lung carcinogens did not account for the excess risks detected.

Results of this large study provide evidence that workers in MER jobs are at an excess risk of lung cancer that is not explained by their smoking habits or exposures to other lung carcinogens. Because no information on type of engine had been collected, it was not possible to determine if the excess risk was due to exposure to DE or gasoline exhaust or a mixture of the two. Among the study's other limitations are a possible bias due to misclassification of jobs reported by the large proportion of next-of-kin interviews. Such a bias would make the effect of DE harder to detect due to broad categorization of jobs and the problems in classifying individuals into uniform occupational groups based on the pooled data in the three studies that used different occupational classification schemes.

7.2.2.7. *Steenland et al. (1990): A Case-Control Study of Lung Cancer and Truck Driving in the Teamsters Union*

Steenland et al. conducted a case-control study of lung cancer deaths in the Teamsters Union to determine the risk of lung cancer among different occupations. Death certificates were obtained from the Teamsters Union files in the central States for 10,485 (98%) male decedents who had filed claims for pension benefits and who had died in 1982 and 1983. Individuals were required to have 20 years' tenure in the union to be eligible to claim benefits. Cases comprised all deaths (n = 1,288) from lung cancer, coded as ICD 162 or 163 for underlying or contributory cause on the death certificate. The 1,452 controls comprised every sixth death from the entire file, excluding deaths from lung cancer, bladder cancer, and motor vehicle accidents. Detailed information on work history and potential confounders such as smoking, diet, and asbestos exposure was obtained by questionnaire. Seventy-six percent of the interviews were provided by spouses and the remainder by some other next of kin. The response rate was 82% for cases and 80% for controls. Using these interview data and the 1980 census occupation and industry codes, subjects were classified either as nonexposed or as having held other jobs with potential DE exposure. Data on job categories were missing for 12% of the study subjects. A second work history file was also created based on the Teamsters Union pension application that lists occupation, employer, and dates of employment. A three-digit U.S. census code for occupation and industry was assigned to each job for each individual. This Teamsters Union work history file did not have information on whether men drove diesel or gasoline trucks, and the four principal occupations were long-haul drivers, short-haul or city drivers, truck mechanics, and dockworkers. Subjects were assigned the job category in which they had worked the longest.

The case-control analysis was done using unconditional logistic regression. Separate analyses were conducted for work histories from the Teamsters Union pension file and from next-of-kin interviews. Covariate data were obtained from next-of-kin interviews. Analyses were also performed for two time periods: employment after 1959 and employment after 1964. These two cut-off years reflect years of presumed dieselization: 1960 for most trucking companies and 1965 for independent driver and nontrucking firms. Data for analysis could be obtained for 994 cases and 1,085 controls using Teamsters Union work history and for 872 cases and 957 controls using next-of-kin work history. When exposure was considered as a dichotomous variable, for both Teamsters Union and next-of-kin work history, no single job category had an elevated risk. From the next-of-kin data, diesel truck drivers had an odds ratio of 1.42 (95% CI = 0.74, 2.47) and diesel truck mechanics had an odds ratio of 1.35 (95% CI = 0.74, 2.47). ORs by duration of employment as a categorical variable were then estimated. For the Teamsters Union work history data, when only employment after 1959 was considered, both long-haul ($p<0.04$) and short-haul drivers (not significant) showed an increase in risk with increased years of exposure. The length-of-employment categories for which the trends were analyzed were 1 to 11 years, 12 to 17 years, and 18 years or more. Using 1964 as the cutoff date, long-haul drivers continued to show a significant positive trend (p=0.04), with an odds ratio of 1.64 (95% CI = 1.05, 2.57) for those who worked for 13+ years, the highest category. Short-haul drivers, however, did not show a positive trend when 1964 was used as the cutoff date. Similar trend analysis was done for most next-of-kin data. A marginal increase in risk with increasing duration of employment as a truck driver (p=0.12) was observed. For truck drivers who primarily drove diesel trucks for 35 years or longer, the odds ratio for lung cancer was 1.89 (95% CI = 1.04, 3.42). Similarly, the corresponding odds ratio was 1.34 (95% CI = 0.81, 2.22) for both gasoline truck drivers and drivers who drove both types of trucks, and 1.09 (95% CI = 0.44, 2.66) for truck mechanics.

No significant interactions between age and DE exposure or smoking and DE exposure were observed. All the ORs were adjusted for age, smoking, and asbestos in addition to various exposure categories.

This is a well-designed and analyzed study. The main strengths of the study are the availability of detailed records from the Teamsters Union, a relatively large sample size, availability of smoking data , and measurements of exposures. The authors acknowledge some limitations of this study, which include possible misclassifications of exposure and smoking habits, as information was provided by next of kin; lack of sufficient latency to observe lung cancer excess; and a small nonexposed group (n = 120). Also, they could not evaluate the concordance between Teamsters Union and next-of-kin job categories easily because job categories were defined differently in each data set. No data were available on levels of diesel exposure for the different job categories. Despite these limitations, the positive findings of this study, which are probably underestimated, provide a positive evidence toward causal association between DE exposure and excess lung cancer.

7.2.2.8. *Steenland et al. (1998): DE and Lung Cancer in the Trucking Industry: Exposure-Response Analyses and Risk Assessment*

Steenland et al. (1998) conducted an exposure-response analysis by supplementing the data from their earlier case-control study of lung cancer and truck drivers in the Teamsters Union (Steenland et al., 1990) with exposure estimates based on a 1990 industrial hygiene survey of elemental carbon exposure, a surrogate for DE in the trucking industry.

Study subjects were long-term Teamsters enrolled in the pension system who died during the period 1982-1983. Using death certificate information, the researchers identified 994 cases of lung cancer for the study period, and 1,085 non-lung-cancer deaths served as controls. Subjects were divided into job categories based on the job each held the longest. Most had held only one type of job. The job categories were short-haul driver, long-haul driver, mechanic, dockworker, other jobs with potential diesel exposure, and jobs outside the trucking industry without occupational diesel exposure. Smoking histories were obtained from next of kin. ORs were calculated for work in an exposed job category at any time and after 1959 (an estimated date when the majority of heavy-duty trucks had converted to diesel) compared with work in nonexposed jobs. ORs were adjusted for age, smoking, and potential asbestos exposure. Trends in effect estimates for duration of work in an exposed job were also calculated.

An industrial hygiene survey by Zaebst et al. (1991) of elemental carbon exposures in the trucking industry provided exposure estimates for each job category in 1990. The elemental carbon measurements were generally consistent with the epidemiologic results, in that mechanics were found to have the highest exposures and relative risk, followed by long-haul and then short-haul drivers, although dockworkers had the highest exposures and the lowest relative risks.

Past exposures were estimated assuming that they were a function of (1) the number of heavy-duty trucks on the road, (2) the particulate emissions (grams/mile) of diesel engines over time, and (3) leaks from truck exhaust systems for long-haul drivers. Estimates of past exposure to elemental carbon, as a marker for DE exposure, for subjects in the case-control study were made by assuming that average 1990 levels for a job category could be assigned to all subjects in that category, and that levels prior to 1990 were directly proportional to vehicle miles traveled by heavy-duty trucks and the estimated emission levels of diesel engines. A 1975 exposure level of elemental carbon in terms of micrograms per cubic meter was estimated by the following equation: 1975 level = 1990 level*(vehicle miles 1975/vehicle miles 1990) (emissions 1975/emissions 1990). Once estimates of exposure for each year of work history were derived for each subject, analyses were conducted by cumulative level of estimated carbon exposure.

Estimates were made for long-haul drivers (n = 1,237), short-haul drivers (n = 297), dockworkers (n = 164), mechanics (n = 88), and those outside the trucking industry (n = 150). Logistic regression was used to estimate ORs adjusted for five categories of age, race, smoking (never, former-quitting before 1963, former-quitting in 1963 or later, current-with <1 pack per day, and current-with 1 or more packs per day), diet, and reported asbestos exposure. A variety of models for cumulative exposure were considered, including a log-linear model with cumulative exposure, a model adding a quadratic term for cumulative exposure, a log transform of cumulative exposure, dummy variables for quartile of cumulative exposure, and smoothing splines of cumulative exposure. The estimates of rate ratios from logistic regression for specific levels of exposure to elemental carbon were then used to derive excess risk estimates for lung cancer after lifetime exposure to elemental carbon.

The survey found that mechanics had the highest current levels of DE exposures and dockworkers who mainly used propane-powered forklifts had the lowest exposure. ORs of 1.69

and 0.93 were observed for the mechanics and dockworkers, respectively. The finding of the highest lung cancer risk for mechanics and lowest for dockworkers is indicative of causal association between the DE exposure and development of lung cancer. The log of cumulative exposure was found to be the best-fitting model and was a significant predictor ($p = 0.01$). However, the risk among mechanics did not increase with increasing duration of employment.

OR for quartile of cumulative exposure show a pattern of significantly increasing trends in risk with increasing exposure, ranging between 1.08 and 1.72, depending on the exposure level and lag structure used. The lifetime excess risk of lung cancer death (through age 75) for a male truck driver was estimated to be in the range of 1.4%-2.3% (95% confidence limits ranged from 0.3% to 4.6%) above the background risk, depending on the emissions scenarios assumed. The authors found that current exposures indicated that truck drivers are exposed to DE at levels about the same as ambient levels on the highways, which are about double the background levels in urban air. They conclude that the data suggest a positive and significant increase in lung cancer risk with increasing estimated cumulative exposure to DE among workers in the trucking industry. They assert that these estimates suggest that the lifetime excess risk for lung cancer is 10 times higher than the OSHA standards, but caution that the results should be viewed as exploratory.

The authors acknowledge that the increasing trend in risk with increasing estimates of cumulative exposure is partly due to the fact that a component of cumulative dose is simple duration of exposure, and that analyses by simple duration also exhibit a positive trend with duration. This analysis essentially weights the duration by contrived estimates of exposure intensity, and the authors acknowledge that this weighting depends on very broad assumptions.

This is not an analysis of new data that provides independent estimates of relative risk for DE and lung cancer incidence. Instead, it is an attempt to convert the data from Steenland's earlier study of lung cancer for the purpose of estimating a different risk metric, “lifetime excess risk of lung cancer,” by augmenting these data with limited industrial hygiene data and rationalizations about plausible models for cumulative exposure.

The Health Effects Institute (HEI, 1999) and others have raised some concerns about the exposure estimations, selection of controls, and control for confounding variables, and hence, this study’s usefulness for quantitative risk assessment. EPA and NIOSH will address these concerns in the year 2001. The HEI (1999) panel noted that some of the strengths of this study include the relevance of exposure levels to the general population and the use of an exposure marker for diesel engine emissions that was an improvement over the concentration of respirable-size particles (RSP). The number of study subjects (996 lung cancer cases) is large. Histories of exposures to asbestos and smoking were obtained, and confounding by these two variables was controlled in the analysis. Thus, it should be noted that these concerns are about the use of these data for quantitative risk assessment, due to limitations of the exposure data. As far as qualitative risk assessment is concerned, this study is still considered to be positive and strong.

7.2.2.9. *Boffetta et al. (1990): Case-Control Study on Occupational Exposure to DE and Lung Cancer Risk*

This is an ongoing (since 1969) case-control study of tobacco-related diseases in 18 hospitals (six U.S. cities). Cases comprise 2,584 males with histologically confirmed primary lung cancers. Sixty-nine cases were matched to 1 control, whereas 2,515 were matched to 2 controls. Controls were individuals who were diagnosed with non-tobacco-related diseases. The matching was done for sex, age (±2 years), hospital, and year of interview. The interviews were conducted at the hospitals at the time of diagnosis. In 1985, the occupational section of the questionnaire was modified to include the usual occupation and up to five other jobs as well as duration (in years) worked in those jobs. After 1985, information was also obtained on exposure to 45 groups of chemicals, including DE at the workplace or during hobby activities. A priori aggregation of occupations was categorized into low probability of DE exposure (reference group), possible exposure (19 occupations), and probable exposure (13 occupations). Analysis was conducted based on "usual occupation" on all study subjects, and any occupation with sufficient cases was eligible for further analysis. In addition, cases enrolled after 1985 for which there were self-reported DE exposure and detailed work histories were also analyzed separately.

Both matched and unmatched analyses were done by calculating the adjusted (for smoking and education) relative odds using the Mantel-Haenzael method and calculating the test-based 95% confidence interval using the Miettinen method. Unconditional logistic regression was used to adjust for potential confounders (the PROC LOGIST of SAS). Linear trends for risk were also tested according to Mantel.

Adjusted relative odds for possible and probable exposure groups as well as the truck drivers were slightly below unity, none being statistically significant for the entire study population. Although slight excesses were observed for the self-reported DE exposure group and the subset of post-1985 enrollees for highest duration of exposure (for self-reported exposure, occupations with probable exposure, and truck drivers), none was statistically significant. Trend tests for the risk of lung cancer among self-reported DE exposure, probable exposure, and truck drivers with increasing exposure (duration of exposure used as surrogate for increasing dose) were nonsignificant too. Statistically significant lung cancer excesses were observed for cigarette smoking only.

The major strength of this study is availability of detailed smoking history. Even though detailed information was obtained for the usual and five other occupations (1985), because it was difficult to estimate or verify the actual exposure to DE, duration of employment was used as a surrogate for dose instead. The numbers of cases and controls were large; however, the number of individuals exposed to DE was relatively few, thus reducing the power of the study. This study did not attempt latency analysis either. Due to these limitations, the findings of this study are unable to provide either positive or negative evidence for a causal association between DE and occurrence of lung cancer.

7.2.2.10. *Emmelin et al. (1993): DE Exposure and Smoking: A Case-Referent Study of Lung Cancer Among Swedish Dock Workers*

This case-control study of lung cancer was drawn from a cohort defined as all male workers who had been employed as dockworkers for at least 6 months between 1950 and 1974. In the population of 6,573 from 20 ports, there were 90 lung cancer deaths (cases), identified through Swedish death and cancer registers, during the period 1960 to 1982. Of these 90 deaths, the 54 who were workers at the 15 ports for which exposure surrogate information was available were chosen for the case-control study. Four controls, matched on port and age, were chosen for each case from the remaining cohort who had survived to the time of diagnosis of the case. Both live and deceased controls were included. The final analyses were done on 50 cases and 154 controls who had complete information on employment dates and smoking data. The smoking strata were created by classifying ex-smokers as nonsmokers if they had not smoked for at least 5 years prior to the date of diagnosis of the case; otherwise they were classified as smokers.

Relative odds and regression coefficients were calculated using conditional logistic regression models. Comparisons were made both with and without smoking included as a variable, and the possible interaction between smoking and DE was tested. Both the weighted linear regressions of the adjusted relative odds and the regression coefficients were used to test mortality trends with all three exposure variables.

Exposure to DE was assessed indirectly by initially measuring: (1) exposure intensity based on exhaust emission, (2) characteristics of the environment in terms of ventilation, and (3) measures of proportion of time in higher exposed jobs. For exhaust emissions, annual diesel fuel consumption at a port was used as the surrogate. For ventilation, the annual proportion of ships with closed or semiclosed holds was used as the surrogate. The proportion of time spent below decks was used as the surrogate for more exposed jobs. Although data were collected for all three measures, only the annual fuel consumption was used for analysis. Because every man was likely to rotate through the various jobs, the authors thought using annual consumption of diesel fuel was the appropriate measure of exposure. Consequently, in a second analysis, the annual fuel consumption was divided by the number of employees in the same port that year to come up with the fuel-per-person measure, which was further used to create a second measure, "exposed time." The "annual fuel" and exposed-time data were entered in a calendar time-exposure matrix for each port, from which individual exposure measures were created. A third measure, "machine time" (years of employment from first exposure), was also used to compare the results with other studies. All exposure measures were accumulated from the first year of employment or first year of diesel machine use, whichever came later. The last year of exposure was fixed at 1979. All exposures up to 2 years before the date of lung cancer diagnosis were omitted from both cases and matched controls. A priori classification into three categories of low, medium, and high exposure was done for all three exposure variables: machine time, fuel, and exposed time.

Conditional logistic regression models, adjusting for smoking status and using low exposures and/or nonsmokers as a comparison group, yielded positive trends for all exposure measures, but no trend test results were reported, and only the relative odds for the exposed-time exposure measure in the high-exposure group (OR = 6.8, 90% CI = 1.3 to 34.9) was reported as statistically significant. For smokers, adjusting for DE exposure level, the relative odds were statistically significant and about equal for all three exposure variables: machine time, OR = 5.7 (90% CI = 2.4 to 13.3); fuel, OR = 5.5 (90% CI = 2.4 to 12.7); and exposed time, OR = 6.2 (90% CI = 2.6 to 14.6). Interaction between DE and smoking was tested by conditional logistic regression in the exposed-time variable. Although there were positive trends for both smokers and nonsmokers, the trend for smokers was much steeper: low, OR = 3.7 (90% CI = 0.9 to 14.6); medium, OR = 10.7 (90% CI = 1.5 to 78.4); and high, OR = 28.9 (90% CI = 3.5 to 240), indicating more than additive interaction between these two variables.

In the weighted linear regression model with the exposed-time variable, the results were similar to those using the logistic regression model. The authors also explored the smoking variable further in various analyses, some of which suggested a strong interaction between DE and smoking. However, with just six nonsmokers and no further categorization of smoking amount or duration, these results are of limited value.

The DE exposure matrices created using three different variables are intricate. Analyses by any of these variables yield essentially the same positive results and positive trends, providing consistent support for a real effect of DE exposure, at least in smokers. However, methodological limitations to this study prevent a more definitive conclusion. The numbers of cases and controls are small. There are very few nonsmokers; thus, testing the effects of DE exposure in them is futile. Lack of information on asbestos exposure, to which dockworkers are usually exposed, may also confound the results. Also, no latency analyses are presented. Overall, despite these limitations, this study supports the earlier findings of excess lung cancer mortality among individuals exposed to DE.

7.2.2.11. *Swanson et al. (1993): Diversity in the Association Between Occupation and Lung Cancer Among Black and White Men*

This population-based case-control study of lung cancer was conducted in metropolitan Detroit. The cases and controls for this study were identified from the Occupational Cancer Incidence Surveillance Study (OCISS). A total of 3,792 incident lung cancer cases and 1,966 colon and rectal cancer cases used as controls, diagnosed between 1984 and 1987 among white and black males aged 40 to 84 years, were selected for the study. Information was obtained by telephone interview either with the individual or a surrogate about lifetime work history and smoking history, as well as medical, demographic, and residential history. Occupation and industry data were coded using the 1980 U.S. Census Bureau classification codes. The investigators selected certain occupations and industries as having little or no exposure to carcinogens and defined them as an unexposed group. Analysis was done using logistic regression method and adjusting for age at diagnosis, pack-years of cigarette smoking, and race.

The results were presented by various occupations and industries; those with potential exposures to DE were drivers of heavy trucks and light trucks, farmers, and railroad workers, respectively. Among white males, increasing lung cancer risks were observed with increasing duration of employment for drivers of heavy trucks, drivers of light trucks, and farmers. Although none of the individual ORs were statistically significant, trend tests were significant for all three occupations ($p \leq 0.05$). On the other hand, among black males increasing lung cancer risks with increasing duration of employment were observed for farmers only, with an OR of 10.4 (95% CI = 1.4, 77.1) reaching significance for employment of 20+ years. As for the railroad industry, increasing lung cancer risks with increasing duration of employment were observed for both white and black males. The trend test was significant for white males only, with an OR of 2.4 (95% CI = 1.1, 5.1) reaching significance for employment of 10+ years.

The main strengths of the study are large sample size, availability of lifetime work history and smoking history, and the population-based study format, precluding selection bias. The major limitation, as in other studies, is lack of direct information on specific exposures. The interesting result of this study is lung cancer excesses observed in farmers, mainly among crop farmers, who have potential exposure to DE from their tractors in addition to pesticides, herbicides, and other $PM_{10.}$ The authors point out that this is the first study to find excess lung cancer in this occupation.

7.2.2.12. *Hansen et al. (1998): Increased Risk of Lung Cancer Among Different Types of Professional Drivers in Denmark*

This is a population-based case-control study of lung cancer, conducted in professional drivers in Denmark. The cases first diagnosed as primary lung cancer between 1970 and 1989 among males born between 1897 and 1966 were identified from the Danish Cancer Registry. The registry provided the information on diagnosis from ICD-7, name, sex, and unique personal identification number (PIDN). Information about past employment was obtained by linkage with the nationwide pension fund. The fund keeps the records by name and PIDN about the date of start and end of each job and unique company number of the employer. The records are kept even after the employee has retired or died. Information about current employment was obtained from the Danish Central Population Registry (CPR) by linkage with the PIDN.

Of 37,597 cases identified from the Registry, 8,853 did not have any employment records. Controls (1:1) for 28,744 lung cancer cases with employment histories were selected randomly from CPR, matched with the case by year of birth and sex. Furthermore, these controls had to be alive, cancer free, and employed prior to the diagnosis of lung cancer in the corresponding case. Employment histories were obtained for the controls in the same fashion as cases from the pension fund. The employment record search resulted in a total of 1,640 lorry/bus drivers and 426 taxi drivers. They were further divided into subgroups by their duration of employment. Information about smoking in drivers was acquired from two national surveys conducted in 1970-72 and 1983. No direct information on smoking was available in either cases or controls. A separate case-control study of mesothelioma indirectly looked at asbestos exposure among professional drivers. OR, adjusting for socioeconomic status and 95% CI, were computed using conditional logistic regression (PECAN procedure in the statistical package EPICURE).

Significant ORs for lung cancer were found for lorry/bus drivers (OR = 1.31, 95% CI = 1.17, 1.46), taxi drivers (OR = 1.64, 95% CI = 1.22, 2.19), and unspecified drivers (OR = 1.39, 95% CI = 1.30, 1.51). Significant ORs were found for both lorry/bus drivers and taxi drivers by duration of employment in 1-5 years and >5 years categories, with no lag time and with a 10-year lag time. The ORs remained the same for lorry/bus drivers in these employment categories for no lag time and 10-year lag time. Among taxi drivers, on the other hand, the OR of 2.2 in >5 year employment in no-lag-time analysis increased to 3.0 in the 10-year lag time analysis. The authors asserted that the higher risk seen in the taxi drivers may be due to higher exposure attributable due to longer time spent in traffic congestion. The trend tests for increasing risk with increasing duration of employment (surrogate for exposure) were statistically significant ($p<0.001$) for both lorry/bus drivers and taxi drivers in no-lag-time and 10-year lag time analysis. All the ORs were adjusted for socioeconomic status.

The main strengths of the study are the large sample size, availability of information on socioeconomic status, and detailed employment records. The main limitation, however, is lack of information on what type of fuel these vehicles used. It is probably safe to assume that the lorry/buses were diesel powered, whereas the taxis could be either diesel or gasoline powered. A personal communication with Dr. Johnni Hansen confirmed that dieselization in Denmark was completed in the late 1940s and lorries, buses, and taxis have been using diesel fuel since then. Although direct adjustments were not done for smoking and exposure to asbestos, indirect information on both these confounders indicates that they are unlikely to explain the observed excesses and the increasing risk with increasing duration of employment. Thus, the results of this study are strongly supportive of DE being associated with increased lung cancer.

7.2.2.13. *Brüske-Hohlfeld et al. (1999): Lung Cancer Risk in Male Workers Occupationally Exposed to Diesel Motor Emissions in Germany*

This paper presents a pooled analysis of two case-control studies of lung cancer. The first study, by Jöckel et al. (1995, 1998), was conducted between 1988 and 1993 and had 1,004 cases and 1,004 controls matched for sex, age, and region of residence, selected randomly from the compulsory municipal registries. The inclusion criteria for cases were: they should have been born in or after 1913, should have been of German nationality, and should have been diagnosed with lung cancer within 3 months prior to the interview. The second study, by Wichmann et al. (1998), was ongoing when it was included in this study. The study span covered the years 1990 to 1996. By 1994 a total of 3,180 cases and 3,249 controls, randomly selected from the compulsory population registries, were frequency matched on sex, age, and region. The cases were less than 76 years old, were residents of the region and living in Germany for more than 25 years, and had a diagnosis not more than 3 months old. Of 4,184 pooled cases and 4,253 pooled controls, the analysis was conducted on 3,498 male cases and 3,541 male controls. A personal interview was conducted with each study participant. Data were collected on basic demographic information, detailed smoking history, and lifelong occupational history about jobs held and industries worked in. The job titles and industries were classified into 33 and 21 categories, respectively, using the German Statistical Office codes.

Based on job codes with potential exposure to diesel motor emission (DME), four exposure groups were constituted. Group A comprised professional drivers of trucks, buses, taxis, etc. Group B comprised other traffic-related jobs such as switchmen, diesel locomotive drivers, and diesel forklift truck drivers. Group C comprised bulldozer operators, graders, and excavators. Group D comprised full-time farm tractor drivers. Validation of the jobs was done by written evaluation of the job task descriptions, which also avoided misclassification. The following information was acquired for the construction of job task descriptions: (1) What were your usual tasks at work and how often (in % of daily working hours) were they performed? (2) What did you produce, manufacture, or transport? (3) Which material was used? (4) What kind of machine did you operate? Some individuals had more than one job task with DME exposure. The exposure assessment was done without knowing the status of the case/control.

For each individual, cumulative exposure was calculated for the complete work history by categorizing the duration of exposure as >0-3, >3-10, >10-20, >20-30, >30 years, and beginning and end of exposure. The first year of exposure was defined as ≤1945, 1946-1955, and ≥1956 while the last year of exposure was defined as ≤1965, 1966-1975, and ≥1976. For professional drivers, hours driven per day were accumulated and were classified as “driving hours.”

A smoker was defined as any individual who had smoked regularly for at least 6 months. Smoking information was acquired in series with the starting time, type of tobacco, amount smoked, duration in years, and calender year of quitting. Asbestos exposure was estimated by certain job-specific supplementary questions.

The cases and controls were post-hoc stratified into 6 age and 17 region categories. ORs adjusted for smoking and asbestos exposure were calculated by conditional logistic regression, using “never exposed” workers as the reference group. The adjustment for cigarette smoking was done by using pack-years as a continuous variable; adjustment for other tobacco products was done by considering them as a binary variable. A total of 716 cases and 430 controls were found to be ever exposed to DME. The smoking- and asbestos-adjusted OR of 1.43 (95% CI = 1.23, 1.67) for all DME exposed was reduced from the crude OR of 1.91. For the entire group the various analyses yielded statistically significant ORs ranging from 1.25 to 2.31, adjusted for smoking and asbestos exposure (West Germany, >10-20 years and >20-30 years of exposure, first year of exposure in 1946-1955 and 1956+, end of exposure in 1966-1975 and 1976+, and for the job categories of Group A, B, and C). The risk increased with increasing years of exposure, and for both the first year of exposure (≤1945, 1946-1955, and ≥1956) and end year of exposure (≤1965, 1966-1975, and ≥1976).

Separate analyses by four job categories (all the ORs were adjusted for smoking and asbestos exposure) showed that for professional drivers (Group A) the overall OR was 1.25 (95% CI = 1.05, 1.47). Significant ORs were found for various factors in West Germany only. The factors were: >0-3 years and >10-20 years of exposure (OR = 1.69, 95% CI = 1.13, 2.53, and OR = 2.02, 95% CI = 1.32, 3.08, respectively), beginning of exposure in 1956+ and end of exposure in 1976+ (OR = 1.56, 95% CI = 1.21, 2.03, and OR = 1.5, 95% CI = 1.14, 1.98, respectively), and 1,000-49,999 driving hours (OR = 1.54, 95% CI = 1.15, 2.07). None of the ORs were significant in East Germany in this group.

For other traffic-related jobs (Group B) the overall OR was 1.53 (95% CI = 1.04, 2.24). The ORs for beginning of exposure in 1956+ and end of exposure in 1976+ were OR = 1.71, 95% CI = 1.05, 2.78, and OR = 2.68, 95% CI = 1.47, 4.90, respectively. The risk increased with increasing duration of exposure and was statistically significant for >10-20 years (OR = 2.49) and more than 20 years (OR = 2.88). No separate analyses for West Germany and East Germany were presented in this category.

For heavy equipment operators (Group C) the overall OR of 2.31 (95% CI = 1.44, 3.7) was highest among all the job categories. Significant ORs were observed for beginning exposure in 1946-1955 (OR = 2.83, 95% CI = 1.10, 7.23) and end exposure in 1966-1975 (OR = 3.74, 95% CI = 1.20, 11.64). The risk increased with increasing duration of exposure and was statistically significant for more than 20 years of exposure (OR = 4.3). Although no separate analyses for West Germany and East Germany were presented, investigators mentioned that for this job group hardly any difference was seen between West Germany and East Germany.

For drivers of the farming tractors (Group D) the overall OR of 1.29 was not significant. Risk increased with increasing duration of exposure and was significant for exposure of more than 30 years (OR = 6.81, 95% CI = 1.17, 39.51). No separate analyses for West Germany and East Germany were presented in this category.

The professional drivers and the other traffic-related job categories probably have mixed exposures to gasoline exhaust in general traffic. On the other hand, it should be noted that exposure to DME among heavy equipment and farm tractor drivers is much higher and not as mixed as in professional drivers. The heavy equipment drivers usually drive repeatedly through their own equipment's exhaust. Therefore, the observed highest risk for lung cancer in this job category establishes a direct link with the DME. The only other study that found significantly higher risk for heavy equipment operators (RR = 2.6) was conducted by Boffeta et al. (1988). Although the only significant excess was observed for farming tractor operators among individuals with more than 30 years of exposure, a steady increase in risk was observed for this job category with increasing exposure. The investigators stated that the working conditions and the DME of tractors remained fairly constant over the years. This increase may be due mainly to exposure to DME and, in addition, $PM_{10.}$

This is a well-designed, well-conducted, and well-analyzed study. Its main strengths are large sample size, resulting in good statistical power; inclusion of incident cases that were diagnosed not more than 3 months prior to the interview; use of only personal interviews, reducing recall bias; diagnosis ascertained by cytology or histology; and availability of lifelong detailed occupational and smoking history. Exposure estimation for each individual was based on job codes and industry codes, which were validated by written job descriptions to avoid misclassification. The main limitation of the study is lack of data on actual exposure to DME. The cumulative quantitative exposures were calculated based on time spent in each job with potential exposure to DME and the type of equipment used. Thus, this study provides strong evidence for a causal association between exposure to DE and occurrence of lung cancer.

Table 7-2 summarizes the above lung cancer case-control studies.

Table 7-2. Epidemiologic studies of the health effects of exposure to DE: case-control studies of lung cancer

Authors	Population studied	DE exposure assessment	Results	Limitations
Hall and Wynder (1984)	502 histologically confirmed lung cancers Cases diagnosed 12 mo prior to interviews 502 matched hospital controls without tobacco-related diseases, matched for age, sex, race, and geographical area Population from 18 hospitals in controls	Based on previous Industrial Hygiene Standards for a particular occupation, usual lifetime occupation coded as "probably high exposure" and "no exposure" NIOSH standards used to classify exposures: High Moderate Low	SNS excess risk after adjustment for smoking for lung cancer: RR = 1.4 (1st criteria) and RR = 1.7 (NIOSH criteria)	Complete lifetime employment history not available Self-reported occupation history not validated No analysis by dose, latency, or duration of exposure No information on nonoccupational diesel exposure
Damber and Larsson (1987)	589 lung cancer cases who had died prior to 1979 reported to Swedish registry between 1972 and 1977 582 matched dead controls (sex, age, year of death, municipality) drawn from National Registry of Cause of Death 453 matched living controls (sex, year of birth, municipality) drawn from National Population Registry	Occupations held for at least 1 year or more A 5-digit code was used to classify the occupations according to Nordic Classification of Occupations	For underground miners: SS OR = 2.7 ($\geq$1 year of employment) SS OR = 9.8 ($\geq$20 years of employment) For professional drivers: SNS OR = 1.2 ($\geq$20 years of employment) with dead controls All ORs adjusted for smoking	Uncertain DE exposure No validation of exposure done Underground miners data not adjusted for other confounders such as radon, etc.

Table 7-2. Epidemiologic studies of the health effects of exposure to DE: case-control studies of lung cancer (continued)

Authors	Population studied	DE exposure assessment	Results	Limitations
Lerchen et al. (1987)	506 lung cancer cases from New Mexico tumor registry (333 males and 173 females) Aged 25-84 years Diagnosed between January 1, 1980, and December 31, 1982 771 (499 males and 272 females) frequency matched with cases, selected from telephone directory	Lifetime occupational history and self-reported exposure history were obtained Coded according to Standard Industrial Classification Scheme	No excess of relative odds were observed for DE exposure	Exposure based on occupational history and self-report, which was not validated 50% occupational history provided by next of kin Absence of lung cancer association with asbestos suggests misclassification of exposure
Garshick et al. (1987)	1,319 lung cancer cases who died between March 1, 1981, and February 28, 1982 2,385 matched controls (two each, age and date of death) Both cases and controls drawn from railroad worker cohort who had worked for 10 or more years	Personal exposure assessed for 39 job categories This was corrected with job titles to dichotomize the exposure into: Exposed Not exposed Industrial hygiene sampling done	SS OR = 1.41 (≤64 year age group) SS OR = 1.64 (≤64 year age group) for ≥20 years DE exposure group when compared to 0- to 4-year exposure group All ORs adjusted for lifetime smoking and asbestos exposure	Probable misclassification of DE exposure jobs Years of exposure used as surrogate for dose 13% of death certificates not ascertained Overestimation of smoking history
Benhamou et al. (1988)	1,260 histologically confirmed lung cancer cases 2,084 non-tobacco-related disease matched controls (sex, age at diagnosis, hospital admission, and interviewer) Occurring between 1976 and 1980 in France	Based on exposures determined by panel of experts The occupations were recorded blindly using International Standard Classification of Occupations as chemical or physical exposures	Significant excess risks were found in motor vehicle drivers (RR = 1.42) and transport equipment operators (RR = 1.35) (smoking adjusted)	Exposure based on occupational histories not validated Exposures classified as chemical and physical exposures, not specific to DE

Table 7-2. Epidemiologic studies of the health effects of exposure to DE: case-control studies of lung cancer (continued)

Authors	Population studied	DE exposure assessment	Results	Limitations
Hayes et al. (1989)	Pooled data from three different studies consisting of 2,291 male lung cancer cases 2,570 controls	Occupational information from next of kin for all jobs held Jobs classified with respect to potential exposure to known and suspected pulmonary carcinogens	SS OR = 1.5 for truck drivers (>10 years of employment) SS positive trend with increasing employment as truck driver Adjusted for age, smoking, & study area	Exposure data based on job description given by next of kin, which was not validated Could have been mixed exposure to both diesel and gasoline exhausts Job description could have led to misclassification
Steenland et al. (1990)	1,058 male lung cancer deaths between 1982 and 1983 1,160, every sixth death from entire mortality file, sorted by Social Security number (excluding lung cancer, bladder cancer, and motor vehicle accidents) Cases and controls were from Central State Teamsters who had filed claims (requiring 20-year tenure)	Longest job held: diesel truck driver, gasoline truck driver, both types of trucks, truck mechanic, and dockworkers	As 1964 cut-off point: SS OR = 1.64 for long-haul drivers with 13+ years of employment Positive trend test for long-haul drivers (p=0.04) SS OR = 1.89 for diesel truck drivers of 35+ years of employment Adjusted for age, smoking, & asbestos	Exposure based on job titles not validated Possible misclassification of exposure and smoking, based on next-of-kin information Lack of sufficient latency
Steenland et al. (1998)	Exposure-response analyses of their 1990 case-control study	Industrial hygiene data of elemental carbon in trucking industry collected by Zaebst et al. (1991) used to estimate individual exposures Cumulative exposures calculated based on estimated lifetime exposures	For mechanics: OR = 1.69 (had the highest DE exposure) Lowest DE exposure and lowest OR = 0.93 observed for dockworkers Increasing risk of lung cancer with increasing exposure Adjusted for age & smoking	

Table 7-2. Epidemiologic studies of the health effects of exposure to DE: case-control studies of lung cancer (continued)

Authors	Population studied	DE exposure assessment	Results	Limitations
Boffetta et al. (1990)	From 18 hospitals (since 1969), 2,584 male lung cancer cases matched to either one control (69) or two controls (2,515) were drawn. Matched on age, hospital, and year of interview	A priori aggregation of occupations categorized into low probability, possible exposure (19 occupations), and probable exposure (13 occupations) to DE	OR slightly below unity SNS Adjusted for smoking	No verification of exposure Duration of employment used as surrogate for dose Number of individuals exposed to DE was small
Emmelin et al. (1993)	50 male lung cancer cases from 15 ports (worked for at least 6 months between 1950 and 1974), 154 controls matched on age and port	Indirect DE exposure assessment done based on (1) exposure intensity, (2) characteristics of ventilation, (3) measure of proportion of time in higher exposure jobs	SS OR for high-exposure group = 6.8 Positive trend for DE observed (trend much steeper for smokers than nonsmokers) Adjusted for smoking	Numbers of cases and controls are small Very few nonsmokers Lack of exposure information on asbestos No latency analysis
Swanson et al. (1993)	Population based case-control study in metropolitan Detroit 3,792 lung cancer cases and 1,966 colon cancer (cases) controls, diagnosed between 1984 and 1987 in white and black males (aged between 40-84)	Telephone interviews with the individual or surrogate about lifetime work history Occupation and industry data coded per 1980 U.S. Census Bureau classification codes Certain occupations and industries were selected as unexposed to carcinogens	SS excess ORs observed for - black farmers OR= 10.4 for 20+ years employment - white railroad industry workers OR= 2.4 for 10+ years employment Among white trend tests were SS for -drivers of heavy duty trucks - drivers of light duty trucks - farmers - railroad workers Among blacks trend test was SS for farmers only All the ORs were adjusted for age at diagnosis, pack-years of cigarette smoking and race	Lack of direct information on specific exposures No latency analysis

Table 7-2. Epidemiologic studies of the health effects of exposure to DE: case-control studies of lung cancer (continued)

Authors	Population studied	DE exposure assessment	Results	Limitations
Hansen et al. (1998)	Population-based case-control study of professional drivers in Denmark Male lung cancer cases diagnosed between 1970-1989, controls matched by year of birth and sex	Information about past employment obtained by linkage with nationwide pension fund Employment as lorry/bus drivers (n=1,640) and taxi drivers (n=426) was used as surrogate for exposure to DE	For lorry/bus drivers: SS OR = 1.31 For taxi drivers: SS OR = 1.64, which increased to 2.2 in > 5-year employment with no lag time & 3.0 in > 5 year employment with 10- year lag time SS trend test for increasing risk with increasing employment for both lorry/bus drivers & taxi drivers ($p<0.001$) All ORs adjusted for socioeconomic status	Lack of information on the type of fuel (personal communication with the principal investigator confirmed that diesel fuel is used for the lorry/buses and taxis since early 1960s) Even though direct adjustment was not done for smoking/asbestos, indirect methods indicate that the results are not likely to be confounded by these factors

Table 7-2. Epidemiologic studies of the health effects of exposure to DE: case-control studies of lung cancer (continued)

Authors	Population studied	DE exposure assessment	Results	Limitations
Brüske-Hohlfeld et al. (1999)	Pooled analysis of two case-control studies (3,498 cases & 3,541 controls) Controls frequency matched on sex, age, & region, randomly selected from the compulsory population registry Inclusion criteria: (1) born in or after 1913/less than 75 years old, (2) German nationality/resident of the region - lived in Germany for more than 25 years, & (3) lung cancer diagnosis should be 3 months prior to the study Information obtained by personal interview on:	Lifetime detailed occupational & smoking histories obtained from each individual in a personal interview Based on job codes (33 job titles & 21 industries) potential DE exposure classified in 4 categories: A- professional drivers of trucks, buses, & taxis; B- other traffic related i.e., switchman, locomotive, & forklift drivers; C- bulldozer operators, graders,& excavators; D- farm tractor drivers Cumulative DE exposures and pack-years (smoking) calculated for each individual	SS higher risk adjusted for smoking observed for all 4 categories: A- ORs ranged from 1.25 to 2.53 B- ORs ranged from 1.53 to 2.88 C- ORs ranged from 2.31 to 4.3 D- 6.81 (exposure < 30 years) Risk increased with increasing exposure	Lack of data on actual exposure to diesel exaust

Abbreviations: OR = odds ratio; RR = relative risk; SNS = statistically nonsignificant; SS = statistically significant.

7.2.3. Summaries of Studies and Meta-Analyses of Lung Cancer

7.2.3.1. *Cohen and Higgins (1995): Health Effects of DE: Epidemiology*

The Health Effects Institute (HEI) reviewed all published epidemiologic studies on the health effects of exposure to DE available through June 1993, identified by a MEDLINE search and by reviewing the reference sections of published research and earlier reviews. HEI identified 35 reports of epidemiologic studies (16 cohort and 19 case-control) of the relation of occupational exposure to diesel emissions and lung cancer published between 1957 and 1993. HEI reviewed the 35 reports for epidemiologic evidence of health effects of exposure to DE for lung cancer, other cancers, and nonmalignant respiratory disease. They found that the data were strongest for lung cancer. The evidence suggested that occupational exposure to DE from diverse sources increases the rate of lung cancer by 20% to 40% in exposed workers generally, and to a greater extent among workers with prolonged exposure. They also found that the results are not explicable by confounding caused by cigarette smoking or other known sources of bias.

Control for smoking was identified in 15 studies. Six studies (17%) reported relative risk estimates less than 1; 29 studies (83%) reported at least one relative risk greater than one indicating positive association. Twelve studies indicating a relative risk greater than 1 had 95% confidence intervals, which excluded unity.

The authors conclude that epidemiologic data consistently show weak associations between exposure to DE and lung cancer. They find that the evidence suggests that long-term exposure to DE in a variety of occupational circumstances is associated with a 1.2- to 1.5-fold increase in the relative risk of lung cancer compared with workers classified as unexposed. Most of the studies that controlled for smoking found that the association between increased risk of lung cancer and exposure to DE persisted after such controls were applied, although in some cases the excess risk was lower. None of the studies measured exposure to diesel emissions or characterized the actual emissions from the source of exposure for the time period most relevant to the development of lung cancer. Most investigators classified exposure based on work histories reported by subjects or their next of kin, or by retirement records. Although these data provide relative rankings of exposure, the absence of concurrent exposure information is the key factor that limits interpretation of the epidemiologic findings and subsequently their utility in making quantitative estimates of cancer risks.

This is a comprehensive and thorough narrative review of studies of the health effects of DE. It does not undertake formal estimation of summary measures of effect or evaluation of heterogeneity in the results. The conclusion drawn about the consistency of the results is based on the author's assessment of the failure of potential biases and alternative explanations for the increase in risk to account for the observed consistency. In many if not most studies, the quality of the data used to control confounding was relatively crude. Although the studies do include qualitative assessment of whether control for smoking is taken into account, careful scrutiny of the quality of the control or adjustment for smoking among the studies is absent. This leaves open the possibility that prevalent residual confounding by inadequate control for smoking in many studies may account for the consistent associations seen.

7.2.3.2. *Bhatia et al. (1998): DE Exposure and Lung Cancer*

Bhatia et al. (1998) report a meta-analysis of 29 published[2] cohort and case-control studies of the relation between occupational exposure to DE and lung cancer. A search of the epidemiologic literature was conducted for all studies concerning lung cancer and DE exposure. Occupational studies involving mining were excluded because of concern about the possible influence of radon and silica exposures. Studies in which the minimum interval from time of first exposure to end of follow-up was less than 10 years, and studies in which work with diesel equipment or engines could not be confirmed or reliably inferred, were excluded. When studies presented risk estimates for more than one specific occupational category of DE-exposed workers, the subgroup risk estimates were used in the meta-analysis. Smoking-adjusted effect measures were used when present.

Of 29 studies 23 met the criteria for inclusion in the meta-analysis. The observed relative risk estimates were greater than 1 in 21 of these studies; this result is unlikely to be due to chance. The pooled relative risk weighted by study precision was 1.33 (95% CI = 1.24, 1.44), indicating increased relative risk for lung cancer from occupational exposure to DE. Subanalyses by study design (case-control and cohort studies) and by control for smoking produced results that did not differ from those of the overall pooled analysis. Cohort studies using internal comparisons showed higher relative risks than those using external comparisons (see Figure 7-1).

Bhatia and colleagues conclude that the analysis shows a small but consistent increase in the risk for lung cancer among workers with exposure to DE. The authors evaluate the dependence of the relative risk estimate on the presence of control for smoking among studies, and provide a table that allows assessment of whether the quality of the data contributing to control for smoking is related to the relative risk estimates (albeit in a limited number of studies). Bhatia et al. assert that residual confounding is not affecting the summary estimates or conclusions for the following reasons: (1) the pooled relative risks for studies adjusted for smoking were the same as those for studies not adjusting for smoking; (2) in those studies giving risk estimates adjusted for smoking and risk estimates not adjusted for smoking, there was only a small reduction in the pooled relative risk from DE exposure; and (3) in studies with internal

[2]Of 35 studies identified in the literature search, 6 pairs of studies represented analyses of the same study population, reducing the number of studies to 29.

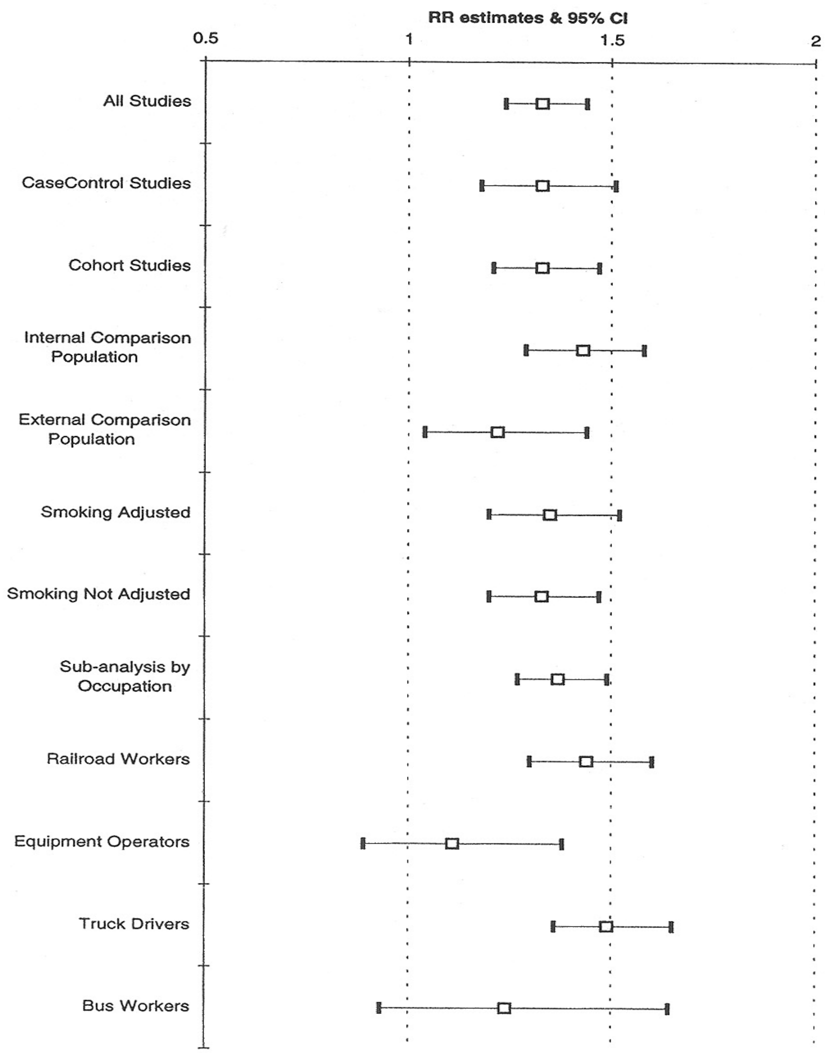


Figure 7-1. Pooled relative risk estimates and heterogeneity-adjusted 95% confidence intervals for all studies and subgroups of studies included in the meta-analysis.

Source: Bhatia et al., 1998.

comparison populations, in which confounding is less likely, the pooled relative risk estimate was 1.43.

The validity of this assessment depends on the adequacy of control for smoking in the individual studies. If inadequate adjustment for smoking is employed and residual confounding by cigarette smoking pertains in the result of the individual studies, then the comparisons and contrasts of the pooled estimates the authors cite as reasons for dismissing the effect of residual confounding by smoking will remain contaminated by residual confounding in the individual studies. In fact, Bhatia et al. erroneously identify the treatment of the smoking data in the main analysis for the 1987 report by Garshick et al. as a continuous variable representing pack-years of smoking, whereas the analysis actually dichotomized the pack-years data into two crude dose categories (above and below the 50 pack-years level). This clearly reduced the quality of the adjustment for smoking, which already suffered from the fact that information on cumulative cigarette consumption was missing for more than 20% of the lung cancer cases. In this instance, the consistency between the adjusted and unadjusted estimates of the relative risk for DE exposure may be attributable to failure of adjustment rather than lack of confounding by cigarette smoking. A similar problem exists for the Bhatia et al. representation of the control for confounding in the study by Boffetta and Stellman (1988).

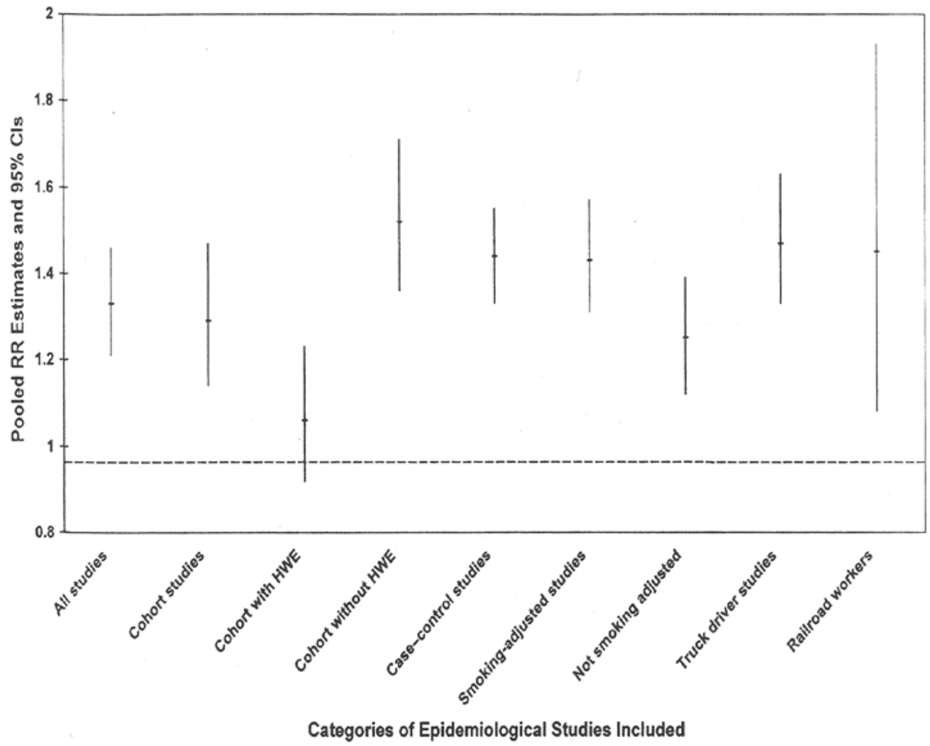
An evaluation of the potential for publication bias is presented that provides reassurance that the magnitude of published effects is not a function of the precision or study power; however, this assessment cannot rule out the possibility of publication bias.

7.2.3.3. *Lipsett and Campleman (1999): Occupational Exposure to DE and Lung Cancer: A Meta-Analysis*

Lipsett and Campleman (1999) conducted electronic searches to identify epidemiologic studies published between 1975 and 1995 of the relationship of occupational exposure to DE and lung cancer. Studies were selected based on the following criteria: (1) Estimates of relative risks and their standard errors must be reported or derivable from the information presented. (2) Studies must have allowed for a latency period of 10 or more years for development of lung cancer after onset of exposure. (3) No obvious bias resulted from incomplete case ascertainment in follow-up studies. (4) Studies must be independent: that is, a single representative study selected from any set of multiple analyses of data from the same population. Studies focusing on occupations involving mining were excluded because of potential confounding by radon, arsenic, and silica, as well as possible interactions between cigarette smoking and exposure to these substances in lung cancer induction.

Thirty of the 47 studies initially identified as relevant met the specified inclusion criteria. Several risk estimates were extracted from six studies reporting results from multiple mutually exclusive diesel-related occupational subgroups. If a study reported effects associated with several levels or durations of exposure, the effect reported for the highest level or longest duration of exposure was used. If estimates for several occupational subsets were reported, the most diesel-specific occupation or exposure was selected. Adjusted risk estimates were used when available.

Thirty-nine independent estimates of relative risk and standard errors were extracted. Pooled estimates of relative risk were calculated using a random-effects model. Among study populations most likely to have had substantial exposure to DE, the pooled smoking- adjusted relative risk was 1.47 (95% CI = 1.29, 1.67) (see Figure 7-2).



Note. CI = confidence interval; HWE = healthy worker effect.

Figure 7-2. Pooled estimates of relative risk of lung cancer in epidemiologic studies involving occupational exposure to DE (random-effects models).

Source: Lipsett and Campleman, 1999.

The between-study variance of the relative risks indicated the presence of significant heterogeneity in the individual estimates. The authors evaluated the potential sources of heterogeneity by subset analysis and linear meta-regressions. Major sources of heterogeneity included control for confounding by smoking, selection bias (a healthy worker effect), and exposure patterns characteristic of different occupational categories. A modestly higher, pooled relative risk was derived for the subset of case-control studies, which, unlike the cohort studies, showed little evidence of heterogeneity.

This meta-analysis also evaluated the potential for publication bias, which provides reassurance that the magnitude of published effects is not a function of the precision or study power. Again, as stated in the Bhatia et al. (1998) review, this assessment cannot rule out the possibility of publication bias.

Although a relatively technical approach was used in deriving summary estimates of relative risk and the evaluation of possible sources of variation in the relative risks in this meta-analysis, this approach should not be confused with rigorous evaluation of the potential weaknesses among the studies included in the analysis. The heterogeneity attributable to statistical adjustment for smoking was evaluated based on a dichotomous assessment of whether control for smoking could be identified in the studies considered. This does not reflect the adequacy of the adjustment for smoking employed in the individual studies considered.

7.2.4. Summary and Discussion

Certain extracts of DE have been demonstrated as both mutagenic and carcinogenic in animals and in humans. Animal data suggest that DE is a pulmonary carcinogen among rodents exposed by inhalation to high doses over long periods of time. While rat lung cancer response to DE is not suitable for dose-response extrapolation to humans, the positive lung cancer response doses imply a hazard for humans. Because large working populations are currently exposed to DE and because nonoccupational ambient exposures currently are of concern as well, the possibility that exposure to this complex mixture may be carcinogenic to humans has become an important public health issue.

Because diesel emissions become diluted in the ambient air, it is difficult to study the health effects in the general population. Nonoccupational exposure to DE is worldwide in urban areas. Thus, “unexposed” reference populations used in occupational cohort studies are likely to contain a substantial number of individuals who are nonoccupationally exposed to DE. Furthermore, the “exposed” group in these studies is based on job titles, which in most instances are not verified or correlated with environmental hygiene measurement. The issue of health effect measurement is further complicated by the fact that occupational cohorts tend to be healthy and have below-average mortality, usually referred to as the “healthy worker effect.” Hence, the usual standard mortality ratios observed in cohort mortality studies are likely to be underestimations of true risk.

A major difficulty with the occupational studies considered here was measurement of actual DE exposure. Because all the cohort mortality studies were retrospective, assessment of health effects from exposure to DE was naturally indirect. In these occupational settings, no systematic quantitative records of ambient air were available. Most studies compared men in job categories with presumably some exposure to DE with either standard populations (presumably no exposure to DE) or men in other job categories from industries with little or no potential for DE exposure. A few studies have included measurements of diesel fumes, but there is no standard method for the measurement. No attempt is made to correlate these exposures with the cancers observed in any of these studies, nor is it clear exactly which extract should have been measured to assess the occupational exposure to DE. All studies have relied on the job categories or self-report of exposure to DE. Gustavsson et al. (1990), Emmelin et al. (1993), and Brüske-Hohlfeld et al. (1999) estimated exposure levels by getting detailed histories of job tasks/categories and computing cumulative exposures, which unfortunately were not verifiable due to of the lack of industrial hygiene data. In the studies by Garshick et al. (1987, 1988), the diesel-exhaust-exposed job categories were verified based on an industrial hygiene survey done by Woskie et al. (1988a,b). The investigators found that in most cases the job titles were good surrogates for DE exposure. Also, in the railroad industry, where only persons who had at least 10 years of work experience were included in the study, the workers tended not to change job categories over the years. Thus, a job known only at one point in time was a reasonable marker of past DE exposure. Unfortunately, the exposure was only qualitatively verified. Quantitative use of this information would have been much more meaningful. Zaebst et al. (1991) conducted an industrial hygiene survey of elemental carbon exposure in the trucking industry by job categories. Using these exposure measurements, Steenland et al. (1998) conducted an exposure-response analysis of their earlier lung cancer case-control study (Steenland et al., 1990). These exposure data are currently being verified and will be used for quantitative risk assessment in the near future.

Occupations involving potential exposure to DE are miners, truck drivers, transportation workers, railroad workers, and heavy equipment operators. No known studies in metal miners have assessed whether DE is associated with lung cancer. Currently, there are about 265 underground metal/nonmetal mines in the United States (Department of Labor, Mine Safety and Health Administration, 2001). Approximately 20,000 miners are employed, but not all of them are currently working in the mines. Diesel engines were introduced in metal mines in the United States in the early to mid-1960s. Although all these mines use diesel equipment, it is difficult to estimate how many of these miners were actually exposed to diesel fumes.

Diesel engines were introduced in coal mines at an even later date in the United States, and their use is still quite limited. There are 910 underground coal mines in the United States, of which only 145 currently use diesel powered equipment (Department of Labor, Mine Safety and Health Administration, 2001). Even if it were possible to estimate how many miners (metal and coal) were exposed to DE, it would be very difficult to separate out the confounding effects of other potential pulmonary carcinogens, such as radon decay products or heavy metals (e.g., arsenic, chromium). Furthermore, the relatively short latency period limits the usefulness of these cohorts of miners.

Both metal and coal mines in Europe and Australia, on the other hand, have been using diesel equipment for more than 50 years. The epidemiologic studies of coal miners conducted in these countries discuss only exposures to coal dust. In most of the coal miner studies, DE exposures are not even mentioned by the investigators as confounding exposures. Therefore, it is not known how many miners, if any, were exposed to DE, for how long, and at what concentrations. Although studies of coal miners reviewed by IARC (1997) generally found lower than expected lung cancer mortality (with some exceptions where some excess of lung cancer was observed), without knowing the concentrations, duration of exposure, and number of miners exposed to DE, it is inappropriate to conclude that the reported lung cancer mortality deficit in these studies provides a proof positive of absence of causal association between DE exposure and occurrence of lung cancer.

7.2.4.1. *Summary of the Cohort Mortality Studies*

The cohort studies mainly demonstrated an increase in lung cancer. Studies of bus company workers by Waller (1981), Rushton et al. (1983), and Edling et al. (1987) failed to demonstrate any statistically significant excess risk of lung cancer, but these studies have certain methodological problems, such as small sample sizes, short follow-up periods (just 6 years in the Rushton et al. study), lack of information on confounding variables, and lack of analysis by duration of exposure, duration of employment, or latency that preclude their use in determining the carcinogenicity of DE. Although the Waller (1981) study had a 25-year follow-up period, the cohort was restricted to employees (ages 45 to 64) currently in service. Employees who left the job earlier, as well as those who were still employed after age 64 and who may have died from cancer, were excluded.

Wong et al. (1985) conducted a mortality study of heavy equipment operators that demonstrated a nonsignificant positive trend for cancer of the lung with length of membership and latency. Analysis of deceased retirees showed a significant excess of lung cancer. Individuals without work histories who started work prior to 1967, when records were not kept, may have been in the same jobs for the longest period of time. Workers without job histories included those who had the same job before and after 1967 and thus may have worked about 12 to 14 years longer; these workers exhibited significant excess risks of lung cancer and stomach cancer. If this assumption about duration of jobs is correct, then these site-specific causes can be linked to DE exposure. One of the methodologic limitations of this study is that most of these men worked outdoors; thus, this cohort might have had relatively low exposure to DE. The authors did not present any environmental measurement data either. Because of the absence of detailed work histories for 30% of the cohort and the availability of only partial work histories for the remaining 70%, jobs were classified and ranked according to presumed diesel exposure.

Information is lacking regarding duration of employment in the job categories (used for surrogate of exposure) and other confounding factors (alcohol consumption, cigarette smoking, etc.). Thus, this study cannot be used to support or refute a causal association between exposure to DE and lung cancer.

A 2-year mortality analysis by Boffetta and Stellman (1988) of the American Cancer Society's prospective study, after controlling for age and smoking, demonstrated an excess risk of lung cancer in certain occupations with potential exposure to DE. These excesses were statistically significant among miners (RR = 2.67, 95% CI = 1.63, 4.37) and heavy equipment operators (RR = 2.6, 95% CI = 1.12, 6.06). Recently Brüske-Hohlfeld et al. (1999) also have observed significantly higher risk for lung cancer, in the range of 2.31 to 4.3, for heavy equipment operators. The elevated risks were nonsignificant in railroad workers (RR = 1.59) and truck drivers (RR = 1.24). A dose response was also observed for truck drivers. With the exception of miners, exposure to DE occurred in the three other occupations showing an increase in the risk of lung cancer. Despite methodologic limitations, such as the lack of representiveness of the study population (composed of volunteers only, who were probably healthier than the general population), leading to an underestimation of the risk, and the questionable reliability of exposure data based on self-administered questionnaires that were not validated, this study is suggestive of a causal association between exposure to DE and excess risk of lung cancer.

Two mortality studies were conducted by Gustavsson et al. (1990) and Hansen (1993) among bus garage workers (Stockholm, Sweden) and truck drivers, respectively. An SMR of 122 was found among bus garage workers, based on 17 cases. A nested case-control study was also conducted in this cohort. Detailed exposure matrices based on job tasks were assembled for both DE and asbestos exposures. Statistically significant increasing lung cancer relative risks of 1.34, 1.81, and 2.43 were observed for DE indices of 10 to 20, 20 to 30, and >30, respectively, using 0 to 10 as a comparison group. Adjustment for asbestos exposure did not change the results. The main strength of this study is the detailed exposure matrices; some of the limitations are low power (small cohort) and lack of smoking histories. But smoking is not likely to be different among study individuals irrespective of their exposure status to DE.

Hansen (1993), on the other hand, found statistically significant SMR of 160 from cancer of bronchus and lung. No dose response was observed, although the excesses were observed in most of the age groups (30 to 39, 45 to 49, 50 to 54, 55 to 59, 60 to 64, and 65 to 74). There are quite a few methodologic limitations to this study. Exposure to DE was assumed in truck drivers for diesel-powered trucks, but no validation of exposure was attempted. Follow-up period was short, no latency analysis was done, and smoking data were lacking. However, a population survey carried out in 1988 showed very little difference in smoking habits of residents of rural area and the total Danish male population, thus, smoking is unlikely to confound the finding of excess lung cancer. The findings of both these studies are consistent with the findings of other truck driver studies and are supportive of causal association.

Two mortality studies of railroad workers were conducted by Howe et al. (1983) and Garshick et al. (1988). The Howe et al. study, which was conducted in Canada, found relative risks of 1.2 ($p<0.01$) and 1.35 ($p<0.001$) among “possibly” and “probably” exposed groups, respectively. The trend test showed a highly significant dose-response relationship with exposure to DE and the risk of lung cancer. The main limitation of the study was the inability to separate overlapping exposures of coal dust/combustion fumes and DE fumes. Information on jobs was available at retirement only. There also was insufficient detail on the classification of jobs by DE exposure. The exposures could have been nonconcurrent or concurrent, but because the data are lacking, it is possible that the observed excess could be due to the effect of both coal dust/combustion fumes and DE fumes and not just one or the other. It should be noted that, so far, coal dust has not been demonstrated to be a pulmonary carcinogen in studies of coal miners. However, lack of data on confounders such as asbestos and smoking (though use of the internal comparison group to compute relative risks minimizes confounding by smoking) makes interpretation of this study difficult. When three DE exposure categories were examined for smoking-related diseases such as emphysema, laryngeal cancer, esophageal cancer, and buccal cancer, positive trends were observed, raising a possibility that the dose response demonstrated for diesel exposure may have been due to smoking. The findings of this study are at best suggestive of DE being a lung carcinogen.

The strong evidence for linking DE exposure to lung cancer comes from the Garshick et al. (1988) railroad worker study conducted in the United States. Relative risks of 1.57 (95% CI = 1.19, 2.06) and 1.34 (95% CI = 1.02, 1.76) were found for ages 40 to 44 and 45 to 49, respectively, after the exclusion of workers exposed to asbestos. The investigators reported that the risk of lung cancer increased with increasing duration of employment. As this was a large cohort study with a lengthy follow-up and adequate analysis, including dose response (based on duration of employment as a surrogate) as well as adjustment for other confounding factors such as asbestos, the observed association between increased lung cancer and exposure to DE is more meaningful. Even though the reanalysis of these data by Crump et al. (1991) found that the relative risk could be positively or negatively related to duration of exposure depending on how age was controlled, additional analysis by Garshick et al. (letter from Garshick, Harvard Medical School, to Chao Chen, U.S. EPA, dated August 15, 1991) found that the relationship between years exposed when adjusted for the attained age and calendar years was flat to negative, depending on the choice of the model. They also found that deaths were underreported by approximately 20% to 70% between 1977 and 1980, and their analysis based on job titles, limited to 1959-1976, showed that the youngest workers still had the highest risk of dying of lung cancer. On the other hand, an analysis of the same data by California EPA (CalEPA, 1998) yielded a positive dose response set using age at 1959 and adding an interaction term of age and calendar year in the model. However, Crump (1999) reported that the negative dose-response continued to be upheld in his latest analysis when age was controlled more carefully and years of exposure quantified more accurately. Crump (1999) asserted that the negative dose-response trends for lung cancer observed with either the cumulative exposure or duration of exposure may be due to underascertainment of deaths in the last 4 years of follow-up of the Garshick et al. (1988) study, as well as incomplete follow-up in earlier years. The HEI (1999) special panel conducted its own analyses using Garshick et al. (1988) data to evaluate their usefulness for quantitative risk assessment and found results similar to those of Crump et al. (1991) and Garshick (letter from Garshick, Harvard Medical School, to Chao Chen, U.S. EPA, dated August 15, 1991). The HEI panel reported consistently elevated risk of lung cancer for train workers compared with clerks for each duration of employment, and that shop workers had an intermediate risk of lung cancer. But they found decreasing risk of lung cancer with increasing duration of employment. The panel discussed various possibilities (different types of biases) for the negative dose-response and advised against using the Garshick et al. (1988) data for quantitative risk assessment. The panel also reported the strengths of the Garshick et al. (1988) study such as large population, control for asbestos, and smoking, and concluded that the study was generally consistent with findings of weak association between exposure to DE and occurrence of lung cancer. Hence, the divergent results of these recent analyses do not negate the positive evidence this study provides for the qualitative evaluation. The observance of dose-response would have strengthened the causal association, but an absence of a dose-response does not negate it.

Suggestive evidence is provided by a recent study of potash miners in Germany. The information on the exposure (including elemental carbon and organics), work chronology, and work category was used by the investigators to calculate cumulative exposures for each worker. Furthermore, information on smoking habits indicated homogeneity in the cohort.
A statistically nonsignificant twofold increase in lung cancer was observed in the production workers as compared to workshop workers. The lack of significance for this finding could be due to short follow-up, not enough latency, and relatively young age of the cohort.

7.2.4.2. *Summary of the Case-Control Studies of Lung Cancer*

Among the 11 lung cancer case-control studies reviewed in this chapter, only 2 studies did not find any increased risk of lung cancer. Lerchen et al. (1987) did not find any excess risk of lung cancer, after adjusting for age and smoking, for diesel fume exposure. The major limitation of this study was a lack of adequate exposure data derived from the job titles obtained from occupational histories. Next of kin provided the occupational histories for 50% of the cases that were not validated. The power of the study was small (analysis done on males only, 333 cases). Similarly, Boffeta et al. (1990) did not find any excess of lung cancer after adjusting for smoking and education. This study had a few methodological limitations. The lung cancer cases and controls were drawn from the ongoing study of tobacco-related diseases. It is interesting to note that the leading risk factor for lung cancer is cigarette smoking. The exposure was not measured. Instead, occupations were used as surrogates for exposure. Furthermore, there were very few individuals in the study who were exposed to DE. On the other hand, statistically nonsignificant excess risks were observed for DE exposure by Hall and Wynder (1984) in workers who were exposed to DE versus those who were not (OR = 1.4 and 1.7 with two different criteria) and by Damber and Larsson (1987) in professional drivers (OR = 1.2). These rates were adjusted for age and smoking. Hall and Wynder (1984) had a high nonparticipation rate of 36%. Therefore, the positive results found in this study are underestimated at best. In addition, the self-reported exposures used in the study by Hall and Wynder (1984) were not validated. This study also had low power to detect excess risk of lung cancer for specific occupations.

The study by Benhamou et al. (1988), after adjusting for smoking, found significantly increased risks of lung cancer among French motor vehicle drivers (RR = 1.42) and transport equipment operators (RR = 1.35). The main limitation of the study was the inability to separate exposures to DE from those to gasoline exhaust because both motor vehicle drivers and transport equipment operators probably were exposed to the exhausts of both types of vehicles.

Hayes et al. (1989) combined data from three studies (conducted in three different states) to increase the power to detect an association between lung cancer and occupations with a high potential for exposure to DE. They found that truck drivers employed for more than 10 years had a significantly increased risk of lung cancer (OR = 1.5, 95% CI = 1.1, 1.9). This study also found a significant trend of increasing risk of lung cancer with increasing duration of employment among truck drivers. The relative odds were computed by adjusting for birth cohort, smoking, and State of residence. The main limitation of this study is again the mixed exposures to diesel and gasoline exhausts, because information on type of engine was lacking. Also, potential bias may have been introduced because the way in which the cause of death was ascertained for the selection of cases varied in the three studies. Furthermore, the methods used in these studies to classify occupational categories were different, probably leading to incompatibility of occupational categories.

Emmelin et al. (1993), in their Swedish dockworkers from 15 ports, found increased relative odds of 6.8 (90% CI = 1.3 to 34.9). A strong interaction between smoking and DE was observed in this study. Of 50 cases and 154 controls, only 6 individuals were nonsmokers. Although intricate exposure matrices were created using three different variables, no direct exposure measurement was done. Despite the limitations of small number of cases and controls; lack of data on asbestos exposure, which is fairly common in dockworkers; and very few nonsmokers; this study provides consistent support for a real effect of DE exposure and occurrence of lung cancer, at least in smokers.

The most convincing evidence comes from the case-control studies among railroad workers by Garshick et al. (1987); among truck drivers of the Teamsters Union by Steenland et al. (1990, 1998); among truck drivers, railroad workers, and farmers in a population-based study by Swanson et al. (1993); among different professional drivers in Denmark by Hansen et al. (1998); and among male workers occupationally exposed to diesel motor emissions in Germany by Brüske-Hohlfeld et al. (1999). Garshick et al. (1987) found that after adjustment for asbestos and smoking, the relative odds for continuous exposure were 1.39 (95% CI = 1.05, 1.83). Among the younger workers with longer DE exposure, the risk of lung cancer increased with duration of exposure after adjusting for asbestos and smoking. Even after the exclusion of recent DE exposure (5 years before death), the relative odds increased to 1.43 (95% CI = 1.06, 1.94). This appears to be a well-conducted and well-analyzed study with reasonably good power. Potential confounders were controlled adequately, and interactions between DE and other lung cancer risk factors were tested. Some of the limitations of this study are misclassification of exposure because ICC job classification was used as surrogate for exposure and use of death certificates for identification of cases and controls.

Steenland et al. (1990), on the other hand, created two separate work history files, one from Teamsters Union pension files and the other from next-of-kin interviews. Using duration of employment as a categorical variable and considering employment after 1959 (when presumed dieselization occurred) for long-haul drivers, the risk of lung cancer increased with increasing years of exposure. Using 1964 as the cutoff, a similar trend was observed for long-haul drivers. For short-haul drivers, the trend was positive with a 1959 cutoff, but not when 1964 was used as the cutoff. For truck drivers who primarily drove diesel trucks and worked for 35 years, the relative odds were 1.89. The main strengths of the study are availability of detailed records from the Teamsters Union, a relatively large sample size, availability of smoking data, and measurements of exposure. The limitations of this study include possible misclassifications of exposure and smoking, lack of levels of diesel exposure, a smaller nonexposed group, and an insufficient latency period. Recently Steenland et al. (1998) conducted an exposure-response analysis on these cases and controls, using the industrial hygiene survey results of Zaebst et al. (1991). The estimates were made for long-haul drivers, short-haul drivers, dockworkers, mechanics, and those outside the trucking industry. The survey found that mechanics had the highest current levels of DE exposures and dockworkers who mainly used propane- powered forklifts had the lowest exposure. The finding of the highest lung cancer risk for mechanics and lowest for dock workers is indicative of a causal association between the DE exposure and development of lung cancer. However, the risk among mechanics did not increase with increasing duration of employment. The ORs for quartile cumulative exposures, computed by using logistic regression adjusted for age, race, smoking, diet, and asbestos exposure, showed a pattern of increasing trends in risk with increasing exposure, between 1.08 and 1.72 depending upon exposure level and lag structure used.

In a population-based lung cancer case-control study Swanson et al. (1993) found statistically significant excess risks adjusted for age at diagnosis, smoking, and race, among white male drivers of heavy trucks employed for $\geq$20 years and railroad workers employed for $\geq$10 years (OR = 2.5, 95% CI = 1.1, 4.4, and OR = 2.4, 95 % CI = 1.1, 5.1, respectively), and among black farmers employed for $\geq$20 years (OR = 10.4, 95% CI = 1.4, 77.1). Although individual ORs were not significant for various occupations with potential exposure to DE, statistically significant trends were observed for drivers of heavy trucks, light trucks, farmers, and railroad industry workers among whites, and among black farmers ($p \leq 0.05$). The main strengths of the study are availability of data on lifetime work history and smoking history; the main limitation is absence of actual specific exposure data. This is the first study that found increased lung cancer risk for farmers, who are exposed to DE of their farm tractors.

Hansen et al. (1998), in their study of professional drivers in Denmark, found statistically significant ORs (adjusted for socioeconomic status) of 1.31, 1.64, and 1.39 for lorry/bus drivers, taxi drivers, and unspecified drivers, respectively. The lag time analyses for duration of employment were unchanged for lorry/bus drivers but increased to OR = 3 from 2.2 in taxi drivers with a lag time of 10 years and duration of employment of > 5 years. The authors asserted that the higher risk seen in the taxi drivers may be due to higher exposure to these drivers because of longer time spent in traffic congestion. Furthermore, the trend tests for increasing risk of lung cancer with increasing duration of employment were statistically significant for both lorry/bus drivers and taxi drivers in both 10-year lag time and no lag time. The main strengths of the study are the large sample size, availability of detailed employment records, and information on socioeconomic status. The main limitations are absence of individual data on smoking habits and asbestos exposure, and information about the type of fuel used for the vehicles driven by these professional drivers. A personal communication with the main investigator revealed that the lorries/buses and taxis have been using diesel fuel since the late 1940s. Moreover, indirect information about smoking and asbestos exposure indicated that these two confounders are unlikely to explain the observed excesses or the trends, resulting in strong support of earlier positive studies.

Brüske-Hohlfeld et al. (1999) recently conducted a pooled analysis of two case-control studies among male workers occupationally exposed to DME in Germany. The investigators collected data on demographic information, detailed smoking, and occupational history. Job titles and industries were classified in 33 and 21 categories respectively. Job descriptions were written and verified to avoid misclassification of estimated exposure to diesel emissions. Individual cumulative DME exposures and smoking pack-years were calculated. Asbestos exposures were estimated by certain job-specific supplementary questions. Analysis of 3,498 lung cancer cases and 3,541 controls yielded statistically significant ORs ranging from 1.25 to 2.31 adjusted for smoking and asbestos exposure. The risk increased with increasing years of exposure for both the first year of exposure and the end year of exposure. These investigators presented analyses by various job categories, by years of exposure, first and end years of exposure and, when possible, separately for West and East Germany. Significantly higher risks were found among all four job categories. For professional drivers (of trucks, buses, and taxis) ORs ranged from 1.25 to 2.53. For other traffic-related jobs (switchmen, diesel locomotive drivers, diesel forklift truck drivers), ORs ranged from 1.53 to 2.88. For heavy equipment operators (bulldozers, graders, and excavators), ORs ranged from 2.31 to 4.3, and for drivers of farming equipment the only significant excess (OR = 6.81) was for exposure for <30 years.

This study shows increased risk for all the DME-exposed job categories. The professional drivers and the other traffic-related jobs also have some mixed exposures to gasoline exhaust in general traffic. On the other hand, it should be noted that exposure to DME among heavy equipment and farm tractor drivers is much higher and not as mixed as in professional drivers. The heavy equipment drivers usually drive repeatedly through their own equipment's exhaust. Therefore, the observed highest risk for lung cancer in this job category establishes a strong link with the DME. The only other study that found significantly higher risk for heavy equipment operators (RR = 2.6) was conducted by Boffeta et al. (1988). Although the only significant excess in the group was observed for farming tractor operators with more than 30 years of exposure, a steady increase in risk was observed for this job category with increasing exposure. The investigators stated that the working conditions and the DME of tractors remained fairly constant over the years. This increase may be due mainly to exposure to DME and $PM_{10.}$

The main strengths of the study are large sample size, resulting in good statistical power; inclusion of incident cases diagnosed not more than 3 months prior to the interview; use of only personal interviews, reducing recall bias; diagnoses ascertained by cytology or histology; and availability of lifelong detailed occupational and smoking history. Exposure estimation done for each individual was based on job codes and industry codes, which were validated by written job descriptions to avoid misclassification.

The main limitation of the study is lack of data on actual exposure to DME. The cumulative quantitative exposures were calculated based on time spent in each job with potential exposure to DME and the type of equipment used. Thus, this study provides strong evidence for causal association between exposure to DE and occurrence of lung cancer.

7.2.4.3. *Summary of the Reviews and Meta-Analyses of Lung Cancer*

Three summaries of studies concerned with the relationship of DE exposure and lung cancer risk are reviewed. The HEI report is a narrative study of 35 epidemiologic studies (16 cohort and 19 case-control) of occupational exposure to diesel emissions published between 1957 and 1993. Control for smoking was identified in 15 studies. Six of the studies (17%) reported relative risk estimates less than 1, whereas 29 (83%) reported at least 1 excess relative risk, indicating a positive association. Twelve studies indicating a relative risk greater than 1 had 95% confidence intervals that excluded unity. These studies found that the evidence suggests that occupational exposure to DE from diverse sources increases the rate of lung cancer by 20% to 40% in exposed workers generally, and to a greater extent among workers with prolonged exposure. They also found that the results are not explicable by confounding due to cigarette smoking or other known sources of bias.

Bhatia et al. (1998) identified 23 studies that met criteria for inclusion in the meta-analysis. The observed relative risk estimates were greater than 1 in 21 of these studies. The pooled relative risk weighted by study precision was 1.33 (95% CI= 1.24, 1.44), which indicated increased relative risk for lung cancer from occupational exposure to DE. Subanalyses by study design (case-control and cohort studies) and by control for smoking produced results that did not differ from those of the overall pooled analysis. Cohort studies using internal comparisons showed higher relative risks than those using external comparisons.

Lipsett and Campleman (1999) identify 39 independent estimates of relative risk among 30 eligible studies of DE and lung cancer published between 1975 and 1995. Pooled relative risks for all studies and for study subsets were estimated using a random effect model. Interstudy heterogeneity was also modeled and evaluated. A pooled smoking-adjusted relative risk was 1.47 (95% CI = 1.29, 1.67). Substantial heterogeneity was found in the pooled-risk estimates. Adjustment for confounding by smoking, having a lower likelihood of selection bias, and increased study power were all found to contribute to lower heterogeneity and increased pooled estimates of relative risk.

There is some variability in the conclusions of these summaries of the association of DE and lung cancer. The three analyses find that smoking is unlikely to account for the observed effects, and all conclude that the data support a causal association between lung cancer and DE exposure. On the other hand, Stöber and Abel (1996), Muscat and Wynder (1995), and Cox

(1997) call into question the assertions by Cohen and Higgins (1995), Bhatia et al. (1998), and Lipsett and Campleman (1999) that the associations seen for DE and lung cancer are unlikely to be due to bias. They argue that methodologic problems are prevalent among the studies, especially in evaluation of diesel engine exposure and control of confounding by cigarette smoking, and thus, the observed association between exposure to DE and excess risk of lung cancer is more likely to be due to bias. The conclusions of the two meta-analyses are based on magnitude of pooled relative risk estimates and evaluation of potential sources of heterogeneity in the estimates. Despite the statistical sophistication of the meta-analyses, the statistical models used cannot compensate for deficiencies in the original studies and will remain biased to the extent that bias exists in the original studies.

7.2.4.4. *Discussion of Relevant Methodologic Issues*

A persistent association of risk for lung cancer and DE exposure has been observed in more than 30 epidemiologic studies published in the literature over the past 40 years. Evaluation of whether this association can be attributed to a causal relation between DE exposure and lung cancer requires careful consideration of whether chance, bias, or confounding might be likely alternative explanations.

A total of 10 cohort and 12 case-control studies are reviewed in this chapter. An increased lung cancer risk was observed in 8 cohort and 10 case-control studies, even though the results were not always statistically significant. There is a consistent tendency for point estimates of relative risk to be greater than one in studies that adjusted (either directly or indirectly) for smoking, had a long enough follow-up, and sufficient statistical power among truck drivers, railroad workers, dock workers, and heavy equipment workers. If this elevated risk was due to chance one would expect almost equal distribution of these point estimates to be above and below one. Many of the studies provide confidence intervals for their estimates of excess risk or statistical tests, which indicate that it is unlikely that the individual study findings were due to random variation. The persistence of this association between DE and lung cancer risk in so many studies indicates that the possibility is remote that the observed association in aggregate is due to chance. It is unlikely that chance alone accounts for the observed relation between DE and lung cancer.

The excess risk is observed in both cohort and case-control designs, which contradicts the concern that a methodologic bias specifically characteristic of either design (e.g., recall bias) might account for the observed effect. Selection bias is certainly present in some of the occupational cohort studies that use external population data in estimating relative risks, but this form of selection bias (a healthy worker effect) would only obscure, rather than spuriously produce, an association between DE and lung cancer. Several occupational epidemiologic studies that use more appropriate data for their estimates are available. Selection biases may be operating in some case-control studies, but it is not obvious how such a bias could be sufficiently uniform in effect, prevalent, and strong enough to lead to the consistent association seen in the aggregate data. Given the variety of designs used in studying the DE and lung cancer association and the number of studies in different populations, it is unlikely that routinely studying noncomparable groups is an explanation for the consistent association seen. Exposure information bias is certainly a problem for almost all of the studies concerned. Detailed and reliable individual-level data on DE exposure for the period of time relevant to the induction of lung cancer are not available and are difficult to obtain. Generally, the only information from which diesel exposure can be inferred is occupational data, which is a poor surrogate for the true underlying exposure distribution. The variability in actual lifetime exposure to DE in an occupational cohort may not be reflected in differences in job title, and there might be considerable variability in actual exposure despite similar job titles. Study endpoints are frequently mortality data taken from death certificate information, which is frequently inaccurate and often does not fully characterize the lung cancer incidence experience of the population in question. Using inaccurate surrogates for lung cancer incidence and for diesel exposure can lead to substantial bias, and these shortcomings are endemic in the field. In most cases these shortcomings will lead to misclassification of exposure and of outcome, which is nondifferential. Nondifferential misclassification of exposure and/or outcome can bias estimates of a DE–lung cancer association, if one exists, toward the null; but it is unlikely that such misclassification would produce a spurious estimate in any one study. It is even more unlikely that it would bias a sufficient number of studies in a uniform direction to account for the consistent aggregate association observed.

Moreover, throughout this chapter, various methodologic limitations of individual studies have been discussed, such as small sample size, short follow-up period, lack of data on confounding variables, use of death certificates to identify the lung cancer cases, and lack of latency analysis. The studies with small sample sizes (i.e., not enough power) and short follow-up periods (i.e., not enough latent period) have been difficult to interpret due to these limitations.

The most important confounding variable is smoking which is a strong risk factor for lung cancer. All the studies considered for this report are either cohort retrospective mortality or case-control studies where history of exposures in the past is elicited. Smoking history is usually difficult to obtain in such instances. The smoking histories obtained from surrogates (next of kin, either spouse or offspring) were found to be accurate by Lerchen and Samet (1986) and McLaughlin et al. (1987). Lerchen and Samet did not detect any consistent bias in the report of cigarette consumption. In contrast, overreporting of cigarette smoking by surrogates was observed by Rogot and Reid (1975), Kolonel et al. (1977), and Humble et al. (1984). Kolonel et al. found that the age at which an individual started smoking was reported within 4 years of actual age 84% of the time. These studies indicate that surrogates were able to provide fairly credible information on the smoking habits of the study subjects. If the surrogates of the cases were more likely to overreport cigarette smoking compared with the controls, then it might be harder to find an effect of DE because most of the increase in lung cancer would be attributed to smoking rather than to exposure to DE.

Some studies do not adjust for tobacco smoke exposure. Even though smoking is a strong risk for lung cancer, it is only a confounder if there are differential smoking habits among individuals exposed to DE versus individuals who are not exposed. Most of the occupational cohorts include workers from the same socioeconomic background or used an internal comparison group; hence, it is unlikely that confounding by cigarette smoking is substantial in these studies. Some studies have adjusted for socioeconomic status and some studies have compared the cigarette smoking habits by conducting rural and urban general population surveys. Besides, in studies with long enough latency, adjustment for cigarette smoking did not alter substantially the observed higher risk.

Another methodologic concern in these studies is use of death certificates to determine cause of death. Death certificates were used by all of the cohort mortality studies and some of the case-control studies of lung cancer to determine cause of death. Use of death certificates could lead to misclassification bias because of overdiagnosis. Studies of autopsies done between 1960 and 1971 demonstrated that lung cancer was overdiagnosed when compared with hospital discharge, with no incidental cases found at autopsy (Rosenblatt et al., 1971). Schottenfeld et al. (1982) also found an overdiagnosis of lung cancer among autopsies conducted in 1977 and 1978. On the other hand, Percy et al. (1981) noted 95% concordance when comparing 10,000 lung cancer deaths observed in the Third National Cancer Survey from 1969 to 1971 (more than 90% were confirmed histologically) to death-certificate-coded cause of death. These more recent findings suggest that the diagnosis of lung cancer on death certificates is better than anticipated. In reality, lung cancer is one cause of death that has been found to be generally reliably reported on the death certificate. Thus, the misclassification bias probably is minimal in the studies described in this chapter.

Finally, several investigators have not conducted latency analysis in their studies. The latent period for lung cancer development is from 20 to 30 years or more. Considering the fact that dieselization was not complete till almost 1959 for locomotives and the 1970s for the trucking industry in the United States, most of the cohort studies conducted in the U.S. population do not have a long enough follow-up period to allow for latency of 20 to 30+ years. In addition, the study inclusion criteria for most of the studies are individuals who worked in the industry for at least 6 months /1 year from the beginning of the follow-up period to the end of the follow-up period. Hence, the later the individual enters the cohort, the shorter the follow-up period; thus, the latent period is insufficient for the occurrence of lung cancer in these late entrants. Therefore, the observed slight to moderate increase in risk of lung cancer could be due to insufficient latency. On the other hand, in certain case-control studies the elapsed period between the identification of the lung cancer cases and exposure to DE is long enough to allow for the 30+ years latency needed for the development of lung cancer (Hansen et al., 1998; Brüske-Hohlfeld et al., 1999). These investigators identified lung cancer cases in the early to mid-1990s and found significant excess risks for lung cancer among the individuals exposed to DE. It should be noted that the use of diesel fuel for trucks, buses, and taxis had started in their countries (Denmark and Germany, respectively) in the late 1940s.

7.2.4.5. *Evaluation of Causal Association*

In most situations, epidemiologic data are used to delineate the causality of certain health effects. Several cancers have been causally associated with exposure to agents for which there is no direct biological evidence. Insufficient knowledge about the biological basis for diseases in humans makes it difficult to identify exposure to an agent as causal, particularly for malignant diseases when the exposure was in the distant past. Consequently, epidemiologists and biologists have used the original or modified version of a set of criteria provided by Hill (1965)[3] that define a causal relationship between exposure and the health outcome. A causal interpretation is enhanced for studies that meet these criteria. None of these criteria actually proves causality; actual proof is rarely attainable when dealing with environmental carcinogens. None of these criteria should be considered either necessary (except temporality of exposure) or sufficient in itself. The absence of any one or even several of these criteria does not prevent a causal interpretation. However, if more criteria apply, this provides more credible evidence for causality.

Thus, applying the Hill criteria (1965) of causal inference, as modified by Rothman (1986), to the studies reviewed here resulted in the following:

- *Strength of association.* This phrase refers to the magnitude of the ratio of incidence or mortality (RRs or ORs). Several studies found statistically significant RRs and ORs that ranged from 1.2 to 2.6 (Howe et al., 1983; Rushton

[3]Hill in his address to the Royal Society of Medicine in 1965 on "The environment and disease: association or causation" explored several aspects of association between exposure and occurrence of an event before deciding that the most likely interpretation of it is causation. He provided nine different aspects of association that he characterized as his viewpoints before interpreting the association being causal. The epidemiologic community universally adopted these (aspects/viewpoints) later as criteria for causality/causal association.

et al., 1983; Wong et al., 1985; Gustavsson et al., 1990; Emmlin et al., 1993; Hansen, 1993; Hansen et al., 1998) and, after adjustment for smoking and/or asbestos, RRs and ORs remained statistically significant and in the same range in certain studies (Dambar and Larson 1987; Garshick et al., 1987, 1988; Benhamou et al., 1988; Boffetta and Stellman, 1988; Hays et al., 1989; Steenland et al., 1990; Swanson et al., 1993; Brüsk-Hohlfeld et al., 1999). In addition, two meta-analyses demonstrated that not only did excess in lung cancer remain the same after stratification/adjustment for smoking and occupation, but in several instances the pooled RRs showed modest increases, with little evidence of heterogeneity. Overall, the studies in epidemiologic terms show relatively modest to weak association between DE and occurrence of lung cancer. Even though strong associations are more likely to be causal than modest-to-weak associations, the fact that association is relatively modest or weak does not rule out the causal link.

- *Consistency*. Increased lung cancer risk has been observed in several cohort and case-control studies, conducted in several industries and occupations in which workers were potentially exposed to DE. However, not all the excesses were statistically significant. Statistically significant lung cancer excesses adjusted for smoking were observed in truck drivers (Hayes et al., 1989; Hansen, 1993; Swanson et al., 1993; Brüske-Hohlfeld et al., 1999), professional drivers (Benhamou et al., 1988; Brüske-Hohlfeld et al., 1999), railroad workers (Garshick et al., 1987; Swanson et al., 1993), heavy equipment drivers (Boffetta and Stellman, 1988; Brüske-Hohlfeld et al., 1999), and farm tractor drivers (Swanson et al., 1993; Brüske-Hohlfeld et al., 1999). Furthermore, the two recent meta-analyses by Bhatia et al. (1998) and Lipsett and Campleman (1999) found that even though a substantial heterogeneity existed in their initial pooled estimates, stratification on several factors demonstrated a relationship between exposure to DE and excess lung cancer that remained positive throughout various analyses.

- *Specificity*. This criterion requires that a single cause lead to a single effect. With respect to exposure to DE, excess for lung cancer is the only effect that is found to be consistently elevated and statistically significant in several studies. Quite a few studies have examined DE for other effects such as bladder cancer, leukemia, gastrointestinal cancers, prostate cancer etc. The evidence for these effects is inadequate.

- *Temporality.* The only necessary, but not sufficient, criterion described by Hill for causality inference is that exposure to a causal agent precedes the effect in time. This criterion is clearly satisfied in the studies reviewed here. Temporality can be explored further in addressing the latency issue. A certain period is necessary for development of an effect after exposure to a causal agent has occurred. For instance, in cancer-causing agents a latent period can vary from 5 years (childhood leukemia) to ≥30 years (mesothelioma). Most of the studies reviewed here did not conduct the latency analysis. Some studies had a short follow-up period that did not allow enough time for the latency period (Waller, 1981; Howe et al., 1983; Rushton et al., 1983; Wong et al., 1985, Hansen, 1993) while several studies clearly allowed for an adequate latency period (Garshick et al., 1987; Gustavsson et al., 1990; Steenland et al., 1990; Swanson et al., 1993; Brüske-Hohlfeld et al., 1999). Both type of studies showed mixed results.

- *Biological gradient.* This criterion refers to the dose-response curve. Due to the lack of quantitative data on DE exposure in most studies reviewed here, analyzing the dose-response curve directly was not possible. In very few studies, exposure to DE was addressed specifically. Most investigators have used job titles/categories and duration of employment as surrogates for exposure and thus have presented response in relation to duration of employment. Significant dose-response (using duration of employment as a surrogate) was observed in various studies for railroad workers (Howe et al., 1983; Garshick et al., 1987; Garshick et al., 1988; Swanson et al., 1993; Cal EPA, 1998), truck drivers (Boffetta and Stellman, 1988; Hayes et al., 1989; Steenland et al., 1990; Swanson et al., 1993; Hansen et al., 1998; Brüske-Hohlfeld et al., 1999), transportation/heavy equipment operators (Wong et al., 1985; Gustavsson et al., 1990; Brüske-Hohlfeld et al., 1999), farmers/farm tractor users (Swanson et al., 1993; Brüske-Hohlfeld et al., 1999), and dockworkers (Emmelin et al., 1993).

- *Biological plausibility.* This criterion refers to the biologic plausibility of the hypothesis, an important concern that may be difficult to judge. The hypothesis considered for this review is that occupational exposure to DE is causally associated with the occurrence of lung cancer and is supported by the following:

First, DE has been shown to cause lung and other cancers in animals (Heinrich et al., 1986b; Iwai et al., 1986b; Mauderly et al., 1987; Pott et al., 1990; Mauderly, 1994). Second, it contains highly mutagenic substances such as polycyclic aromatic hydrocarbons as well as nitroaromatic compounds (Claxton, 1983; Ball et al., 1990; Gallagher et al., 1993; Sera et al., 1994; Nielsen et al., 1996a) that are recognized human pulmonary carcinogens (IARC, 1989). Third, DE consists of carbon core particles with surface layers of organics and gases; the tumorigenic activity may reside in one, some, or all of these components. As explained in Chapter 4, there is clear evidence that the mixture of organic constituents, both in particles and vapor phases, have the capacity to interact with DNA and give rise to mutations, chromosomal aberrations, and cell transformations, all well-established steps in the process of carcinogenesis. Further, increased levels of peripheral blood cell DNA adducts associated with occupational exposure to DE have been observed in humans (Nielsen et al., 1996a,b). Thus, the above evidence makes a convincing case that occupational exposures to DE are causally associated with the occurrence of lung cancer is highly plausible biologically.

In conclusion, the epidemiologic studies of exposure to DE and occurrence of lung cancer furnish evidence that is consistent with a causal association. This association observed in several studies is unlikely to be due to chance or bias. Although many studies did not have information on smoking, significant confounding by smoking is unlikely in these studies because the comparison population was from the same socioeconomic class. The strength of association (i.e., RRs/ORs between 1.2 and 2.6) was weak to modest by epidemiologic standards, with dose-response relationships observed in several studies. Last, but not least, there is highly plausible biological evidence that exposure to DE could result in excess risk of lung cancer in humans.

7.3. CARCINOGENICITY OF DIESEL EXHAUST IN LABORATORY ANIMALS

This chapter summarizes studies that assess the carcinogenic potential of DE in laboratory animals. The first portion of this chapter summarizes results of inhalation studies. Experimental protocols for the inhalation studies typically consisted of exposure (usually chronic) to diluted exhaust in whole-body exposure chambers using rats, mice, and hamsters as model species. Some of these studies used both filtered (free of particulate matter) DE and unfiltered (whole) DE to differentiate gaseous-phase effects from effects induced by diesel PM (DPM) and its adsorbed components. Other studies were designed to evaluate the relative importance of the carbon core of the diesel particle versus that of particle-adsorbed compounds.

Finally, a number of exposures were carried out to determine the combined effect of inhaled DE and tumor initiators, tumor promoters, or cocarcinogens.

Particulate matter concentrations in the DE used in these studies ranged from 0.1 to 12 mg DPM /m^3. In this chapter, any mention of statistical significance implies that $p \leq 0.05$ was reported in the reviewed publications. A summary of the animal inhalation carcinogenicity studies and their results is presented in Table 7-3.

Results of lung implantation and intratracheal instillation studies of whole diesel particles, extracted diesel particles, and particle extracts are reported in Section 7.3.3 and in Tables 7-4 and 7-5. Studies destined to assess the carcinogenic effects of DPM as well as solvent extracts of DPM following subcutaneous (s.c.) injection, intraperitoneal (i.p.) injection, or intratracheal (itr.) instillation in rodents are summarized in Section 7.3.5. Individual chemicals present in the gaseous phase or adsorbed to the particle surface were not included in this review because assessments of those of likely concern (i.e., formaldehyde, acetaldehyde, benzene, polycyclic aromatic hydrocarbons [PAHs]) have been published elsewhere (U.S. EPA, 1993).

7.3.1. Inhalation Studies (Whole Diesel Exhaust)

7.3.1.1. *Rat Studies*

The potential carcinogenicity of inhaled DE was first evaluated by Karagianes et al. (1981). Male Wistar rats (40 per group) were exposed to room air or diesel engine exhaust diluted to a DPM concentration of 8.3 (± 2.0) mg/m^3, 6 hr/day, 5 days/week for up to 20 months. The animals were exposed in 3,000 L plexiglass chambers. Airflow was equal to 50 liters per minute. Chamber temperatures were maintained between 25 °C and 26.5 °C. Relative humidity ranged from 45% to 80%. Exposures were carried out during the daytime. The connected to an electric generator and operated at varying loads and speeds to simulate operating conditions in an occupational situation. To control the CO concentration at 50 ppm, the exhaust was diluted 35:1 with clean air. Six rats per group were sacrificed after 4, 8, 16, and 20 months exposure for gross necropsy and histopathological examination.

The only tumor detected was a bronchiolar adenoma in the group exposed over 16 months to DE. No lung tumors were reported in controls. The equivocal response may have been caused by the relatively short exposure durations (20 months) and small numbers of animals examined. In more recent studies, for example, Mauderly et al. (1987), most of the tumors were detected in rats exposed for more than 24 months.

Table 7-3. Summary of animal inhalation carcinogenicity studies

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m^3)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]				Comments
								Adenomas				
Karagianes et al. (1981)	Rat/Wistar	M, 40	Clean air	8.3	None	6 hr/day, 5 days/ week, for up to 20 mo	NA	0/6 (0)				
		M, 40	Whole exhaust		None			1/6 (16.6)				
								Bronchoalveolar carcinoma				
Kaplan et al. (1983) White et al. (1983)	Rat/F344	M, 30	Clean air	0	None	20 hr/day, 7 days/ week, for up to 15 mo	8 mo	0/30 (0)				
		M, 30	Whole exhaust	0.25	None		8 mo	1/30 (3.3)				
		M, 30	Whole exhaust	0.75	None		8 mo	3/30 (10.0)				
		M, 30	Whole exhaust	1.5	None		8 mo	1/30 (3.3)				
								Adenomas	Carcinomas	Squamous cell tumors	All tumors	
Heinrich et al. (1986a,b) Mohr et al. (1986)	Rat/ Wistar	F, 96	Clean air	4	None	19 hr/day, 5 days/ week for up to 35 mo	NA	0/96 (0)	0/96 (0)	0/96 (0)	0/96 (0)	
		F, 92	Filtered exhaust		None			0/92 (0)	0/92 (0)	0/92 (0)	0/92 (0)	
		F, 95	Whole exhaust		None			8/95 (8.4)	0/95 (0)	9/95 (9.4)	17/95 (17.8)[c]	
								Adenomas	Adenocarcinoma and adenosquamous carcinoma	Large cell and squamous cell carcinomas	All tumors	
Iwai et al. (1986a,b)	Rat/F344	F, 24	Clean air	4.9	None	8 hr/day, 7 days/ week, for 24 mo	NA	1/22 (4.5)	0/22 (0)	0/22 (0)	1/22 (4.5)[f]	
		F, 24	Filtered exhaust		None			0/16 (0)	0/16 (0)	0/16 (0)	0/16 (0)	
		F, 24	Whole exhaust		None			3/19 (0)	3/19 (15.8)	2/19 (10.5)	8/19 (42.1)[c,g]	

Table 7-3. Summary of animal inhalation carcinogenicity studies (continued)

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m^3)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]				Comments
									Adenoma	Carcinoma		
Takemoto et al. (1986)	Rat/F344	F, 12	Clean air	0	None	4 hr/day,	NA		0/12 (0)	0/12 (0)		
		F, 21	Clean air	0	DIPN[h]	4 days/			10/21 (47.6)	4/21 (19)		
		F, 15	Whole	2-4	None	week,			0/15 (0)	0/15 (0)		
		F, 18	exhaust	2-4	DIPN[h]	18-24 mo			12/18 (66.7)	7/18 (38.9)		
			Whole									
			exhaust									
								Adenomas	Adenocarcinoma + squamous cell carcinoma	Squamous cysts	All tumors	
Mauderly et al. (1987)	Rat/F344	M + F,	Clean air	0	None	7 hr/day,	NA	(0)	(0.9)	(0)	(0.9)	
		230[b]	Whole	0.35	None	5 days/		(0)	(1.3)	(0)	(1.3)	
		M + F, 223	exhaust	3.5	None	week up to		(2.3)	(0.5)	(0.9)	(3.6)[c]	
		M + F, 221	Whole	7.1	None	30 mo		(0.4)	(7.5)	(4.9)	(12.8)[c]	
		M + F, 227	exhaust									
			Whole									
			exhaust									
								Adenomas	Adenosquamous carcinomas	Squamous cell	All tumors	
Ishinishi et al. (1988a)	Rat/F344	M + F, 123	Clean air	0	None	16 hr/day,	NA	0/123 (0)	1/123 (0.8)	carcinomas	1/123 (0.8)	
		M + F, 123	Whole	0.5	None	6 days/		0/123 (0)	0/123 (0)	0/123 (0)	1/123 (0.8)	
		M + F, 125	exhaust	1.0	None	week,		0/125 (0)	0/125 (0)	1/123 (0.8)	0/125 (0)	
Heavy-duty		M + F, 123	Whole	1.8	None	for up to		0/123 (0)	4/123 (3.3)	0/125 (0)	4/123 (3.3)	
engine		M + F, 124	exhaust	3.7	None	30 mo		0/124 (0)	6/124 (4.8)	0/123 (0)	8/124	
			Whole							2/124 (1.6)	(6.5)[c]	
			exhaust									
			Whole									
			exhaust									

Table 7-3. Summary of animal inhalation carcinogenicity studies (continued)

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m^3)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]			Comments
								Adenomas	Carcinomas	All tumors	
Ishinishi et	Rat/F344	NS, 5	Whole	0.1	None	16 hr/day,	6 mo	0/5 (0)	0/5 (0)	0/5 (0)	
al.		NS, 8	exhaust	0.1	None	6 days/	12 mo	0/8 (0)	0/8 (0)	0/8 (0)	
(1988a)		NS, 11	Whole	0.1	None	week,	18 mo	0/11 (0)	0/11 (0)	0/11 (0)	
		NS, 5	exhaust	1.1	None	for 12 mo	6 mo	0/5 (0)	0/5 (0)	0/5 (0)	
Light duty		NS, 9	Whole	1.1	None		12 mo	0/9 (0)	0/9 (0)	0/9 (0)	
		NS, 11	exhaust	1.1	None		18 mo	0/11 (0)	0/11 (0)	0/11 (0)	
			Whole								
			exhaust								
			Whole								
			exhaust								
			Whole								
			exhaust								
Heavy duty		NS, 5	Whole	0.5	None	16 hr/day,	6 mo	0/5 (0)	0/5 (0)	0/5 (0)	
		NS, 9	exhaust	0.5	None	6 days/	12 mo	0/9 (0)	0/9 (0)	0/9 (0)	
		NS 11	Whole	0.5	None	week,	18 mo	0/11 (0)	0/11 (0)	0/11 (0)	
		NS, 5	exhaust	1.8	None	for 12 mo	6 mo	0/5 (0)	0/5 (0)	0/11 (0)	
		NS, 6	Whole	1.8	None		12 mo	0/6 (0)	0/6 (0)	0/6 (0)	
		NS, 13	exhaust	1.8	None		18 mo	0/13 (0)	1/13 (0)	1/13 (0)	
			Whole								
			exhaust								
			Whole								
			exhaust								
			Whole								
			exhaust								

Table 7-3. Summary of animal inhalation carcinogenicity studies (continued)

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m³)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]		Comments
								Primary lung tumors		
Brightwell et al. (1989)	Rat/344	M + F, 260	Clean air	0	None	16 hr/day, 5 days/ week, for 24 mo	NA	3/260 (1.2)		Tumor incidence for all rats dying or sacrificed
		M + F, 144	Filtered exhaust (medium exposure)	0	None			0/144 (0)		
		M + F, 143	Filtered exhaust (high exposure)	0	None			0/143 (0)		
		M + F, 143	Whole exhaust	0.7	None			1/143 (0.7)		♀ 24/25 (96%) after 24 mo
		M + F, 144	Whole exhaust	2.2	None			14/144 (9.7)[c]		♂ 12/27 (44%) after 24 mo
		M + F, 143	Whole exhaust	6.6	None			55/143 (38.5)[c]		
								Squamous cell carcinoma	All lung tumors	
Henrich et al. (1989a)	Rat/Wistar	F, NS	Clean air	0	DPN[d]	19 hr/day, 5 days/ week for 24 to 30 mo	NA	(4.4)	(84.8)	
		F, NS	Whole exhaust	4.2	DPN[d]			(46.8)[c]	(83.0)	
		F, NS	Filtered exhaust	0	DPN[d]			(4.4)	(67.4)	
		F, NS	Clean air	0	DPN[e]			(16.7)	(93.8)	
		F, NS	Whole exhaust	4.2	DPN[e]			(31.3)[c]	(89.6)	
		F, NS	Filtered exhaust	0	DPN[e]			(14.6)	(89.6)	
Lewis et al. (1989)	Rat/F344	M + F, 288[n]	Clean air		None	7 hr/day, 5 days/ week, 24 mo	NA	No tumors	0/192 (0)	
			Whole exhaust	2	None				0/192 (0)	

Table 7-3. Summary of animal inhalation carcinogenicity studies (continued)

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m^3)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]				Comments
								Adeno-squamous carcinomas	Squamous cell carcinomas	All tumors		
Takaki et al.	Rat/F344	M + F, 123	Clean air	0	None	16 hr/day,	NA	1/23 (0.8)	2/123 (1.6)	1/23 (0.8)	4/123 (3.3)	
(1989)		M + F, 123	Whole	0.1	None	6 days/		1/23 (0.8)	1/23 (0.8)	1/23 (0.8)	3/123 (2.4)	
Light-duty		M + F, 125	exhaust	0.4	None	week, for		1/25 (0.8)	0/125 (0)	0/125 (0)	1/125 (0.8)	
engine		M + F, 123	Whole	1.1	None	up to		0/23 (0)	5/123 (4.1)	0/123 (0)	5/123 (4.1)	
		M + F, 124	exhaust	2.3	None	30 mo		1/24 (8.1)	2/124 (1.6)	0/124 (0)	3/124 (2.4)	
			Whole									
			exhaust									
			Whole									
			exhaust									
								Adenomas	Adenocarcinomas	Squamous cell carcinomas	Benign squamous cell tumors	
Heinrich et	Rat/Wistar	F, 220	Clean air	0	None	18 hr/day,	6 mo	0/217 (0)	1/217 (<1)	0/217 (0)	0/217 (0)	
al.		F, 200	Whole	0.8	None	5 days/		0/198 (0)	0/198 (0)	0/198 (0)	0/198 (0)	
(1995)		F, 200	exhaust	2.5	None	week,		2/200 (1)	1/200 (<1)	0/200 (0)	7/200 (3.5)	
		F, 100	Whole	7.0	None	for up to		4/100 (4)	4/100 (4)	2/100 (2)	14/100 (14)	Tumor
		F, 100	exhaust	11.6	None	24 mo		13/100	13/100 (13)	4/100 (4)	20/100 (20)	incidences
		F, 100	Whole	10.0	None			(13)	13/100 (13)	3/100 (3)	20/100 (20)	after 30 mo
			exhaust					4/100 (4)				
			Carbon black									
			TiO_2									
								Adenomas	Adenocarcinomas	Squamous cell carcinoma	Adeno-squamous carcinoma	Other neoplasms
Nikula et al.	Rat/F344	M + F,	Clean air	0	None	16 hr/day,	6 weeks	1/214 (<1)	1/214 (<1)	1/214 (<1)	0/214 (0)	0/214 (0)
(1995)		214[b]	Whole	2.5	None	5 days/		7/210 (3)	4/210 (2)	3/210 (1)	0/210 (0)	0/210 (0)
		M + F, 210	exhaust	6.5	None	week for		23/212	22/212 (10)	3/212 (1)	1/212 (<1)	0/212 (0)
		M + F, 212	Whole	2.5	None	up to		(11)	7/213 (3)	0/213 (0)	0/213 (0)	1/213 (<1)
		M + F, 213	exhaust	6.5	None	24 mo		3/213 (1)	21/211 (10)	3/211 (1)	2/211 (<1)	0/211 (0)
		M + F, 211	Carbon black					13/211 (6)				
			Carbon black									

Table 7-3. Summary of animal inhalation carcinogenicity studies (continued)

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m^3)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]	Comments
Iwai et al. (1997)	F/344	121, F	Clean air	0	None	NA	NA	5/121(4%) type not stated	Cumulative exposure dose ranged from 154-274 mg/m^3
		108, F	Filtered air	0	None	48-56 hr/day	6 mo	2/108(4%) type not stated	
		153, F	Whole exhaust	3.2-9.4	None	48-56 hr/day	6 mo	53/153(35%) 61.3% adenoma, 25.8% adenocarcinoma, 2.2% benign squamous cell tumor, 7.5% squamous cell carcinoma, 3.2% adenosquamous carcinoma	
Orthoefer et al. (1981) (Pepelko and Peirano, 1983)	Mouse/ Strong A	M, 25	Clean air	0	None	20 hr/day, 7 days/ week, for 7 weeks		3/22 (13.6)	0.13 tumors/ mouse
			Whole exhaust	6.4	None		26 weeks	7/19 (36.8)	0.63 tumors/ mouse
			Whole exhaust	6.4	UV irradiated		26 weeks	6/22 (27.3)	0.27 tumors/ mouse

Table 7-3. Summary of animal inhalation carcinogenicity studies (continued)

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m^3)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]	Comments
								Lung tumors	
	Mouse/ Jackson A	M + F, 40	Clean air	0	None	20 hr/day, 7 days/ week,	8 weeks	16/36 (44.4)	0.5 tumors/ mouse
		M + F, 40	Whole exhaust	6.4	None	for 8 weeks	8 weeks	11/34 (32.3)	0.4 tumors/ mouse
	Mouse/ Jackson A	F, 60	Clean air	0	None			4/58 (6.9)	0.09 tumors/ mouse
		F, 60	Clean air	0	Urethan[l]	20 hr/day, 7 days/ week, for approx.		9/52 (17.3)	0.25 tumors/ mouse
		F, 60	Whole exhaust	6.4	None	7 mo.		14/56 (25.0)	0.32 tumors/ mouse
		F, 60		6.4	Urethan[k]			22/59 (37.3)	0.39 tumors/ mouse
		M, 429	Whole exhaust	0	None			73/403 (18.0)	0.23 tumors/ mouse
		M, 430	Clean air	6.4	None			66/368 (17.9)	0.20 tumors/ mouse
			Whole exhaust						
Kaplan et al. (1982)	Mouse A/J	M, 458 M, 18 M, 485	Clean air Clean air Whole exhaust	1.5	None Urethan[k] None	20 hr/day, 7 days/ week, for 3 mo	6 mo	Pulmonary adenomas 144/458 (31.4) 18/18 (100) 165/485 (34.2)	
								Pulmonary adenoma	
Kaplan et al. (1983) White et al. (1983)	Mouse/ A/J	M, 388 M, 388 M, 399 M, 396	Clean air Whole exhaust Whole exhaust Whole exhaust	0 0.25 0.75 1.5	None None None None	20 hr/day, 7 days/ week, for up to 8 mo	NA	130/388 (33.5) 131/388 (33.8) 109/399 (27.3) 99/396 (25.0)	

Table 7-3. Summary of animal inhalation carcinogenicity studies (continued)

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m³)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]			Comments
								Adenomas	Carcinomas	All tumors	
Pepelko and Peirano (1983)	Mouse/ Sencar	M + F, 260	Clean air	121212	None	Continuous for 15 mo	NA	(5.1)	(0.5)	(5.6)	
			Clean air		BHT[l]			(12.2)	(1.7)	(2.8)	
			Clean air		Urethan[k]			(8.1)	(0.9)	(9.0)	
			Whole exhaust		None			(10.2)[c]	(1.0)	(11.2)[c]	
			Whole exhaust		BHT[l]			(5.4)	(2.7)	(8.1)	
			Whole exhaust		Urethan[l]			(8.7)	(2.6)	(11.2)	

Table 7-3. Summary of animal inhalation carcinogenicity studies (continued)

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m^3)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]				Comments
								All tumors				
Pepelko and Peirano (1983)	Mouse/ Strain A	M + F, 90	Clean air	1212012	None		NA	21/87 (24)				0.29 tumors/ mouse
			Clean air		Exposure (darkness)			59/237 (24.9)				0.27 tumors/ mouse
			Whole exhaust		Exposure (darkness)			10/80 (12.5)				0.14
								22/250 (0.10)				0.10
			Whole exhaust		Urethan[m]			66/75 (88)				2.80
					Urethan[m]			42/75 (0.95)				0.95
			Clean air									
			Whole exhaust									
								Adenomas	Adenocarcinoma	Squamous cell tumors	All tumors	
Heinrich et al. (1986a,b)	Mouse/ NMRI	M + F, 84	Clean air	4	None	19 hr/day,	NA	9/84 (11)	2/84 (2)	—	11/84 (13)	
		M + F, 93	Filtered exhaust		None	5 days/ week		11/93 (12)	18/93 (19)[c]	—	29/93 (31)[c]	
		M + F, 76	Whole exhaust		None	for up to 30 mo		11/76 (15)	13/76 (17)[c]	—	24/76 (32)[c]	
Takemoto et al. (1986)	Mouse/ IRC	M + F, 45	Clean air	0	None	4 hr/day,	NA					
		M + F, 69	Whole exhaust	2-4	None	4 days/ week, for 19-28 mo						
									Adenoma	Adenocarcinoma		
	Mouse/ C57BL	M + F, 12	Clean air	0	None	4 hr/day,	NA		3/45 (6.7)	1/45 (2.2)		
		M + F, 38	Whole exhaust	2-4	None	4 days/ week for 19-28 mo			6/69 (8.7)	3/69 (4.3)		

Table 7-3. Summary of animal inhalation carcinogenicity studies (continued)

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m^3)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]					Comments
Heinrich et al. (1995)	Mouse/ C57BL/6N	F, 120	Clean air	4.5	None	18 hr/day, 5 days/ week, for up to 21 mo	6 mo		1/12 (8.3)	0/12 (0)			5.1% tumor rate
		F, 120	Whole exhaust		None				8/38 (21.1)	3/38 (7.9)			8.5% tumor rate
		F, 120	Particle-free exhaust		None								3.5% tumor rate
									Adenomas	Adenocarcinomas			
	Mouse/ NMRI	F, 120	Clean air	0	None	18 hr/day, 5 days/ week for up to 13.5 mo	9.5 mo		(25)	(15.4)			
		F, 120	Whole exhaust	4.5	None				(21.8)	(15.4)			
			Carbon black	11.6	None				(11.3)	(10)			
			TiO_2	10	None				(11.3)	(2.5)			
	Mouse/ NMRI	F, 120	Clean air	4.5	None	18 hr/day, 5 days/ week, 23 mo	None		(25)	(8.8)			
		F, 120	Whole exhaust		None				(18.3)	(5.0)			
		F, 120	Particle-free exhaust		None				(31.7)	(15)			
								Multiple adenomas	Multiple carcinomas	Adenomas/ carcinoma	Alveolar/ bronchiolar adenoma	Alveolar/ bronchiolar carcinoma	
Mauderly et al. (1996)	Mouse/ CD-1	M + F, 157[b]	Clean air	0	None	7 hr/day, 5 days/week, for up to 24 mo	None	1/157 (0.6)	2/157 (1.3)	1/157 (0.6)	10/157 (6.4)	7/157 (4.5)	
		M + F, 171	Whole exhaust	0.35	None			2/171 (1.2)	1/171 (0.6)	1/171 (0.6)	16/171 (9.4)	5/171 (2.9)	
		M + F, 155	Whole exhaust	3.5	None			0/155 (0)	1/155 (0.6)	0/155 (0)	8/155 (5.2)	6/155 (3.9)	
		M + F, 186	Whole exhaust	7.1	None			0/186 (0)	0/186 (0)	0/186 (0)	10/186 (5.4)	4/186 (2.2)	
								Adenomas	Adenocarcinoma	Squamous cell tumors	All tumors		
Heinrich et al. (1986a,b)	Hamster/ Syrian	M + F, 96	Clean air		None	19 hr/day 5 days/week for up to 30 mo		0/96(0)	0/96(0)	0/96	0/96(0)		
		M + F, 96	Filtered exhaust		None			0/96(0)	0/96(0)	0/96	0/96(0)		
		M + F, 96	Whole exhaust	4	None		NA	0/96(0)	0/96(0)	0/96	0/96(0)		

Table 7-3. Summary of animal inhalation carcinogenicity studies (continued)

Study	Species/ strain	Sex/total number	Exposure atmosphere	Particle concentration (mg/m³)	Other treatment	Exposure protocol	Post-exposure observation	Tumor type and incidence (%)[a]	Comments
								Primary lung tumors	
Brightwell et al. (1989)	Hamster/ Syrian Golden	M + F,	Clean air	0	None	16 hr/day, 5 days/ week, for 24 mo	NA	7/202 (3.5)	Respiratory tract tumors not related to exhaust exposure for any of the groups
		M + F, 202	Clean air	0	DEN[j]			4/104 (3.8)	
		M + F, 104	Filtered exhaust (medium dose)	0	DEN[j]			9/104 (8.7)	
		M + F, 104	Filtered exhaust (high dose)	0	DEN[j]			2/101 (2.0)	
		M + F, 101	Whole	0.7	DEN[j]			6/102 (5.9)	
		M + F, 102	exhaust	2.2	DEN[j]			4/101 (3.9)	
		M + F, 101	Whole	6.6	DEN[j]			1/204 (0.5)	
		M + F, 204	exhaust Whole exhaust	0	None			0/203 (0)	
		M + F, 203	Filtered exhaust (high dose) Whole exhaust	6.6	None				

[a]Table values indicate number with tumors/number examined (% animals with tumors).
[b]Number of animals examined for tumors.
[c]Significantly different from clean air controls.
[d]Dipentylnitrosamine; 6.25 mg/kg/week s.c. during first 25 weeks of exposure.
[e]Dipentylnitrasamine; 12.5 mg/kg/week s.c. during first 25 weeks of exposure.
[f]Splenic lymphomas also detected in controls (8.3%), filtered exhaust group (37.5%) and whole exhaust group (25%).
[g]5.3% incidence of large cell carcinomas.
[h]1 g/kg, i.p. 1/week for 3 weeks starting 1 mo into exposure.
[i]Includes adenomas, squamous cell carcinomas, adenocarcinomas, adenosquamous cell carcinoma, and mesotheliomas.
[j]4.5 mg/diethylnitrosamine (DEN)/kg, s.c., 3 days prior to start of inhalation exposure.
[k]Single i.p. dose 1 mg/kg at start of exposure.
[l]Butylated hydroxytoluene 300 mg/kg, i.p. for week 1, 83 mg/kg for week 2, and 150 mg/kg for weeks 3 to 52.
[m]12 mg/m³from 12 weeks of age to termination of exposure. Prior exposure (in utero) and of parents was 6 mg/m³.
[n]120-121 males and 71-72 females examined histologically.
[o]Not all animals were exposed for full term, at least 10 males were killed at 3, 6, and 12 mo of exposure.
NS = Not specified.

NA = Not applicable.

Table 7-4. Tumor incidences in rats following intratracheal instillation of DE particles (DPM), extracted DPM, carbon black (CB), benzo[*a*]pyrene (B[*a*]P), or particles plus B[*a*]P

Experimental group	Number of animals	Total dose	Animals with tumors (percent)	Statistical significance[a]
Control	47	4.5 mL	0 (0)	-
DPM (original)	48	15 mg	8 (17)	< 0.01
DPM (extracted)	48	30 mg	10 (21)	< 0.001
DPM (extracted)	48	15 mg	2 (4)	NS
CB (printex)	48	15 mg	10 (21)	< 0.001
CB (lampblack)	48	14 mg	4 (8)	NS
B[*a*]P	47	30 mg	43 (90)	< 0.001
B[*a*]P	48	15 mg	12 (25)	< 0.001
DEP + B[*a*]P	48	15 mg + 170 μg B[*a*]P	4 (8)	NS
CB (printex) + B[*a*]P	48	15 mg + 443 μg B[*a*]P	13 (27)	< 0.001

Table 7-5. Tumorigenic effects of dermal application of acetone extracts of DPM

Number of animals	Strain/sex	Sample material	Time to first tumor (mo)	Survivors at time of first tumor	Total tumors	Duration of experiment (mo)
52	C57BL/40 F C57BL/12 M	Extract of DPM obtained during warmup	13	33	2	22
50	Strain A/M	Extract of DPM obtained during full load	15	8	4	23
25	Strain A/F	Extract of DPM obtained during full load	13	20	17	17

Source: Kotin et al., 1955.

General Motors Research Laboratories sponsored chronic inhalation studies at the Southwest Research Institute using male Fischer 344 rats, 30 per group, exposed to DPM concentrations of 0.25, 0.75, or 1.5 mg/m^3 (Kaplan et al., 1983; White et al., 1983). The animals were exposed in 12.6 m^3 exposure chambers. Airflow was adjusted to provide 13 changes per hour. Temperature was maintained at 22 ± 2 °C. The exposure protocol was 20 hr/day, 7 days/week for 9 to 15 months. Exposures were halted during normal working hours for servicing. Some animals were sacrificed following completion of exposure, while others were returned to clean air atmospheres for an additional 8 months. Control animals received clean air. Exhaust was generated by 5.7-L Oldsmobile engines (four different engines used throughout the experiment) operated at a steady speed and load simulating a 40-mph driving speed of a full-size passenger car.

Although five instances of bronchoalveolar carcinoma were observed in 90 rats exposed to DE for 15 months and held an additional 8 months in clean air, compared with none among controls, statistical significance was not achieved in any of the exposure groups. These included one tumor in the 0.25 mg/m^3 group, three in the 0.75 mg/m^3 group, and one in the 1.5 mg/m^3 group. Rats kept in clean-air chambers for 23 months did not exhibit any carcinomas. No tumors were observed in any of the 180 rats exposed to DE for 9 or 15 months without a recovery period, or in the respective controls for these groups. Equivocal results may again have been due to less-than-lifetime duration of the study as well as insufficient exposure concentrations. Although the increases in tumor incidences in the groups exposed for 15 months and held an additional 8 months in clean air were not statistically significant, relative to controls, they were slightly greater than the historic background incidence of 3.7% for this specific lesion in this strain of rat (Ward, 1983). The first definitive studies linking inhaled DE to induction of lung cancer in rats were reported by researchers in Germany, Switzerland, Japan, and the United States in the mid-to-late 1980s. In a study conducted at the Fraunhofer Institute exhaust-generating system and exposure atmosphere characteristics are presented in Appendix A. The type of engine used (3-cylinder, 43 bhp diesel) is normally used in mining situations and was of Toxicology and Aerosol Research, female Wistar rats were exposed for 19 hr/day, 5 days/week to both filtered and unfiltered (total) DE at an average particulate matter concentration of 4.24 mg/m^3. Animals were exposed for a maximum of 2.5 years. The exposure system as described by Heinrich et al. (1986a) used a 40 kilowatt 1.6-L diesel engine operated continuously under the U.S. 72 FTP driving cycle. The engines used European Reference Fuel with a sulfur content of 0.36%. Filtered exhaust was obtained by passing engine exhaust through a Luwa FP-65 HT 610 particle filter heated to 80 °C and a secondary series of filters (Luwa FP-85, Luwa NS-30, and Drager CH 63302) at room temperature. The filtered and unfiltered exhausts were diluted 1:17 with filtered air and passed through respective 12 m^3 exposure chambers. Mass median aerodynamic diameter of DPM was 0.35 ± 0.10 μm (mean ± SD). The gas-phase components of the DE atmospheres are presented in Appendix A.

The effects of exposure to either filtered or unfiltered exhaust were described by Heinrich et al. (1986b) and Stöber (1986). Exposure to unfiltered exhaust resulted in 8 bronchoalveolar adenomas and 9 squamous cell tumors in 15 of 95 female Wistar rats examined, for a 15.8% tumor incidence. Although statistical analysis was not provided, the increase appears to be highly significant. In addition to the bronchioalveolar adenomas and squamous cell tumors, there was a high incidence of bronchioalveolar hyperplasia (99%) and metaplasia of the bronchioalveolar epithelium (65%). No tumors were reported among rats exposed to filtered exhaust (n = 92) or clean air (n = 96).

Mohr et al. (1986) provided a more detailed description of the lung lesions and tumors identified by Heinrich et al. (1986a,b) and Stöber (1986). Substantial alveolar deposition of carbonaceous particles was noted for rats exposed to unfiltered DE. Squamous metaplasia was observed in 65.3% of the rats breathing unfiltered DE, but not in the control rats. Of nine squamous cell tumors, one was characterized as a Grade I carcinoma (borderline atypia, few to moderate mitoses, and slight evidence of stromal invasion), and the remaining eight were classified as benign keratinizing cystic tumors.

Iwai et al. (1986b) examined the long-term effects of DE inhalation on female F344 rats. The exhaust was generated by a 2.4-L displacement truck engine. The exhaust was diluted 10:1 with clean air at 20 °C to 25 °C and 50% relative humidity. The engines were operated at 1,000 rpm with an 80% engine load. These operating conditions were found to produce exhaust with the highest particle concentration and lowest NO_2 and SO_2 content. For those chambers using filtered exhaust, proximally installed high-efficiency particulate air (HEPA) filters were used. Three groups of 24 rats each were exposed to unfiltered DE, filtered DE, or filtered room air for 8 hr/day, 7 days/week for 24 months. Particle concentration was 4.9 mg/m^3 for unfiltered exhaust. Concentrations of gas-phase exhaust components were 30.9 ppm NO_x, 1.8 ppm NO_2, 13.1 ppm SO_2, and 7.0 ppm CO.

No lung tumors were found in the 2-year control (filtered room air) rats, although one adenoma was noted in a 30-months control rat, providing a spontaneous tumor incidence of 4.5%. No lung tumors were observed in rats exposed to filtered DE. Nineteen of the 24 exposed to unfiltered exhaust survived for 2 years. Of these, 14 were randomly selected for sacrifice at this time. Four of the rats developed lung tumors; two of these were malignant. Five rats of this 2-year exposure group were subsequently placed in clean room air for 3 to 6 months and four eventually (time not specified) exhibited lung tumors (three malignancies). Thus, the lung tumor incidence for total tumors was 42.1% (8/19) and 26.3% (5/19) for malignant tumors in rats exposed to whole DE. The tumor types identified were adenoma (3/19), adenocarcinoma

(1/19), adenosquamous carcinoma (2/19), squamous carcinoma (1/19), and large-cell carcinoma (1/19). The lung tumor incidence in rats exposed to whole DE was significantly greater than that of controls ($p \leq 0.01$). Tumor data are summarized in Table 7-3. Malignant splenic lymphomas were detected in 37.5% of the rats in the filtered exhaust group and in 25.0% of the rats in the unfiltered exhaust group; these values were significantly ($p \leq 0.05$) greater than the 8.2% incidence noted in the control rats. The study demonstrates production of lung cancer in rats following 2-year exposure to unfiltered DE. In addition, splenic malignant lymphomas occurred during exposure to both filtered and unfiltered DE. This is the only report to date of tumor induction at an extrarespiratory site by inhaled DE in animals.

A chronic (up to 24 months) inhalation exposure study was conducted by Takemoto et al. (1986), in which female Fischer 344 rats were exposed to DE generated by a 269-cc YANMAR-40CE NSA engine operated at an idle state (1,600 rpm). Exposures were 4 hours/day, 4 days/week. The animals were exposed in a 376-L exposure chamber. Air flow was maintained at 120 L/min. Exhaust was diluted to produce a particle concentration of 2-4 mg/m^3. When not exposed the animals were maintained in an air-conditioned room at a temperature of 24 ± 2°C and a relative humidity of 55 ± 5% with 12 hr of light and darkness. Temperature and humidity in the exposure chambers was not noted. The particle concentration of the DE in the exposure chamber was 2 to 4 mg/m^3. B[a]P and 1-nitropyrene concentrations were 0.85 and 93 μg/g of particles, respectively. No lung tumors were reported in the diesel-exposed animals. It was also noted that the diesel engine employed in this study was originally used as an electrical generator and that its operating characteristics (not specified) were different from those of a diesel-powered automobile. However, the investigators deemed it suitable for assessing the effects of diesel emissions.

Mauderly et al. (1987) provided data affirming the carcinogenicity of automotive diesel engine exhaust in F344/Crl rats following chronic inhalation exposure. Male and female rats were exposed to diesel engine exhaust at nominal DPM concentrations of 0.35 (n = 366), 3.5 (n = 367), or 7.1 (n = 364) mg/m^3 for 7 hr/day, 5 days/week for up to 30 mo. Sham-exposed (n = 365) controls breathed filtered room air. A total of 230, 223, 221, and 227 of these rats (sham-exposed, low-, medium-, and high-exposure groups, respectively) were examined for lung tumors. These numbers include those animals that died or were euthanized during exposure and those that were terminated following 30 months of exposure. The exhaust was generated by 1980 model 5.7-L Oldsmobile V-8 engines operated through continuously repeating U.S. Federal Test Procedure (FTP) urban certification cycles. The engines were equipped with automatic transmissions connected to eddy-current dynamometers and flywheels simulating resistive and inertial loads of a midsize passenger car. The D-2 diesel control fuel (Phillips Chemical Co.) met U.S. EPA certification standards and contained approximately 30% aromatic hydrocarbons and 0.3% sulfur. Following passage through a standard automotive muffler and tailpipe, the exhaust was diluted 10:1 with filtered air in a dilution tunnel and serially diluted to the final concentrations. The primary dilution process was such that particle coagulation was retarded. Mokler et al. (1984) provided a detailed description of the exposure system. No exposure-related changes in body weight or lifespan were noted for any of the exposed animals, nor were there any signs of overt toxicity. Collective lung tumor incidence was greater (z statistic, $p \leq 0.05$) in the high (7.1 mg/m^3) and medium (3.5 mg/m^3) exposure groups (12.8% and 3.6%, respectively) versus the control and low (0.35 mg/m^3) exposure groups (0.9% and 1.3%, respectively). In the high-dose group the incidences of tumor types reported were adenoma (0.4%), adenocarcinomas plus squamous cell carcinomas (7.5%), and squamous cysts (4.9%). In the medium-dose group adenomas were reported in 2.3% of animals, adenocarcinomas plus squamous cell carcinomas in 0.5%, and squamous cysts in 0.9%. In the low-exposure group adenocarcinomas plus squamous cell carcinomas were detected in 1.3% of the rats. Using the same statistical analysis of specific tumor types, adenocarcinoma plus squamous cell carcinoma and squamous cyst incidence was significantly greater in the high-exposure group, and the incidence of adenomas was significantly greater in the medium-exposure group. A significant ($p<0.001$) exposure-response relationship was obtained for tumor incidence relative to exposure concentration and lung burden of DPM. These data are summarized in Table 7-3. A logistic regression model estimating tumor prevalence as a function of time, dose (lung burden of DPM), and sex indicated a sharp increase in tumor prevalence for the high dose level at about 800 days after the commencement of exposure. A less pronounced, but definite, increase in prevalence with time was predicted for the medium-dose level. Significant effects were not detected at the low concentration. DPM (mg per lung) of rats exposed to 0.35, 3.5, or 7.1 mg of DPM/m^3 for 24 months were 0.6, 11.5, and 20.8, respectively, and affirmed the greater-than-predicted accumulation that was the result of decreased particle clearance following high-exposure conditions.

In summary, this study demonstrated the pulmonary carcinogenicity of high concentrations of whole, diluted DE in rats following chronic inhalation exposure. In addition, increasing lung particle burden resulting from this high-level exposure and decreased clearance was demonstrated. A logistic regression model presented by Mauderly et al. (1987) indicated that both lung DPM burden and exposure concentration may be useful for expressing exposure-effect relationships.

A long-term inhalation study (Ishinishi et al., 1988a; Takaki et al., 1989) examined the effects of emissions from a light-duty (LD) and a heavy-duty (HD) diesel engine on male and female Fischer 344/Jcl rats. The LD engines were 1.8-L, 4-cylinder, swirl-chamber-type power plants, and the HD engines were 11-L, 6-cylinder, direct-injection-type power plants. The engines were connected to eddy-current dynamometers and operated at 1,200 rpm (LD engines) and 1,700 rpm (HD engines). Nippon Oil Co. JIS No. 1 or No. 2 diesel fuel was used. The 30-months whole-body exposure protocol (16 h/day, 6 days/week) used DPM concentrations of 0, 0.5, 1, 1.8, or 3.7 mg/m^3 from HD engines and 0, 0.1, 0.4, 1.1, or 2.3 mg/m^3 from LD engines. The animals inhaled the exhaust emissions from 1700 to 0900 h. Sixty-four male rats and 59 to 61 female rats from each exposure group were evaluated for carcinogenicity.

For the experiments using the LD series engines, the highest incidence of hyperplastic lesions plus tumors (72.6%) was seen in the highest exposure (2.3 mg/m^3) group. However, this high value was the result of the 70% incidence of hyperplastic lesions; the incidence of adenomas was only 0.8% and that of carcinomas 1.6%. Hyperplastic lesion incidence was considerably lower for the lower exposure groups (9.7%, 4.8%, 3.3%, and 3.3% for the 1.1, 0.4, and 0.1 mg/m^3 and control groups, respectively). The incidence of adenomas and carcinomas, combining males and females, was not significantly different among exposure groups (2.4%, 4.0%, 0.8%, 2.4%, and 3.3% for the 2.3, 1.1, 0.4, and 0.1 mg/m^3 groups and the controls, respectively).

For the experiments using the HD series engines, the total incidence of hyperplastic lesions, adenomas, and carcinomas was highest (26.6%) in the 3.7 mg/m^3 exposure group. The incidence of adenomas plus carcinomas for males and females combined equaled 6.5%, 3.3%, 0%, 0.8%, and 0.8% at 3.7, 1.8, 1, and 0.4 mg/m^3 and for controls, respectively. A statistically significant difference was reported between the 3.7 mg/m^3 and the control groups for the HD series engines. The carcinomas were identified as adenomas, adenosquamous carcinomas, and squamous cell carcinomas. Although the number of each was not reported, it was noted that the majority were squamous cell carcinomas. A progressive dose-response relationship was not demonstrated. Tumor incidence data for this experiment are presented in Table 7-3.

The Ishinishi et al. (1988a) study also included recovery tests in which rats exposed to whole DE (DPM concentration of 0.1 or 1.1 mg/m^3 for the LD engine and 0.5 or 1.8 mg/m^3 for the HD engine) for 12 months were examined for lung tumors following 6-, 12-, or 18-month recovery periods in clean air. The incidences of neoplastic lesions were low, and pulmonary DPM burden was lower than for animals continuously exposed to whole DE and not provided a recovery period. The only carcinoma observed was in a rat examined 12 months following exposure to exhaust (1.8 mg/m^3) from the HD engine.

Brightwell et al. (1986, 1989) studied the effects of DE on male and female F344 rats. The DE was generated by a 1.5-L Volkswagen engine that was computer-operated according to the U.S. 72 FTP driving cycle. The engine was replaced after 15 mo. The engine emissions were diluted by conditioned air delivered at 800 m^3/h to produce the high-exposure (6.6 mg/m^3) DE atmosphere. Further dilutions of 1:3 and 1:9 produced the medium- (2.2 mg/m^3) and low-

(0.7 mg/m^3) exposure atmospheres. The CO and NO_x concentrations (mean ± SD) were 32 ± 11 ppm and 8 ± 1 ppm in the high-exposure concentration chamber. The inhalation exposures were conducted overnight to provide five 16-h periods per week for 2 years; surviving animals were maintained for an additional 6 mo.

For males and females combined, a 1.2% (3/260), 0.7% (1/144), 9.7% (14/144), and 38.5% (55/143) incidence of primary lung tumors occurred in F344 rats following exposure to clean air or 0.7, 2.2, and 6.6 mg of DPM/m^3, respectively (Table 7-3). DE-induced tumor incidence in rats was dose-related and higher in females than in males (Table 7-3). These data included animals sacrificed at the interim periods (6, 12, 18, and 24 mo); therefore, the tumor incidence does not accurately reflect the effects of long-term exposure to the DE atmospheres. When tumor incidence is expressed relative to the specific intervals, a lung tumor incidence of 96% (24/25), 76% (19/25) of which were malignant, was reported for female rats in the high-dose group exposed for 24 months and held in clean air for the remainder of their lives. For male rats in the same group, the tumor incidence equaled 44% (12/27), of which 37% (10/27) were malignant. It was also noted that many of the animals exhibiting tumors had more than one tumor, often representing multiple histological types. The numbers and types of tumors identified in the rats exposed to DE included adenomas (40), squamous cell carcinomas (35), adenocarcinomas (19), mixed adenoma/adenocarcinomas (9), and mesothelioma (1). It should be noted that exposure during darkness (when increased activity would result in greater respiratory exchange and greater inhaled dose) could account, in part, for the high response reported for the rats.

Lewis et al. (1989) also examined the effects of inhalation exposure of DE and/or coal dust on tumorigenesis on F344 rats. Groups of 216 male and 72 female rats were exposed to clean air, whole DE (2 mg soot/m^3), coal dust (2 mg/m^3 respirable concentration; 5 to 6 mg/m^3 total concentration), or DE plus coal dust (1 mg/m^3 of each respirable concentration; 3.2 mg/m^3 total concentration) for 7 h/day, 5 days/week during daylight hours for up to 24 mo. Groups of 10 or more males were sacrificed at intermediate intervals (3, 6, and 12 mo). The DE was produced by a 7.0-L, 4-cycle, water-cooled Caterpillar Model 3304 engine using No. 2 diesel fuel (<0.5% sulfur by mass). The exhaust was passed through a Wagner water scrubber, which lowered the exhaust temperature and quenched engine backfire. The animals were exposed in 100-cubic-foot chambers. Temperature was controlled at 22 ± 2 °C and relative humidity at 50%±10%. The exhaust was diluted 27-fold with chemically and biologically filtered clean air to achieve the desired particle concentration.

Histological examination was performed on 120 to 121 male and 71 to 72 female rats terminated after 24 months of exposure. The exhaust exposure did not significantly affect the tumor incidence beyond what would be expected for aging F344 rats. There was no postexposure period, which may explain, in part, the lack of significant tumor induction. The particulate matter concentration was also less than the effective dose in several other studies.

In a more recent study reported by Heinrich et al. (1995), female Wistar rats were exposed to whole DE (0.8, 2.5, or 7.0 mg/m^3) 18 h/day, 5 days/week for up to 24 mo, then held in clean air an additional 6 mo. The animals were exposed in either 6 or 12 m^3 exposure chambers. Temperature and relative humidity were maintained at 23-25 °C and 50%-70%, respectively. DE was generated by two 40-kw 1.6-L diesel engines (Volkswagen). One of them was operated according to the U.S. 72 cycle. The other was operated under constant load conditions. The first engine did not supply sufficient exhaust, which was filled by the second engine. Cumulative exposures for the rats in the various treatment groups were 61.7, 21.8, and 7.4 g/m^3 × h for the high, medium, and low whole-exhaust exposures. Significant increases in tumor incidences were observed in the high (22/100; p<0.001) and mid (11/200; p<0.01) exposure groups relative to clean-air controls (Table 7-3). Only one tumor (1/217), an adenocarcinoma, was observed in clean-air controls. Relative to clean-air controls, significantly increased incidences were observed in the high-exposure rats for benign squamous cell tumors (14/100; p<0.001), adenomas (4/100; p<0.01), and adenocarcinomas (5/100; p<0.05). Only the incidence of benign squamous cell tumors (7/200; p<0.01) was significantly increased in the mid-exposure group relative to the clean-air controls.

Particle lung burden and alveolar clearance also were determined in the Heinrich et al. (1995) study. Relative to clean air controls, alveolar clearance was significantly compromised by exposure to mid and high DE. For the high-diesel-exhaust group, 3-mo recovery time in clean air failed to reverse the compromised alveolar clearance.

In a study conducted at the Inhalation Toxicology Research Institute (Nikula et al., 1995) F344 rats (114-115 per sex per group) were exposed 16 hr/day, 5 days/week during daylight hours to DE diluted to achieve particle concentrations of 2.5 or 6.5 mg/m^3 for up to 24 mo. Controls (118 males, 114 females) were exposed to clean air. Surviving rats were maintained an additional 6 weeks in clean air, at which time mortality reached 90%. DE was generated with two 1988 Model LH6 General Motors 6.2-L V-8 engines burning D-2 fuel that met EPA certification standards. Chamber air flow was sufficient to provide about 15 exchanges per hour. Relative humidity was 40% to 70% and temperature ranged from 23 to 25 °C.

Following low and high DE exposure, the lung burdens were 36.7 and 80.7 mg, respectively, for females and 45.1 and 90.1 mg, respectively, for males. The percentages of susceptible rats (males and females combined) with malignant neoplasms were 0.9 (control), 3.3 (low DE), and 12.3 (high DE). The percentages of rats (males and females combined) with malignant or benign neoplasms were 1.4 (control), 6.2 (low DE), and 17.9 (high DE). All primary neoplasms were associated with the parenchyma rather than the conducting airways of the lungs. The first lung neoplasm was observed at 15 mo. Among 212 males and females examined in the high-dose group, adenomas were detected in 23 animals, adenocarcinomas in 22 animals, squamous cell carcinomas in 3 animals, and an adenosquamous carcinoma in 1 animal. For further details see Table 7-3. Analysis of the histopathologic data suggested a progressive process from alveolar epithelial hyperplasia to adenomas and adenocarcinomas.

Iwai et al. (1997) carried out a series of exposures to both filtered and whole exhaust using a light-duty (2,369 mL) diesel engine. The protocol for engine operation was not stated. Groups of female SPF F344 Fischer rats were exposed for 2 years for 8 hr/day, 7 days/week, 8 hr/day, 6 days/week, or 18 hr/day, 3 days/week to either filtered exhaust or exhaust diluted to a particle concentration of 9.4, 3.2, and 5.1 mg/m^3, respectively. Cumulative exposure (mg/m^3 × hrs of exposure) equaled 274.4, 153.6, and 258.1 mg/m^3. The animals were then held for an additional 6 months in clean air. Lung tumors were reported in 5/121 (4%) of controls, 4/108 (4%) of those exposed to filtered exhaust, and 50/153 (35%) among those exposed to whole exhaust. Among rats exposed to whole DE the following number of tumors were detected; 57 adenomas, 24 adenocarcinomas, 2 benign squamous cell tumors, 7 squamous cell carcinomas, and 3 adenosquamous carcinomas. The authors stated that benign squamous cell tumors probably corresponded to squamous cysts in another classification.

7.3.1.2. *Mouse Studies*

A series of inhalation studies using strain A mice was conducted by Orthoefer et al. (1981). Strain A mice are usually given a series of intraperitoneal injections with the test agent; they are then sacrificed at about 9 months and examined for lung tumors. In the present series, inhalation exposure was substituted. DE was provided by one of two Nissan CN6-33 diesel engines having a displacement of 3244 cc and run on a Federal Short Cycle. Flow through the exposure chambers was sufficient to provide 15 air changes per hour. Temperature was maintained at 24 °C and relative humidity at 75%. In the first study, groups of 25 male Strong A strain (A/S) mice were exposed to irradiated DE (to simulate chemical reactions induced by sunlight) or nonirradiated DE (6 mg/m^3) for 20 h/day, 7 days/week. Additional groups of 40 Jackson A strain (S/J) mice (20 of each sex) were exposed similarly to either clean air or DE, then held in clean air until sacrificed at 9 months of age. No tumorigenic effects were detected at 9 months of age. Further studies were conducted in which male A/S mice were exposed 8 hr/day, 7 days/week until sacrifice (approximately 300 at 9 months of age and approximately 100 at 12 months of age). With the exception of those treated with urethan, the number of tumors per mouse did not exceed historical control levels in any of the studies. Exposure to DE, however, significantly inhibited the tumorigenic effects of the 5-mg urethan treatment. Results are listed in Table 7-3.

Kaplan et al. (1982) also reported the effects of diesel exposure in strain A mice. Groups of male strain A/J mice were exposed for 20 h/day, 7 days/week for 90 days and held until 9 months of age. Briefly, the animals were exposed in inhalation chambers to DE generated by a 5.7-L Oldsmobile engine operated continuously at 40 mph at DPM concentrations of 0, 0.25, 0.75, or 1.5 mg/m^3. Controls were exposed to clean air. Temperature was maintained at 22 ± 2 °C and relative humidity at 50% ± 10% within the chambers. Among 458 controls and 485 exposed animals, tumors were detected in 31.4% of those breathing clean air versus 34.2% of those exposed to DE. The mean number of tumors per mouse also failed to show significant differences.

In a follow-up study, strain A mice were exposed to DE for 8 months (Kaplan et al., 1983; White et al., 1983). After exposure to the highest exhaust concentration (1.5 mg/m^3), the percentage of mice with pulmonary adenomas and the mean number of tumors per mouse were significantly less ($p<0.05$) than those for controls (25.0% vs. 33.5% and 0.30 ± 0.02 [S.E.] vs. 0.42 ± 0.03 [S.E.]) (Table 7-3).

Pepelko and Peirano (1983) summarized a series of studies on the health effects of diesel emissions in mice. Exhaust was provided by two Nissan CN 6-33, 6-cylinder, 3.24-L diesel engines coupled to a Chrysler A-272 automatic transmission and Eaton model 758-DG dynamometer. Sixty-day pilot studies were conducted at a 1:14 dilution, providing DPM concentrations of 6 $mg/m^{3.}$ The engines were operated using the Modified California Cycle. These 20-hr/day, 7-days/week pilot studies using rats, cats, guinea pigs, and mice produced decreases in weight gain and food consumption. Therefore, at the beginning of the long-term studies, exposure time was reduced to 8 h/day, 7 days/week at an exhaust DPM concentration of 6 mg/m^3. During the final 12 months of exposure, however, the DPM concentration was increased to 12 mg/m^3. For the chronic studies, the engines were operated using the Federal Short Cycle. Chamber temperature was maintained at 24 °C and relative humidity at 50%. Airflow was sufficient for 15 changes per hour.

Pepelko and Peirano (1983) described a two-generation study using Sencar mice exposed to DE. Male and female parent-generation mice were exposed to DE at a DPM concentration of 6 mg/m^3 prior to (from weaning to sexual maturity) and throughout mating. The dams continued exposure through gestation, birth, and weaning. Groups of offspring (130 males and 130 females) were exposed to either DE or clean air. The exhaust exposure was increased to a DPM concentration of 12 mg/m^3 when the offspring were 12 weeks of age and was maintained until termination of the experiment when the mice were 15 months old.

The incidence of pulmonary adenomas (16.3%) was significantly increased in the mice exposed to DE compared with 6.3% in clean-air controls. The incidence in males and females combined was 10.2% in 205 animals examined compared with 5.1% in 205 clean-air controls. This difference was also significant. The incidence of carcinomas was not affected by exhaust exposure in either sex. These results provided the earliest evidence for cancer induction following inhalation exposure to DE. The increase in the sensitivity of the study, allowing detection of tumors at 15 mo, may have been the result of exposure from conception. It is likely that Sencar mice are sensitive to induction of lung tumors because they are also sensitive to induction of skin tumors. These data are summarized in Table 7-3.

Takemoto et al. (1986) reported the effects of inhaled DE (2 to 4 mg/m^3, 4 h/day, 4 days/week, for up to 28 mo) in ICR and C57BL mice exposed from birth. Details of the exposure conditions are presented in Section 7.3.2.1. All numbers reported are for males and females combined. Four adenomas and 1 adenocarcinoma were detected in 34 DE-exposed ICR mice autopsied at 13 to 18 mo, compared with 3 adenomas among 38 controls. Six adenomas and 3 adenocarcinomas were reported in 22 diesel-exposed ICR mice autopsied at 19 to 28 mo, compared with 3 adenomas and 1 adenocarcinoma in 22 controls. Four adenomas and 2 adenocarcinomas were detected in 79 C57BL mice autopsied at 13 to 18 mo, compared with none in 19 unexposed animals. Among males and females autopsied at 19 to 28 mo, 8 adenomas and 3 adenocarcinomas were detected in 71 exposed animals, compared with 1 adenoma among 32 controls. No significant increases in adenoma or adenocarcinoma were reported for either strain of exposed mice. However, the significance of the increase in the combined incidence of adenomas and carcinomas was not evaluated statistically. A statistical analysis by Pott and Heinrich (1990a) indicated that the difference in combined benign and malignant tumors between whole DE-exposed C57BL/6N mice and corresponding controls was significant at $p<.05$. See Table 7-3 for details of tumor incidence.

Heinrich et al. (1986b) and Stöber (1986), as part of a larger study, also evaluated the effects of DE in mice. Details of the exposure conditions reported by Heinrich et al. (1986a) are given in Section 7.3.1.1 and Appendix A. Following lifetime (19 h/day, 5 days/week, for a maximum of 120 weeks) exposure to DE diluted to achieve a particle concentration of 4.2 mg/m^3, 76 female NMRI mice exhibited a total lung tumor incidence of adenomas and adenocarcinomas combined of 32%. Tumor incidences reported for control mice (n = 84) equaled 11% for adenomas and adenocarcinomas combined. While the incidence of adenomas showed little change, adenocarcinomas increased significantly from 2.4% for controls to 17% for exhaust-exposed mice. In a follow-up study, however, Heinrich et al. (1995) reported a lack of tumorigenic response in either female NMRI or C57BL/6N mice exposed 17 h/day, 5 days/week for 13.5 to 23 months to whole DE diluted to produce a particle concentration of 4.5 mg/m^3. These data are summarized in Table 7-3.

The lack of a carcinogenic response in mice was reported by Mauderly et al. (1996). In this study, groups of 540 to 600 CD-1 male and female mice were exposed to whole DE (7.1, 3.5, or 0.35 mg DPM/m^3) for 7 hr/day, 5 days/week for up to 24 mo. Controls were exposed to filtered air. DE was provided by 5.7-L Oldsmobile V-8 engines operated continuously on the U.S. Federal Test Procedure urban certification cycle. The chambers were maintained at 25 °C-28 °C, relative humidity at 40%-60%, and a flow rate sufficient for 15 air exchanges per hour. Animals were exposed during the light cycle, which ran from 6:00 AM to 6:00 PM. DPM accumulation in the lungs of exposed mice was assessed at 6, 12, and 18 months of exposure and was shown to be progressive; DPM burdens were 0.2 ± 0.02, 3.7 ± 0.16, and 5.6 ± 0.39 mg for the low-, medium-, and high-exposure groups, respectively. The lung burdens in both the medium- and high-exposure groups exceeded that predicted by exposure concentration ratio for the low-exposure group. Contrary to what was observed in rats (Heinrich et al., 1986b; Stöber, 1986; Nikula et al., 1995; Mauderly et al., 1987), an exposure-related increase in primary lung neoplasms was not observed in the CD-1 mice, supporting the contention of a species difference in the pulmonary carcinogenic response to poorly soluble particles. The percentage incidence of mice (males and females combined) with one or more malignant or benign neoplasms was 13.4, 14.6, 9.7, and 7.5 for controls and low-, medium-, and high-exposure groups, respectively.

Although earlier studies provided some evidence for tumorigenic responses in diesel-exposed mice, no increases were reported in the two most recent studies by Mauderly et al. (1996) and Heinrich et al. (1995), which utilized large group sizes and were well designed and conducted. Overall, the results in mice must therefore be considered to be equivocal.

7.3.1.3. *Hamster Studies*

Heinrich et al. (1982) examined the effects of DE exposure on tumor frequency in female Syrian golden hamsters. Groups of 48 to 72 animals were exposed to clean air or whole DE at a mean DPM concentration of 3.9 mg/m^3. Inhalation exposures were conducted 7 to 8 hr/day, 5 days/week for 2 years. The exhaust was produced by a 2.4-L Daimler-Benz engine operated under a constant load and a constant speed of 2,400 rpm. Flow rate was sufficient for about 20 exchanges per hour in the 250-L chambers. No lung tumors were reported in either exposure group.

In a subsequent study, Syrian hamsters were exposed 19 hr/day, 5 days/week for a lifetime to DE diluted to a DPM concentration of 4.24 mg/m^3 (Heinrich et al., 1986b; Stöber, 1986). Details of the exposure conditions are reported in Appendix A. Ninety-six animals per group were exposed to clean air or exhaust. No lung tumors were seen in either the clean-air group or in the DE-exposed group.

In a third study (Heinrich et al., 1989b), hamsters were exposed to exhaust from a Daimler-Benz 2.4-L engine operated at a constant load of about 15 kW and at a uniform speed of 2,000 rpm. The exhaust was diluted to an exhaust-clean air ratio of about 1:13, resulting in a mean particle concentration of 3.75 mg/m^3. Exposures were conducted in chambers maintained at 22 to 24 °C and 40% to 60% relative humidity for up to 18 mo. Surviving hamsters were maintained in clean air for up to an additional 6 mo. The animals were exposed 19 hr/day, 5 days/week beginning at noon each day, under a 12-hr light cycle starting at 7 AM. Forty animals per group were exposed to whole DE or clean air. No lung tumors were detected in either the clean-air or diesel-exposed hamsters.

Brightwell et al. (1986, 1989) studied the effects of DE on male and female Syrian golden hamsters. Groups of 52 males and 52 females, 6 to 8 weeks old, were exposed to DE at DPM concentrations of 0.7, 2.2, or 6.6 mg/m^3. They were exposed 16 hr/day, 5 days/week for a total of 2 years and then sacrificed. Exposure conditions are described in Section 7.3.1.1. No statistically significant (*t* test) relationship between tumor incidence and exhaust exposure was reported.

In summary, DE alone did not induce an increase in lung tumors in hamsters of either sex in several studies of chronic duration at high exposure concentrations.

7.3.1.4. *Monkey Studies*

Fifteen male cynomolgus monkeys were exposed to DE (2 mg/m^3) for 7 hr/day, 5 days/week for 24 months (Lewis et al., 1989). The same numbers of animals were also exposed to coal dust (2 mg/m^3 respirable concentration; 5 to 6 mg/m^3 total concentration), DE plus coal dust (1 mg/m^3 respirable concentration for each component; 3.2 mg/m^3 total concentration), or filtered air. Details of exposure conditions were listed previously in the description of the Lewis et al. (1989) study with rats (Section 7.3.1.1) and are listed in Appendix A.

None of the monkeys exposed to DE exhibited a significantly increased incidence of preneoplastic or neoplastic lesions. It should be noted, however, that the 24-mo time frame employed in this study may not have allowed the manifestation of tumors in primates, because this duration is only a small fraction of the monkeys' expected lifespan. In fact, there have been no near-lifetime exposure studies in nonrodent species.

7.3.2. Inhalation Studies (filtered DE)

Several studies have been conducted in which animals were exposed to DE filtered to remove PM. As these studies also included groups exposed to whole exhaust, details can be found in Sections 7.3.1.1 for rats, 7.3.1.2 for mice, and 7.3.1.3 for hamsters. Heinrich et al.

(1986b) and Stöber (1986) reported negative results for lung tumor induction in female Wistar rats exposed to filtered exhaust diluted to produce an unfiltered particle concentration of 4.24 mg/m^3. Negative results were also reported in female Fischer 344 rats exposed to filtered exhaust diluted to produce an unfiltered particle concentration of 4.9 mg/m^3 (Iwai et al., 1986a), in Fischer 344 rats of either sex exposed to filtered exhaust diluted to produce an unfiltered particle concentration of 6.6 mg/m^3 (Brightwell et al., 1989), in female Wistar rats exposed to filtered exhaust diluted to produce an unfiltered particle concentration of 7.0 mg/m^3 (Heinrich et al., 1995), and in female Fischer 344 rats exposed to filtered exhaust diluted to produce unfiltered particle concentrations of 5.1, 3.2, or 9.4 mg/m^3 (Iwai et al., 1997). In the Iwai et al. (1986a) study, splenic lymphomas were detected in 37.5% of the exposed rats compared with 8.2% in controls.

In the study reported by Heinrich at al. (1986a) and Stober (1986), primary lung tumors were seen in 29/93 NMRI mice (males and females combined) exposed to filtered exhaust, compared with 11/84 in clean-air controls, a statistically significant increase. In a repeat study by Heinrich et al. (1995), however, significant lung tumor increases were not detected in either female NMRI or C57BL/6N mice exposed to filtered exhaust diluted to produce an unfiltered particle concentration of 4.5 mg/m^3.

Filtered exhaust also failed to induce lung tumor induction in Syrian Golden hamsters (Heinrich et al., 1986a; Brightwell et al., 1989).

Although lung tumor increases were reported in one study and lymphomas in another, these results could not be confirmed in subsequent investigations. It is therefore concluded that little direct evidence exists for carcinogenicity of the vapor phase of DE in laboratory animals at concentrations tested.

7.3.3. Inhalation Studies (DE plus Cocarcinogens)

Details of the studies reported here have been described earlier and in Table 7-3. Tumor initiation with urethan (1 mg/kg body weight i.p. at the start of exposure) or promotion with butylated hydroxytolulene (300 mg/kg body weight i.p. week 1, 83 mg/kg week 2, and 150 mg/kg for weeks 3-52) did not influence tumorigenic responses in Sencar mice of both sexes exposed to concentrations of DE up to 12 mg/m^3 (Pepelko and Peirano, 1983).

Heinrich et al. (1986b) exposed Syrian hamsters of both sexes to DE diluted to a particle concentration of 4 mg/m^3. See Section 7.3.1.1 for details of the exposure conditions. At the start of exposure the hamsters received either one dose of 4.5 mg diethylnitrosamine (DEN) subcutaneously per kg body weight or 20 weekly intratracheal instillations of 250 μ*g* B[*a*]P. Female NMRI mice received weekly intratracheal instillations of 50 or 100 μ*g* B[*a*]P for 10 or 20 weeks, respectively, or 50 μ*g* dibenz[ah]anthracene (DBA) for 10 weeks. Additional groups of 96 newborn mice received one s.c. injection of 5 or 10 μ*g* DBA between 24 and 48 hr after birth. Female Wistar rats received weekly subcutaneous injections of dipentylnitrosamine

(DPN) at doses of 500 and 250 mg/kg body weight, respectively, during the first 25 weeks of exhaust inhalation exposure. Neither DEN, DBA, or DPN treatment enhanced any tumorigenic responses to DE. Response to B[*a*]P did not differ from that of BaP alone in hamsters, but results were inconsistent in mice. Although 20 B[*a*]P instillations induced a 71% tumor incidence in mice, concomitant diesel exposure resulted in only a 41% incidence. However, neither 10 B[*a*]P instillations nor DBA instillations induced significant effects.

Takemoto et al. (1986) exposed Fischer 344 rats for 2 years to DE at particle concentrations of 2 to 4 mg/m^3. One month after start of inhalation exposure one group of rats received di-isopropyl-nitrosamine (DIPN) administered i.p. at 1 mg/kg weekly for 3 weeks. Among injected animals autopsied at 18 to 24 mo, 10 adenomas and 4 adenocarcinomas were reported in 21 animals exposed to clean air, compared with 12 adenomas and 7 adenocarcinomas in 18 diesel-exposed rats. According to the authors, the incidence of adenocarcinomas was not significantly increased by exposure to DE.

Brightwell et al. (1989) investigated the concomitant effects of DE and DEN in Syrian hamsters exposed to DE diluted to produce particle concentrations of 0.7, 2.2, or 6.6 mg/m^3 for 2 years. The animals received a single dose of 4.5 mg DEN s.c. 3 days prior to start of inhalation exposure. DEN did not affect the lack of responsiveness to DE alone. Heinrich et al. (1989b) also exposed Syrian hamsters of both sexes to DE diluted to a particle concentration of 3.75 mg/m^3 for up to 18 mo. After 2 weeks of exposure, groups were treated with either 3 or 6 mg DEN/kg body weight, respectively. Again, DEN did not significantly influence the lack of tumorigenic responses to DE.

Heinrich et al. (1989a) investigated the effects of DPN in female Wistar rats exposed to DE diluted to achieve a particle concentration of 4.24 mg/m^3 for 2-2.5 years. DPN at doses of 250 and 500 mg/kg body weight was injected subcutaneously once a week for the first 25 weeks of exposure. The tumorigenic responses to DPN were not affected by exposure to DE. For details of exposure conditions of the hamster studies see Section 7.3.1.3.

Heinrich et al. (1986a) and Mohr et al. (1986) compared the effects of exposure to particles having only a minimal carbon core but a much greater concentration of PAHs than DPM does. The desired exposure conditions were achieved by mixing coal oven flue gas with pyrolyzed pitch. The concentration of B[a]P and other PAHs per milligram of DPM was about three orders of magnitude greater than that of DE. Female rats were exposed to the flue gas-pyrolyzed pitch for 16 hr/day, 5 days/week at particle concentrations of 3 to 7 mg/m^3 for 22 mo, then held in clean air for up to an additional 12 mo. Among 116 animals exposed, 22 tumors were reported in 21 animals, for an incidence of 18.1%. One was a bronchioloalveolar adenoma, one was a bronchioloalveolar carcinoma, and 20 were squamous cell tumors. Among the latter, 16 were classified as benign keratinizing cystic tumors and 4 were classified as carcinomas. No tumors were reported in 115 controls. The tumor incidence in this study was comparable to that reported previously for the DE-exposed animals.

In analyzing the studies of Heinrich et al. (1986a,b), Heinrich (1990b), Mohr et al. (1986), and Stöber (1986), it must be noted that the incidence of lung tumors occurring following exposure to whole DE, coal oven flue gas, or carbon black (15.8%, 18.1%, and 8% to 17%, respectively) was very similar. This occurred despite the fact that the PAH content of the PAH-enriched pyrolyzed pitch was more than three orders of magnitude greater than that of DE; carbon black, on the other hand, had only traces of PAHs. Based on these findings, particle-associated effects appear to be the primary cause of diesel-exhaust-induced lung cancer in rats exposed at high concentrations. This issue is discussed further in Chapter 7.

7.3.4. Lung Implantation or Intratracheal Instillation Studies

7.3.4.1. *Rat Studies*

Grimmer et al. (1987), using female Osborne Mendel rats (35 per treatment group), provided evidence that PAHs in DE that consist of four or more rings have carcinogenic potential. Condensate was obtained from the whole exhaust of a 3.0-L passenger-car diesel engine connected to a dynamometer operated under simulated city traffic driving conditions. This condensate was separated by liquid-liquid distribution into hydrophilic and hydrophobic fractions representing 25% and 75% of the total condensate, respectively. The hydrophilic, hydrophobic, or reconstituted hydrophobic fractions were surgically implanted into the lungs of the rats. Untreated controls, vehicle (beeswax/trioctanoin) controls, and positive (B[a]P) controls were also included in the protocol (Table 7-6). Fraction Ilb (made up of PAHs with four to seven rings), which accounted for only 0.8% of the total weight of DPM condensate, produced the highest incidence of carcinomas following implantation into rat lungs. A carcinoma incidence of 17.1% was observed following implantation of 0.21 mg IIb/rat, whereas the nitro-PAH fraction (IId) at 0.18 mg/rat accounted for only a 2.8% carcinoma incidence. Hydrophilic fractions of the DPM extracts, vehicle (beeswax/trioctanoin) controls, and untreated controls failed to exhibit carcinoma formation. Administration of all hydrophobic fractions (IIa-d) produced a carcinoma incidence (20%) similar to the summed incidence of fraction IIb (17.1%) and IId (2.8%). The B[a]P positive controls (0.03, 0.1, 0.3 mg/rat) yielded a carcinoma incidence of 8.6%, 31.4%, and 77.1%, respectively. The study showed that the tumorigenic agents were primarily four- to seven-ring PAHs and, to a lesser extent, nitroaromatics. However, these studies demonstrated that simultaneous administration of various PAH compounds resulted in a varying of the tumorigenic effect, thereby implying that the tumorigenic potency of PAH mixtures may not depend on any one individual PAH. This study did not provide any information regarding the bioavailability of the particle-associated PAHs that might be responsible for carcinogenicity.

Kawabata et al. (1986) compared the effects of activated carbon and DE on lung tumor formation. One group of 59 F344 rats was intratracheally instilled with DPM (1 mg/week for 10

Table 7-6. Tumor incidence and survival time of rats treated by surgical lung implantation with fractions from DE condensate (35 rats/group)

Material portion by weight (%)	Dose (mg)	Median survival time in weeks (range)	Number of carcinomas[a]	Number of adenomas[b]	Carcinoma incidence (%)
Hydrophilic fraction (I) (25)	6.7	97 (24-139)	0	1	0
Hydrophobic fraction (II) (75)	20.00	99 (50-139)	50601	1000	14.2
Nonaromatics +					
PAC[c] 2 + 3 rings (IIa) (72)	19.22	103 (25-140)			0
PAH[d] 4 to 7 rings (IIb) (0.8)	0.21	102 (50-140)			17.1
Polar PAC (IIc) (1.1)	0.29	97 (44-138)			0
Nitro-PAH (IId) (0.7)	0.19	106 (32-135)			2.8
Reconstituted hydrophobics (Ia, b, c, d) (74.5)	19.91	93 (46-136)	70027113	101000	20.0
Control, unrelated		110 (23-138)			0
Control (beeswax/trioctanoin)		103 (51-136)			0
B[*a*]P	0.3	69 (41-135)			77.1
	0.1	98 (22-134)			31.4
	0.03	97 (32-135)			8.6

[a]Squamous cell carcinoma.

[b]Bronchiolar/alveolar adenoma.
[c]PAC = polycyclic aromatic compounds.
[d]PAH = polycyclic aromatic hydrocarbons.

Source: Adapted from Grimmer et al., 1987.

weeks). A second group of 31 rats was instilled with activated carbon using the same dosing regime. Twenty-seven rats received only the solvent (buffered saline with 0.05% Tween 80), and 53 rats were uninjected. Rats dying after 18 months were autopsied. All animals surviving 30 months or more postinstillation were sacrificed and evaluated for histopathology. Among 42 animals exposed to DPM surviving 18 months or more, tumors were reported in 31, including 20 malignancies. In the subgroup surviving for 30 mo, tumors were detected in 19 of 20 animals, including 10 malignancies. Among the rats exposed to activated carbon, the incidence of lung tumors equaled 11 of 23 autopsied, with 7 cases of malignancy. Data for those dying between 18 and 30 months and those sacrificed at 30 months were not reported separately. Statistical analysis indicated that activated carbon induced a significant increase in lung tumor incidence compared with no tumors in 50 uninjected controls and 1 tumor in 23 solvent-injected controls. The tumor incidence was significantly greater in the DPM-instilled group and was significantly greater than the increase in the carbon-instilled group.

A study reported by Rittinghausen et al. (1997) suggested that organic constituents of diesel particles play a role in the induction of lung tumors in rats. An incidence of 16.7% pulmonary cystic keratinizing squamous cell lesions was noted in rats intratracheally instilled with 15 mg whole DE particles, compared with 2.1% in rats instilled with 15 mg particles extracted to remove all organic constituents, and none among controls. Instillation of 30 mg of extracted particles induced a 14.6% incidence of squamous lesions, indicating the greater effectiveness of particles alone as lung particle overload increased.

Iwai et al. (1997) instilled 2, 4, 8, and 10 mg of whole diesel particles over a 2- to 10-week period into female F/344 rats, 50 or more per group. Tumors were reported in 6%, 20%, 43%, and 74% of the rats, with incidence of malignant tumors equal to 2%, 13%, 34%, and 48%, respectively. In a second experiment comparing whole with extracted diesel particles, tumor incidence equaled 1/48 (2%) in uninjected controls, 3/55 (5%) in solvent controls, 12/56 (21%) in extracted diesel particles, and 13/106 (12%) in animals injected with unextracted particles. Although the extracted particles appeared to be more potent, when converted to a lung burden basis (mg/100 mg dry lung) the incidence was only 14% among those exposed to extracted exhaust compared with 31% in those exposed to whole particles.

Dasenbrock et al. (1996) conducted a study to determine the relative importance of the organic constituents of diesel particles and particle surface area in the induction of lung cancer in rats. Fifty-two female Wistar rats were intratracheally instilled with 16-17 doses of DPM, extracted DPM, printex carbon black (PR), lampblack (LB), B[*a*]P, DPM + B[*a*]P, or PR + B[*a*]P. The animals were held for a lifetime or sacrificed when moribund. The lungs were necropsied and examined for tumors. Diesel particles were collected from a Volkswagen 1.6-L engine operating on a US FTP-72 driving cycle. The mass median aerodynamic diameter (MMAD) of the diesel particles was 0.25 μm and the specific surface area was 12 m^2/gm.

Following extraction with toluene, specific surface area increased to 138 m^2/gm. The MMAD for extracted PR was equal to 14 nm, while the specific surface area equaled 271 m^2/gm. The MMAD for extracted lampblack was equal to 95 nm, with a specific surface area equal to 20 m^2/gm. The B[*a*]P content of the treated particles was 11.3 mg per gm diesel particles and 29.5 mg B[*a*]P per gm PR. Significant increases in lung tumors were detected in rats instilled with 15 mg unextracted DPM and 30 mg extracted DPM, but not 15 mg extracted DPM. Printex CB was more potent than lampblack CB for induction of lung tumors, whereas B[*a*]P was effective only at high doses. Total dose and tumor responses are shown in Table 7-4.

A number of conclusions can be drawn from these results. First of all, particles devoid of organics are capable of inducing lung tumor formation, as indicated by positive results in the groups treated with high-dose extracted diesel particles and printex. Nevertheless, toluene extraction of organics from diesel particles results in a decrease in potency, indicating that the organic fraction does play a role in cancer induction. A relationship between cancer potency and particle surface area was also suggested by the finding that printex with a large specific surface area was more potent than either extracted DPM or lampblack, which have smaller specific areas. Finally, while very large doses of B[*a*]P are very effective in the induction of lung tumors, smaller doses adsorbed to particle surfaces had little detectable effect, suggesting that other organic components of DE may be of greater importance in the induction of lung tumors at low doses pf B[*a*]P (0.2-0.4 mg).

7.3.4.2. *Syrian Hamster Studies*

Kunitake et al. (1986) and Ishinishi et al. (1988b) conducted a study in which total doses of 1.5, 7.5, or 15 mg of a dichloromethane extract of DPM were instilled intratracheally over 15 weeks into male Syrian hamsters that were then held for their lifetimes. The tumor incidences of 2.3% (1/44), 0% (0/56), and 1.7% (1/59) for the high-, medium-, and low-dose groups, respectively, did not differ significantly from the 1.7% (1/56) reported for controls. Addition of 7.5 mg of B[a]P to a DPM extract dose of 1.5 mg resulted in a total tumor incidence of 91.2% and malignant tumor incidence of 88%. B[a]P (7.5 mg over 15 weeks) alone produced a tumor incidence rate of 88.2% (85% of these being malignant), which was not significantly different from the DPM extract + B[a]P group. Intratracheal administration of 0.03 μg B[a]P, the equivalent content in 15 mg of DPM extract, failed to cause a significant increase in tumors in rats. This study demonstrated a lack of detectable interaction between DPM extract and B[a]P, the failure of DPM extract to induce carcinogenesis, and the propensity for respiratory tract carcinogenesis following intratracheal instillation of high doses of B[a]P. For studies using the DPM extract, some concern must be registered regarding the known differences in chemical composition between DPM extract and DPM. As with all intratracheal instillation protocols, DPM extract lacks the complement of volatile chemicals found in whole DE.

The effects on hamsters of intratracheally instilled DPM suspension, DPM with Fe_2O_3, or DPM extract with Fe_2O_3 as the carrier were studied by Shefner et al. (1982). The DPM component in each of the treatments was administered at concentrations of 1.25, 2.5, or 5.0 mg/week for 15 weeks to groups of 50 male Syrian golden hamsters. The total volume instilled was 3.0 mL (0.2 mL/week for 15 weeks). The DPM and dichloromethane extracts were suspended in physiological saline with gelatin (0.5% w/v), gum arabic (0.5% w/v), and propylene glycol (10% by volume). The Fe_2O_3 concentration, when used, was 1.25 mg/0.2 mL of suspension. Controls received vehicle and, where appropriate, carrier particles (Fe_2O_3) without the DPM component. Two replicates of the experiments were performed. Adenomatous hyperplasia was reported to be most severe in those animals treated with DPM or DPM plus Fe_2O_3 particles and least severe in those animals receiving DPM plus Fe_2O_3. Of the two lung adenomas detected microscopically, one was in an animal treated with a high dose of DPM and the other was in an animal receiving a high dose of DPM extract. Although lung damage was increased by instillation of DPM, there was no evidence of tumorigenicity.

7.3.4.3. *Mouse Studies*

Ichinose et al. (1997a) intratracheally instilled 36 four-week-old male ICR mice per group weekly for 10 weeks with sterile saline or 0.05, 0.1, or 0.2 mg DPM. Particles were collected from a 2.74-L four-cylinder Isuzu engine run at a steady speed of 1,500 rpm under a load of 10 torque (kg/m). Twenty-four hours after the last instillation, six animals per group were sacrificed for measurement of lung 8-hydroxydeoxyguanosine (8-OHdG). The remaining animals were sacrificed after 12 months for histopathological analysis. Lung tumor incidence varied from 4/30 (13.3%) for controls to 9/30 (30%), 9/29 (31%), and 7/29 (24.1%) for mice instilled with 0.05, 0.1, and 0.2 mg/week, respectively. The increase in animals with lung tumors compared with controls was statistically significant for the 0.1 mg dose group, the only group analyzed statistically. Increases in 8-OHdG, an indicator of oxidative DNA damage, correlated well with the increase in tumor incidence in the 0.05 mg dose group, although less so with the other two. The correlation coefficients r = 0.916, 0.765, and 0.677 for the 0.05, 0.10, and 0.20 mg DPM groups, respectively.

In a similar study, 33 four-week-old male ICR mice per group were intratracheally instilled weekly for 10 weeks with sterile saline, 0.1 mg DPM, or 0.1 mg DPM from which the organic constituents were extracted with hexane (Ichinose et al., 1997b). Exhaust was collected from a 2.74-L four-cylinder Izuzu engine run at a steady speed of 2,000 rpm under a load of 6 torque (kg/m). Twenty-four hours after the last instillation, six animals per group were sacrificed for measurement of 8-OHdG. Surviving animals were sacrificed after 12 mo. The incidence of lung tumors increased from 3/27 (11.1%) among controls to 7/27 (25.9%) among those instilled with extracted diesel particles and 9/26 (34.6%) among those instilled with unextracted particles. The increase in number of tumor-bearing animals was statistically significant compared with controls ($p<0.05$) for the group treated with unextracted particles. The increase in 8-OHdG was highly correlated with lung tumor incidence, r = 0.99.

7.3.5. Subcutaneous and Intraperitoneal Injection Studies

7.3.5.1. *Mouse Studies*

In addition to inhalation studies, Orthoefer et al. (1981) also tested the effects of i.p. injections of DPM on male (A/S) strain mice. Three groups of 30 mice were injected with 0.1 mL of a suspension (particles in distilled water) containing 47, 117, or 235 μg of DPM collected from Fluoropore filters in the inhalation exposure chambers. The exposure system and exposure atmosphere are described in Appendix A. Vehicle controls received injections of particle suspension made up of particulate matter from control exposure filters, positive controls received 20 mg of urethan, and negative controls received no injections. Injections were made three times weekly for 8 weeks, resulting in a total DPM dose of 1.1, 2.8, and 5.6 mg for the low-, medium-, and high-dose groups and 20 mg of urethan for the positive control group. These animals were sacrificed after 26 weeks and examined for lung tumors. For the low-, medium-, and high-dose DPM groups, the tumor incidence was 2/30, 10/30, and 8/30, respectively. The incidence among urethan-treated animals (positive controls) was 100% (29/29), with multiple tumors per animal. The tumor incidence for the DPM-treated animals did not differ significantly from that of vehicle controls (8/30) or negative controls (7/28). The number of tumors per mouse was also unaffected by treatment.

In further studies conducted by Orthoefer et al. (1981), an attempt was made to compare the potency of DPM with that of other environmental pollutants. Male and female Strain A mice were injected i.p. three times weekly for 8 weeks with DPM, DPM extracts, or various environmental mixtures of known carcinogenicity, including cigarette smoke condensate, coke oven emissions, and roofing tar emissions. Injection of urethan or dimethylsulfoxide (DMSO) served as positive or vehicle controls, respectively. In addition to DPM from the Nissan diesel previously described, an eight-cylinder Oldsmobile engine operated at the equivalent of 40 mph was also used to compare emission effects from different makes and models of diesel engine. The mice were sacrificed at 9 months of age and their lungs examined for histopathological changes. The only significant findings, other than for positive controls, were small increases in numbers of lung adenomas per mouse in male mice injected with Nissan DPM and in female mice injected with coke oven extract. Furthermore, the increase in the extract-treated mice was significant only in comparison with uninjected controls (not injected ones) and did not occur when the experiment was repeated. Despite the use of a strain of mouse known to be sensitive to tumor induction, the overall findings of this study were negative. The authors provided several possible explanations for these findings, the most likely of which were (1) the carcinogens that were present were very weak, or (2) the concentrations of the active components reaching the lungs were insufficient to produce positive results.

Kunitake et al. (1986) conducted studies using DPM extract obtained from a 1983 HD MMC—6D22P 11-L V-6 engine. Five s.c. injections of DPM extract (500 mg/kg per injection) resulted in a significant (p<0.01) increase in subcutaneous tumors for female C57BL mice (5/22 [22.7%] vs. 0/38 among controls). Five s.c. doses of DPM extract of 10, 25, 30, 100, or 200 mg/kg failed to produce a significant increase in tumor incidence. One of 12 female ICR mice (8.3%) and 4 of 12 male ICR mice (33.3%) developed malignant lymphomas following neonatal s.c. administration of 10 mg of DPM extract per mouse. The increase in malignant lymphoma incidence for the male mice was statistically significant at p<0.05 compared with an incidence of 2/14 (14.3%) among controls. Treatment of either sex with 2.5 or 5 mg of DPM extract per mouse did not result in statistically significant increases in tumor incidence.

Additional studies using DPM extract from LD (1.8-L, 4-cylinder) as well as HD engines with female ICR and nude mice (BALB/c/cA/JCL-nu) were also reported (Kunitake et al., 1988). Groups of 30 ICR and nude mice each were given a single s.c. injection of 10 mg HD extract, 10 mg HD + 50 μg 12-O-tetradecanoylphorbol 13-acetate (TPA), 10 mg LD extract + 50 μg TPA, or 50 μg TPA. No malignant tumors or papillomas were observed. One papillomatous lesion was observed in an ICR mouse receiving LD extract + TPA, and acanthosis was observed in one nude mouse receiving only TPA.

In what appears to be an extension of the Kunitake et al. (1986) s.c. injection studies, Takemoto et al. (1988) presented additional data for subcutaneously administered DPM extract from HD and LD diesel engines. In this report, the extracts were administered to 5-week-old and neonatal (<24 hr old) C57BL mice of both sexes. DPM extract from HD or LD engines was administered weekly to the 5-week-old mice for 5 weeks at doses of 10, 25, 50, 100, 200, or 500 mg/kg, with group sizes ranging from 15 to 54 animals. After 20 weeks, comparison with a control group indicated a significant increase in the incidence of subcutaneous tumors for the 500 mg/kg HD group (5 of 22 mice [22.7%], p<0.01), the 100 mg/kg LD group (6 of 32 [18.8%],
p<0.01), and the 500 mg/kg LD group (7 of 32 [21.9%], p<0.01) in the adult mouse experiments. The tumors were characterized as malignant fibrous histiocytomas. No tumors were observed in other organs. The neonates were given single doses of 2.5, 5, or 10 mg DPM extract subcutaneously within 24 hr of birth. There was a significantly higher incidence of malignant lymphomas in males receiving 10 mg of HD extract and of lung tumors for males given 2.5 mg HD extract and for males given 5 mg and females given 10 mg LD extract. A dose-related trend that was not significant was observed for the incidences of liver tumors for both the HD extract- and LD extract-treated neonatal mice. The incidence of mammary tumors in female mice and multiple-organ tumors in male mice was also greater for some extract-treated

mice, but was not dose related. The report concluded that LD DPM extract showed greater carcinogenicity than did HD DPM extract.

7.3.6. Dermal Studies

7.3.6.1. *Mouse Studies*

In one of the earliest studies of diesel emissions, the effects of dermal application of extract from DPM were examined by Kotin et al. (1955). Acetone extracts were prepared from the DPM of a diesel engine (type and size not provided) operated at warmup mode and under load. These extracts were applied dermally three times weekly to male and female C57BL and strain A mice. Results of these experiments are summarized in Table 7-5. In the initial experiments using 52 (12 male, 40 female) C57BL mice treated with DPM extract from an engine operated in warmup mode, two papillomas were detected after 13 mo. Four tumors were detected 16 months after the start of treatment in 8 surviving of 50 exposed male strain A mice treated with DPM extract from an engine operated under full load. Among female strain A mice treated with DPM extract from an engine operated under full load, 17 tumors were detected in 20 of 25 mice surviving longer than 13 mo. This provided a significantly increased tumor incidence of 85%. Carcinomas as well as papillomas were seen, but the numbers were not reported.

Depass et al. (1982) examined the potential of DPM and dichloromethane extracts of DPM to act as complete carcinogens, carcinogen initiators, or carcinogen promoters. In skin-painting studies, the DPM was obtained from an Oldsmobile 5.7-L diesel engine operated under constant load at 65 km/h. The DPM was collected at a temperature of 100°C. Groups of 40 C3H/HeJ mice were used because of their low spontaneous tumor incidence. For the complete carcinogenesis experiments, DPM was applied as a 5% or 10% suspension in acetone. Dichloromethane extract was applied as 5%, 10%, 25%, or 50% suspensions. Negative controls received acetone, and positive controls received 0.2% B[a]P. For tumor-promotion experiments, a single application of 1.5% B[a]P was followed by repeated applications of 10% DPM suspension, 50% DPM extract, acetone only (vehicle control), 0.0001% phorbol 12-myristate 13-acetate (PMA) as a positive promoter control, or no treatment (negative control). For the tumor-initiation studies, a single initiating dose of 10% diesel particle suspension, 50% diesel particle extract, acetone, or PMA was followed by repeated applications of 0.0001% PMA. Following 8 months of treatment, the PMA dose in the initiation and promotion studies was increased to 0.01%. Animals were treated three times per week in the complete carcinogenesis and initiation experiments and five times per week in promotion experiments. All test compounds were applied to a shaved area on the back of the mouse.

In the complete carcinogenesis experiments, one mouse receiving the high-dose (50%) suspension of extract developed a squamous cell carcinoma after 714 days of treatment. Tumor incidence in the B[a]P group was 100%, and no tumors were observed in any of the other groups. For the promotion studies, squamous cell carcinomas with pulmonary metastases were identified in one mouse of the 50% DPM extract group and in one in the 25% extract group. Another mouse in the 25% extract group developed a grossly diagnosed papilloma. Nineteen positive control mice had tumors (11 papillomas, 8 carcinomas). No tumors were observed for any of the other treatment groups. For the initiation studies, three tumors (two papillomas and one carcinoma) were identified in the group receiving DPM suspension and three tumors (two papillomas and one fibrosarcoma) were found in the DPM extract group. These findings were reported to be statistically insignificant using the Breslow and Mantel-Cox tests.

Although these findings were not consistent with those of Kotin et al. (1955), the occurrence of a single carcinoma in a strain known to have an extremely low spontaneous tumor incidence may be of importance. Furthermore, a comparison between studies employing different strains of mice with varying spontaneous tumor incidences may result in erroneous assumptions.

Nesnow et al. (1982) studied the formation of dermal papillomas and carcinomas following dermal application of dichloromethane extracts from coke oven emissions, roofing tar, DPM, and gasoline engine exhaust. DPM from five different engines, including a preproduction Nissan 220C, a 5.7-L Oldsmobile, a prototype Volkswagen Turbo Rabbit, a Mercedes 300D, and a HD Caterpillar 3304, was used for various phases of the study. Male and female Sencar mice (40 per group) were used for tumor initiation, tumor promotion, and complete carcinogenesis studies. For the tumor-initiation experiments, the DPM extracts were topically applied in single doses of 100, 500, 1,000, or 2,000 μg/mouse. The high dose (10,000 μg/mouse) was applied in five daily doses of 2,000 μg. One week later, 2 μg of the tumor promoter TPA was applied topically twice weekly. The tumor-promotion experiments used mice treated with 50.5 μg of B[a]P followed by weekly (twice weekly for high dose) topical applications (at the aforementioned doses) of the extracts. For the complete carcinogenesis experiments, the test extracts were applied weekly (twice weekly for the high doses) for 50 to 52 weeks. Only extracts from the Nissan, Oldsmobile, and Caterpillar engines were used in the complete carcinogenesis experiments.

In the tumor-initiation studies, both B[a]P alone and the Nissan engine DPM extract followed by TPA treatment produced a significant increase in tumor (dermal papillomas) incidence at 7 to 8 weeks postapplication. By 15 weeks, the tumor incidence was greater than 90% for both groups. No significant carcinoma formation was noted for mice in the tumor-initiation experiments following exposure to DPM extracts of the other diesel engines, although the Oldsmobile engine DPM extract at 2.0 mg/mouse did produce a 40% papilloma incidence in male mice at 6 mo. This effect, however, was not dose dependent.

B[a]P (50.5 μg/week), coke oven extract (at 1.0, 2.0, or 4.0 mg/week), and the highest dose of roofing tar extract (4.0 mg/week) all tested positive for complete carcinogenesis activity. DPM extracts from only the Nissan, Oldsmobile, and Caterpillar engines were tested for complete carcinogenic potential, and all three proved to be negative using the Sencar mouse assay.

The results of the dermal application experiments by Nesnow et al. (1982) are presented in Table 7-7. The tumor initiation-promotion assay was considered positive if a dose-dependent response was obtained and if at least two doses provided a papilloma-per-mouse value that was three times or greater than that of the background value. Based on these criteria, only emissions from the Nissan were considered positive. Tumor initiation and complete carcinogenesis assays required that at least one dose produce a tumor incidence of at least 20%. None of the DPM samples yielded positive results based on this criterion.

Kunitake et al. (1986, 1988) evaluated the effects of a dichloromethane extract of DPM obtained from a 1983 MMC M-6D22P 11-L V-6 engine. An acetone solution was applied in 10 doses every other day, followed by promotion with 2.5 μg of TPA three times weekly for 25 weeks. Exposure groups received a total dose of 0.5, 5, 15, or 45 mg of extract. Papillomas were reported in 2 of 50 animals examined in the 45 mg exposure group and in 1 of 48 in the 15 mg group compared with 0 of 50 among controls. Differences, however, were not statistically significant.

7.3.7. Summary and Conclusions of Laboratory Animal Carcinogenicity Studies

As early as 1955, Kotin et al. (1955) provided evidence for tumorigenicity and carcinogenicity of acetone extracts of DPM following dermal application and also provided data suggesting a difference in this potential depending on engine operating mode. Until the early 1980s, no chronic studies assessing inhalation of DE, the relevant mode for human exposure, had been reported. Since then long-term inhalation bioassays with DE have been carried out in the United States, Germany, Switzerland, and Japan, testing responses of rats, mice, and Syrian hamsters, and to a limited extent cats and monkeys.

Table 7-7. Dermal tumorigenic and carcinogenic effects of various emission extracts

	Tumor initiation		Complete carcinogenesis	Tumor promotion
Sample	**Papillomas[a]**	**Carcinomas[b]**	**Carcinomas[b]**	**Papillomas[a]**
Benzo[*a*]pyrene	+/+[c]	+/+	+/+	+/+
Topside coke oven	+/+	-/+	ND[d]	ND
Coke oven main	+/+	+/+	+/+	+/+
Roofing tar	+/+	+/+	+/+	+/+
Nissan	+/+	+/+	-/-	ND
Oldsmobile	+/+	-/-	-/-	ND
VW Rabbit	+/+	-/-	I[e]	ND
Mercedes	+/-	-/-	ND	ND
Caterpillar	-/-	-/-	-/-	ND
Residential furnace	-/-	-/-	ND	ND
Mustang	+/+	-/+	ND	ND

[a]Scored at 6 mo.

[b]Cumulative score at 1 year.

[c]Male/female.

[d]ND = Not determined.

[e]I = Incomplete.

Source: Nesnow et al., 1982.

It can be reasonably concluded that with adequate exposure, inhalation of DE is capable of inducing lung cancer in rats. Responses best fit cumulative exposure (concentration × daily exposure duration × days of exposure). Examination of rat data shown in Table 7-8 indicates a trend of increasing tumor incidence at exposures exceeding 1×10^4 mg·hr/m^3. Exposures greater than approximately this value result in lung particle overload, characterized by slowed particle clearance and lung pathology, as discussed in Chapters 3 and 5, respectively. Tumor induction at high doses may therefore be primarily the result of lung particle overload with associated inflammatory responses. Although tumorigenic responses could not be detected under non-particle-overload conditions, the animal experiments lack sensitivity to determine if a threshold exists. However, studies such as those reported by Driscoll et al. (1996) support the existence of a threshold if it is assumed that inflammation is a prerequisite for lung tumor induction. If low-dose effects do occur, it can be hypothesized that the organic constituents are playing a role. See Chapter 7 for a discussion of this issue.

Although rats develop adenomas, adenocarcinomas, and adenosquamous cell carcinomas, they also develop squamous keratinizing lesions. This latter spectrum appears for the most part to be peculiar to the rat. In a recent workshop aimed at classifying these tumors (Boorman et al., 1996), it was concluded that when these lesions occur in rats as part of a carcinogenicity study, they must be evaluated on a case-by-case basis and regarded as a part of the total biologic profile of the test article. If the only evidence of tumorigenicity is the presence of cystic keratinizing epitheliomas, it may not have relevance to human safety evaluation of a substance or particle. Their use in quantifying cancer potency is even more questionable.

The evidence for response of common strains of laboratory mice exposed under standard inhalation protocols is equivocal. Inhalation of DE induced significant increases in lung tumors in female NMRI mice (Heinrich et al., 1986b; Stöber, 1986) and in female Sencar mice (Pepelko and Peirano, 1983). An apparent increase was also seen in female C57BL mice (Takemoto et al., 1986). However, in a repeat of their earlier study, Heinrich et al. (1995) failed to detect lung tumor induction in either NMRI or C57BL/6N mice. No increases in lung tumor rates were reported in a series of inhalation studies using strain A mice (Orthoefer et al., 1981; Kaplan et al., 1982, 1983; White et al., 1983). Finally, Mauderly et al. (1996) reported no tumorigenic responses in CD-1 mice exposed under conditions resulting in positive responses in rats. The successful induction of lung tumors in mice by Ichinose et al. (1997a,b) via intratracheal instillation may have been the result of focal deposition of larger doses. Positive effects in Sencar mice may be due to use of a strain sensitive to tumor induction in epidermal tissue by organic agents, as well as exposure from conception, although proof for such a hypothesis is lacking.

Table 7-8. Cumulative (concentration × time) exposure data for rats exposed to whole DE

Study	Exposure rate/duration (hr/week, mo)	Total exposure time (hr)	Particle concentration (mg/m^3)	Cumulative exposure ($mg·hr/m^3$) Per week	Total	Tumor incidence (%)[a]
Mauderly et al. (1987)	35, 30	4.20042004e+15	0	0	14701470029820	0.9
	35, 30		0.35	12.25		1.3
	35, 30		3.5	122.5		3.6
	35, 30		7.1	248.5		12.8
Nikula et al. (1995)	80, 23	736073607360	0	0	1840047840	1.0
	80, 23		2.5	200.0		7.0
	80, 23		6.5	520.0		18.0
Heinrich et al. (1986a)	95, 35	1330013300	4.24	402.8	56392	17.8
	95, 35					
Heinrich et al. (1995)	90, 24	8.64086409e+15	0	0	74002180061700	0
	90, 24		0.8	72.0		0
	90, 24		2.5	225.0		5.5
	90, 24		7.0	630.0		22.0
Ishinishi et al. (1988a)	96, 30	1.15201152e+49	0	0	1.1524	3.3
(Light-duty engine)	96, 30		0.1	9.6	60813e+37	2.4
	96, 30		0.4	38.4		0.8
	96, 30		1.1	105.6		4.1
(Heavy-duty engine)	96, 30		2.3	220.8		2.4
	96, 30		0	0		0.8
	96, 30		0.5	48.0		0.8
	96, 30		1.0	96.0		0
	96, 30		1.8	172.8		3.3
	96, 30		3.7	355.2		6.5

Table 7-8. Cumulative (concentration × time) exposure data for rats exposed to whole DE (continued)

Study	Exposure rate/duration (hr/week, mo)	Total exposure time (hr)	Particle concentration (mg/m^3)	Cumulative exposure ($mg\cdot hr/m^3$)		Tumor incidence (%)[a]
				Per week	Total	
Brightwell et al. (1989)	80, 24	7.6807681e+15	0	0	53761689650688	1.2
	80, 24		0.7	56.0		0.7
	80, 24		2.2	176.0		9.7
	80, 24		6.6	528.0		38.5
Kaplan et al. (1983)	140, 15	8.4008401e+15	0	0	2100630012600	0
	140, 15		0.25	35.0		3.3
	140, 15		0.75	105.0		10.0
	140, 15		1.5	210.0		3.3
Iwai et al. (1986b)	56, 24	53765376	4.9	274.4	26342	36.8
	56, 24					
Takemoto et al. (1986)	16, 18-24	1,152-1,536	0	0	0	0
	16, 18-24	1,152-1,536	2-4	32-64	3,456-4,608	
Karagianes et al. (1981)	30, 20	24002400	8.3	249	19920	16.6
	30, 20					
Iwai et al. (1997)	56, 24	537649925616	9.4	526154275	5.47041597e+14	421242
	48, 24		3.2			
	54, 24		5.1			

Attempts to induce significant increases in lung tumors in Syrian hamsters by inhalation of whole DE were unsuccessful (Heinrich et al., 1982, 1986b, 1989b; Brightwell et al., 1986). However, hamsters are considered to be relatively insensitive to lung tumor induction. For example, while cigarette smoke, a known human carcinogen, was shown to induce laryngeal cancer in hamsters, the lungs were relatively unaffected (Dontenwill et al., 1973).

Neither cats (Pepelko and Peirano, 1983 [see Chapter 7]) nor monkeys (Lewis et al., 1989) developed tumors following 2-year exposure to DE. The duration of these exposures, however, was likely to be inadequate for these two longer-lived species, and group sizes were quite small. Exposure levels were also below the maximum tolerated dose (MTD) in the monkey studies and, in fact, only borderline for detection of lung tumor increases in rats.

Long-term exposure to DE filtered to remove particulate matter failed to induce lung tumors in rats (Heinrich et al., 1986b; Iwai et al., 1986b; Brightwell et al., 1989), or in Syrian hamsters (Heinrich et al., 1986b; Brightwell, 1989). A significant increase in lung carcinomas was reported by Heinrich et al. (1986b) in NMRI mice exposed to filtered exhaust. However, in a more recent study the authors were unable to confirm earlier results in either NMRI or C57BL/6N mice (Heinrich et al., 1995). Although filtered exhaust appeared to potentiate the carcinogenic effects of DEN (Heinrich et al., 1982), because of the lack of positive data in rats and equivocal or negative data in mice it can be concluded that filtered exhaust is either not carcinogenic or has a low cancer potency.

Kawabata et al. (1986) demonstrated the induction of lung tumors in Fischer 344 rats following intratracheal instillation of DPM. Rittinghausen et al. (1997) reported an increase in cystic keratinizing epitheliomas following intratracheal instillation of rats with either original DPM or DPM extracted to remove the organic fraction, with the unextracted particles inducing a slightly greater effect. Grimmer et al. (1987) showed not only that an extract of DPM was carcinogenic when instilled in the lungs of rats, but also that most of the carcinogenicity resided in the portion containing PAHs with four to seven rings. Intratracheal instillation did not induce lung tumors in Syrian hamsters (Kunitake et al., 1986; Ishinishi et al., 1988b).

Dermal exposure and s.c. injection in mice provided additional evidence for tumorigenic effects of DPM. Particle extracts applied dermally to mice have been shown to induce significant skin tumor increases in two studies (Kotin et al., 1955; Nesnow et al., 1982). Kunitake et al. (1986) also reported a marginally significant increase in skin papillomas in ICR mice treated with an organic extract from an HD diesel engine. Negative results were reported by Depass et al. (1982) for skin-painting studies using mice and acetone extracts of DPM suspensions. However, in this study the exhaust particles were collected at temperatures of 100 °C, which would minimize the condensation of vapor-phase organics and, therefore, reduce the availability of potentially carcinogenic compounds that might normally be present on DE particles. A significant increase in the incidence of sarcomas in female C57Bl mice was reported by Kunitake et al. (1986) following s.c. administration of LD DPM extract at doses of

500 mg/kg. Takemoto et al. (1988) provided additional data for this study and reported an increased tumor incidence in the mice following injection of LD engine DPM extract at doses of 100 and 500 mg/kg. Results of i.p. injection of DPM or DPM extracts in strain A mice were generally negative (Orthoefer et al., 1981; Pepelko and Peirano, 1983), suggesting that the strain A mouse may not be a good model for testing diesel emissions.

Results of experiments using tumor initiators such as DEN, B[a]P, DPN, or DBA (Brightwell et al., 1986; Heinrich et al., 1986b; Takemoto et al., 1986) were generally inconclusive regarding the tumor-promoting potential of either filtered or whole DE. A report by Heinrich et al. (1982), however, indicated that filtered exhaust may promote the tumor-initiating effects of DEN in hamsters.

Several reports (Wong et al., 1985; Bond et al., 1990) affirm observations of the potential carcinogenicity of DE by providing evidence for DNA damage in rats. These findings are discussed in more detail in Chapter 3, Section 3.6. Evidence for the mutagenicity of organic agents present in diesel engine emissions is also provided in Chapter 4.

Evidence for the importance of the carbon core was initially provided by studies of Kawabata et al. (1986), which showed induction of lung tumors following intratracheal instillation of carbon black that contained no more than traces of organics, and studies of Heinrich (1990b) that indicated that exposure via inhalation to carbon black (Printex 90) particles induced lung tumors at concentrations similar to those effective in DPM studies. Additional studies by Heinrich et al. (1995) and Nikula et al. (1995) confirmed the capability of carbon particles to induce lung tumors. Induction of lung tumors by other particles of low solubility, such as titanium dioxide (Lee et al., 1986), confirmed the capability of particles to induce lung tumors. Pyrolyzed pitch, on the other hand, essentially lacking a carbon core but having much higher PAH concentrations than DPM, also was effective in tumor induction (Heinrich et al., 1986a, 1994).

The relative importance of the adsorbed organics, however, remains to be elucidated and is of some concern because of the known carcinogenic capacity of some of these chemicals. These include polycyclic aromatics as well as nitroaromatics, as described in Chapter 2. Organic extracts of particles also have been shown to induce tumors in a variety of injection, intratracheal instillation, and skin-painting studies, and Grimmer et al. (1987) have, in fact, shown that the great majority of the carcinogenic potential following instillation resided in the fraction containing four- to seven-ring PAHs.

In summary, based on positive inhalation studies in rats exposed to high concentrations, intratracheal instillation studies in rats and mice exposed to high doses, and supported by positive mutagenicity studies, the evidence for carcinogenicity of DE is considered to be adequate in animals. The contribution of the various fractions of DE to the carcinogenic response is less certain. Exposure to filtered exhaust generally failed to induce lung tumors. The presence of known carcinogens adsorbed to diesel particles and the demonstrated tumorigenicity of particle extracts in a variety of injection, instillation, and skin-painting studies indicate a carcinogenic potential for the organic fraction. Studies showing that long-term exposure at high concentrations of poorly soluble particles (e.g., carbon black, TiO_2) can also induce tumors, on the other hand, have provided definitive evidence that the carbon core of the diesel particle is primarily instrumental in the carcinogenic response observed in rats under sufficient exposure conditions. The ability of DE to induce lung tumors at non-particle-overload conditions, and the relative contribution of the particles' core versus the particle-associated organics (if effects do occur at low doses) remains to be determined.

7.4. MODE OF ACTION OF DIESEL EXHAUST-INDUCED CARCINOGENESIS

As noted in Chapter 2, DE is a complex mixture that includes a vapor phase and a particle phase. The particle phase consists of an insoluble carbon core with a large number of organic compounds, as well as inorganic compounds such as sulfates, adsorbed to the particle surface. Some of the semivolatile and particle-associated compounds, in particular PAHs, nitro-PAHs, oxy-PAHs, and oxy-nitro-PAHs (Scheepers and Bos, 1992), are considered likely to be carcinogenic in humans. The vapor phase also contains a large number of organic compounds, including several known or probable carcinogens such as benzene and 1,3-butadiene. Because exposure to the vapor phase alone, even at high concentrations, failed to induce lung cancer in laboratory animals (Heinrich et al., 1986b), the mode-of-action discussion will focus on the particulate matter phase. Additive or synergistic effects of vapor-phase components, however, cannot be ruled out, as chronic inhalation bioassays involving exposure to diesel particles alone have not been carried out.

Several hypotheses regarding the primary mode of action of DE have been proposed. Initially it was generally believed that cancer was induced by particle-associated organics acting via a genotoxic mechanism. By the late 1980s, however, studies indicated that carbon particles virtually devoid of organics could also induce lung cancer at sufficient inhaled concentrations (Heinrich, 1990b). This finding provided support for a hypothesis originally proposed by Vostal (1986) that induction of lung tumors arising in rats exposed to high concentrations of DE is related to overloading of normal lung clearance mechanisms, accumulation of particles, and cell damage followed by regenerative cell proliferation. The action of particles is therefore mediated by epigenetic mechanisms that can be characterized more by promotional than initiation stages of the carcinogenic process. More recently several studies have focused upon the production of reactive oxygen species generated from particle-associated organics, which may induce oxidative DNA damage at exposure concentrations lower than those required to produce lung particle overload. Because it is likely that more than one of these factors is involved in the carcinogenic process, a key consideration is their likely relative contribution at different exposure levels. The following discussion will therefore consider the possible relationship of the organic components of exhaust, inflammatory responses associated with lung particle overload, reactive oxygen species, and physical characteristics of diesel particles to cancer induction, followed by a hypothesized mode of action, taking into account the likely contribution of the factors discussed.

7.4.1. Potential Role of Organic Exhaust Components in Lung Cancer Induction

More than 100 carcinogenic or potentially carcinogenic components have been specifically identified in diesel emissions, including various PAHs and nitroarenes such as 1-nitropyrene (1-NP) and dinitropyrenes (DNPs). The majority of these compounds are adsorbed to the carbon core of the particulate phase of the exhaust and, if desorbed, may become available for biological processes such as metabolic activation to mutagens. Among such compounds identified from DE are B[*a*]P, dibenz[*a*,*h*]anthracene, pyrene, chrysene, and nitroarenes such as 1-NP, 1,3-DNP, 1,6-DNP, and 1,8-DNP, all of which are mutagenic, carcinogenic, or implicated as procarcinogens or cocarcinogens (Stenback et al., 1976; Weinstein and Troll, 1977; Thyssen et al., 1981; Pott and Stöber, 1983; Howard et al., 1983; Hirose et al., 1984; Nesnow et al., 1984; El-Bayoumy et al., 1988). More recently Enya et al. (1997) reported isolation of 3-nitrobenzanthrone, one of the most powerful direct-acting mutagens known to date, from the organic extracts of DE.

Grimmer et al. (1987) separated DE particle extract into a water- and a lipid-soluble fraction, and the latter was further separated into a PAH-free, a PAH-containing, and a polar fraction by column chromatography. These fractions were then tested in Osborne-Mendel rats by pulmonary implantation at doses corresponding to the composition of the original DE. The water-soluble fraction did not induce tumors; the incidences induced by the lipid-soluble fractions were 0% with the PAH-free fraction, 25% with the PAH and nitro-PAH- containing fractions, and 0% with the polar fraction. The PAH and nitro-PAH-containing fraction, comprising only 1% by weight of the total extract, was thus shown to be responsible for most, if not all, of the carcinogenic activity.

Exposure of rats by inhalation to 2.6 mg/m^3 of an aerosol of tar-pitch condensate with no carbon core but containing 50 μg/m^3 B[*a*]P along with other PAHs for 10 months induced lung tumors in 39% of the animals. The same amount of tar-pitch vapor condensed onto the surface of carbon black particles at 2 and 6 mg/m^3 resulted in tumor rates that were roughly two times higher (89% and 72%). Because exposure to 6 mg/m^3 carbon black almost devoid of extractable organic material induced a lung tumor rate of 18%, the combination of PAHs and particles increases their effectiveness (Heinrich et al., 1994). Although this study shows the tumor-inducing capability of PAHs resulting from combustion, it should be noted that the B[*a*]P content in the coal-tar pitch was about three orders of magnitude greater than in diesel soot. Moreover, because organics are present on diesel particles in a thinner layer and the particles are quite convoluted, they may be more tightly bound and less bioavailable. Nevertheless, these studies provide evidence supporting the involvement of organic constituents of diesel particles in the carcinogenic process.

Exposure of humans to related combustion emissions provides some evidence for the involvement of organic components. Mumford et al. (1989) reported greatly increased human lung cancer mortality in Chinese communes burning so-called smoky coal, but not wood, in unvented open-pit fires used for heating and cooking. Although particle concentrations were similar, PAH levels were five to six times greater in the air of communes burning smoky coal. Coke oven emissions, containing high concentrations of PAHs but lacking an insoluble carbon core, have also been shown to be carcinogenic in humans (Lloyd, 1971).

Adsorption of PAHs to a carrier particle such as hematite, CB, aluminum, or titanium dioxide enhances their carcinogenic potency (Farrell and Davis, 1974). As already noted, adsorption to carbon particles greatly enhanced the tumorigenicity of pyrolyzed pitch condensate containing B[*a*]P and other aromatic carcinogens (Heinrich et al., 1995). The increased effectiveness can be partly explained by more efficient transport to the deep lung. Slow release also enhances residence time in the lungs and prevents overwhelming of activating pathways. As discussed in Chapter 3, free organics are likely to be rapidly absorbed into the bloodstream, which may explain why the vapor-phase component of exhaust is relatively ineffective in the induction of pathologic or carcinogenic effects.

Even though the organic constituents may be tightly bound to the particle surface, significant elution is still likely because particle clearance half-times are nearly 1 year in humans (Bohning et al., 1982). Furthermore, Gerde et al. (1991) presented a model demonstrating that large aggregates of inert dust containing crystalline PAHs are unlikely to form at doses typical of human exposure. This allows the particles to deposit and react with the surrounding lung medium, without interference from other particles. Particle-associated PAHs can then be expected to be released more rapidly from the particles. Bond et al. (1984) provided evidence that alveolar macrophages from beagle dogs metabolized B[*a*]P coated on diesel particles to proximate carcinogenic forms. Unless present on the particle surface, B[*a*]P is more likely to pass directly into the bloodstream and escape activation by phagocytic cells.

The importance of DE-associated PAHs in the induction of lung cancer in humans may be enhanced because of the possibility that the human lung is more sensitive to these compounds than are rat lungs. Rosenkranz (1996) summarized information indicating that in humans and mice, large proportions of lung cancers contain both mutated *p*53 suppressor genes and K-*ras* genes. Induction of mutations in these genes by genotoxins, however, is much lower in rats than in humans or mice.

B[*a*]P, although only one of many PAHs present in DE, is the one most extensively studied. Bond et al. (1983, 1984) demonstrated metabolism of particle-associated B[*a*]P and free B[*a*]P by alveolar macrophages (AM) and by type II alveolar cells. The respiratory tract cytochrome P-450 systems have an even greater concentration in the nonciliated bronchiolar cells (Boyd, 1984). It is worth noting that bronchiolar adenomas that develop following diesel exposure have been found to resemble both Type II and nonciliated bronchiolar cells. It should also be noted that any metabolism of procarcinogens by these latter two cell types probably involves the preextraction of carcinogens in the extracellular lining fluid and/or other endocytotic cells, as they are not especially important in phagocytosis of particles. Thus, bioavailability is an important issue in assessing the relative importance of PAHs.

Additionally, a report by Borm et al. (1997) indicates that incubating rat lung epithelial-derived cells with human polymorphonucleocytes (PMNs) (either unactivated or activated by preexposure to phorbol myristate acetate) increases DNA adduct formation caused by exposure to B[*a*]P; at 0.05 to 0.5 micromolar concentration, addition of more activated PMN in relation to the number of lung cells further increased adduct formation in a dose-dependent manner. The authors suggest that “an inflammatory response in the lung may increase the biologically effective dose of PAHs, and may be relevant to data interpretation and risk assessment of PAH-containing particles.” These data raise the possibility that DE exposure at low concentrations may result in levels of neutrophil influx that would not necessarily be detectable via histopathological examination as acute inflammation, but that might be effective at amplifying any potential DE genotoxic effect.

Nitro-PAHs have also been implicated as potentially involved in diesel-exhaust-induced lung cancer. Although the nitro-PAH fraction of diesel was less effective than PAHs in the induction of lung cancer when implanted into the lungs of rats (Grimmer et al., 1987), in a study of various extracts of DE particles, 30%-40% of the total mutagenicity could be attributed to a group of six nitroarenes (Salmeen et al., 1984). Moreover, Gallagher et al. (1994) reported results suggesting that DNA adducts are formed from nitro-PAHs present in DNA and may play a role in the carcinogenic process. Nitroarenes, however, quantitatively represent a very small percentage of diesel particle extract (Grimmer et al., 1987), making their role in the tumorigenic response uncertain.

The induction of DNA adducts in humans occupationally exposed to DE indicates the likelihood that PAHs are participating in the tumorigenic response, and that these effects can occur at exposure levels less than those required to induce lung particle overload. Distinct adduct patterns were found among garage workers occupationally exposed to DE when compared with nonexposed controls (Nielsen and Autrup, 1994). Furthermore, the findings were concordant with the adduct patterns observed in groups exposed to low concentrations of PAHs from combustion processes. Hemminki et al. (1994) also reported significantly elevated levels of DNA adducts in lymphocytes from garage workers with known DE exposure compared with unexposed mechanics. Hou et al. (1995) found elevated adduct levels in bus maintenance workers exposed to DE. Although no difference in mutant frequency was observed between the groups, the adduct levels were significantly different (3.2 vs. 2.3×10^{-8}). Nielsen et al. (1996b) measured three biomarkers in DE-exposed bus garage workers: lymphocyte DNA adducts, hydroxyethylvaline adducts in hemoglobin, and 1-hydroxypyrene in urine. Significantly increased levels were reported for all three. Qu et al. (1996) detected increased adduct levels, as well as increases in some individual adducts, in the blood of underground coal miners exposed to DE.

7.4.2. Role of Inflammatory Cytokines and Proteolytic Enzymes in the Induction of Lung Cancer in Rats by Diesel Exhaust

It is well recognized that the deposition of particles in the lung can result in the efflux of PMNs from the vascular compartment into the alveolar space compartment in addition to expanding the AM population size. Following acute exposures, the influx of the PMNs is transient, lasting only a few days (Adamson and Bowden, 1978; Bowden and Adamson, 1978; Lehnert et al., 1988). During chronic exposure the numbers of PMNs lavaged from the lungs of diesel-exposed rats generally increased with increasing exposure duration and inhaled DPM concentration (Strom, 1984). Strom (1984) also found that PMNs in diesel-exposed lungs remained persistently elevated for at least 4 months after cessation of exposure, a potential mechanism that may be related to an ongoing release of phagocytized particles. Evidence in support of this possibility was reported by Lehnert et al. (1989) in a study in which rats were intratracheally instilled with 0.85, 1.06, or 3.6 mg of polystyrene particles. The PMNs were not found to be abnormally abundant during the clearance of the two lower lung burdens, but they became progressively elevated in the lungs of the animals in which alveolar-phase clearance was inhibited. Moreover, the particle burdens in the PMNs became progressively greater over time. Such findings are consistent with an ongoing particle relapse process, in which particles released by dying phagocytes are ingested by new ones.

The inflammatory response, characterized by efflux of PMNs from the vascular compartment, is mediated by inflammatory chemokines. Driscoll et al. (1996) reported that inhalation of high concentrations of carbon black stimulated the release of macrophage inflammatory protein 2 (MIP-2) and monocyte chemotactic protein 1 (MCP-1). They also reported a concomitant increase in hprt mutants. In a following study it was shown that particle exposure stimulates production of tumor necrosis factor TNF-α, an agent capable of activating expression of several proteins that promote both adhesion of leucocytes and chemotaxis (Driscoll et al., 1997a). In addition, alveolar macrophages also have the ability to release several other effector molecules or cytokines that can regulate numerous functions of other lung cells, including their rates of proliferation (Bitterman et al., 1983; Jordana et al., 1988; Driscoll et al., 1996).

Another characteristic of AMs and PMNs under particle overload conditions is the release of a variety of potentially destructive hydrolytic enzymes, a process known to occur simultaneously with the phagocytosis of particles (Sandusky et al., 1977). The essentially continual release of such enzymes during chronic particle deposition and phagocytosis in the lung may be detrimental to the alveolar epithelium, especially to Type I cells. Evans et al. (1986) showed that injury to Type I cells is followed shortly thereafter by a proliferation of Type

II cells. Type II cell hyperplasia is a common feature observed in animals that have received high lung burdens of various types of particles, including unreactive polystyrene microspheres. Exaggerated proliferation as a repair or defensive response to DPM deposition may have the effect of amplifying the likelihood of neoplastic transformation in the presence of carcinogens beyond that which would normally occur with lower rates of proliferation, assuming an increase in the cycling of target cells and the probability of a neoplastic-associated genomic disturbance.

7.4.3. Role of Reactive Oxygen Species in Lung Cancer Induction by Diesel Exhaust

Phagocytes from a variety of rodent species produce elevated levels of oxidant reactants in response to challenges, with the physiochemical characteristics of a phagocytized particle being a major factor in determining the magnitude of the oxidant-producing response. Active oxygen species released by the macrophages and lymphatic cells can cause lipid peroxidation in the membrane of lung epithelial cells. These lipid peroxidation products can initiate a cascade of oxygen free radicals that progress through the cell to the nucleus, where they damage DNA. If this damage occurs during the epithelial cell’s period of DNA synthesis, there is some probability that the DNA will be replicated unrepaired (Lechner and Mauderly, 1994). The generation of reactive oxygen species by both AMs and PMNs should therefore be considered as one potential factor of what probably is a multistep process that culminates in the development of lung tumors in response to chronic deposition of DPM.

Even though products of phagocytic oxidative metabolism, including superoxide anions, hydrogen peroxide, and hydroxyl radicals, can kill tumor cells (Klebanoff and Clark, 1978), and the reactive oxygen species can peroxidize lipids to produce cytotoxic metabolites such as malonyldialdehyde, some products of oxidative metabolism apparently can also interact with DNA to produce mutations. Cellular DNA is damaged by oxygen free radicals generated from a variety of sources (Ames, 1983; Trotter, 1980). Along this line, Weitzman and Stossel (1981) found that human peripheral leukocytes are mutagenic in the Ames assay. This mutagenic activity was related to PMNs and blood monocytes; blood lymphocytes alone were not mutagenic. These investigators speculated that the mutagenic activity of the phagocytes was a result of their ability to produce reactive oxygen metabolites, inasmuch as blood leukocytes from a patient with chronic granulomatous diseases, in which neutrophils have a defect in the NADPH oxidase generating system (Klebanoff and Clark, 1978), were less effective in producing mutations than were normal leukocytes. Of related significance, Phillips et al. (1984) demonstrated that the incubation of Chinese hamster ovary cells with xanthine plus xanthine oxidase (a system for enzymatically generating active oxygen species) resulted in genetic damage hallmarked by extensive chromosomal breakage and sister chromatid exchange and produced an increase in the frequency of thioguanidine-resistant cells (HGPRT test). Aside from interactions of oxygen species with DNA, increasing evidence also points to an important role of phagocyte-derived oxidants and/or oxidant products in the metabolic activation of procarcinogens to their ultimate carcinogenic form (Kensler et al., 1987).

Driscoll et al. (1997b) have demonstrated that exposure to doses of particles producing significant neutrophilic inflammation are associated with increased mutation in rat alveolar type II cells. The ability of particle-elicited macrophages and neutrophils to exert a mutagenic effect on epithelial cells in vitro supports a role for these inflammatory cells for the in vivo mutagenic effects of particle exposure. The inhibition of bronchoalveolar lavage cell-induced mutations by catalase implies a role for cell-derived oxidants in this response.

Hatch and co-workers (1980) have demonstrated that interactions of guinea pig AMs with a wide variety of particles, such as silica, metal oxide-coated fly ash, polymethylmethacrylate beads, chrysotile asbestos, fugitive dusts, polybead carboxylate microspheres, glass and latex beads, uncoated fly ash, and fiberglass increase the production of reactive oxygen species. Similar findings have been reported by numerous investigators for human, rabbit, mouse, and guinea pig AMs (Drath and Karnovsky, 1975; Allen and Loose, 1976; Beall et al., 1977; Lowrie and Aber, 1977; Miles et al., 1977; Rister and Baehner, 1977; Hoidal et al., 1978). PMNs are also known to increase production of superoxide radicals, hydrogen peroxide, and hydroxyl radicals in response to membrane-reactive agents and particles (Goldstein et al., 1975; Weiss et al., 1978; Root and Metcalf, 1977). Although these responses may occur at any concentration, they are likely to be greatly enhanced at high exposure concentrations with slowed clearance and lung particle overload.

Reactive oxygen species can also be generated from particle-associated organics. Sagai et al. (1993) reported that DPM can nonenzymatically generate active oxygen species (e.g., superoxide [O_2^-] and hydroxyl radical [$^{\cdot}OH$] in vitro without any biologically activating systems) such as microsomes, macrophages, hydrogen peroxide, or cysteine. Because DPM washed with methanol could no longer produce these radicals, it was concluded that the active components were compounds extractable with organic solvents. However, the nonenzymatic contribution to the DPM-promoted active oxygen production was negligible compared with that generated via an enzymatic route (Ichinose et al., 1997a). They reported that O_2^- and $^{\cdot}OH$ can be enzymatically generated from DPM by the following process. Soot-associated quinone-like compounds are reduced to the semiquinone radical by cytochrome P-450 reductase. These semiquinone radicals then reduce O_2 to O_2^-, and the produced superoxide reduces ferric ions to ferrous ions, which catalyzes the homobiotic cleavage of H_2O_2 dismutated from O_2 by superoxide dismutase or spontaneous reactions to produce $^{\cdot}OH$. According to Kumagai et al. (1997), while quinones are likely to be the favored substrates for this reaction, the participation of nitroaromatics cannot be ruled out.

One of the critical lesions to DNA bases generated by oxygen free radicals is 8-hydroxydeoxyguanosine (8-OHdG). The accumulation of 8-OhdG as a marker of oxidative DNA damage could be an important factor in enhancing the mutation rate leading to lung cancer

(Ichinose et al., 1997a). For example, formation of 8-OHdG adducts leads to G:C to T:A transversions unless repaired prior to replication. Nagashima et al. (1995) demonstrated that the production of (8-OHdG) is induced in mouse lungs by intratracheal instillation of DPM. Ichinose et al. (1997b) reported further that although intratracheal instillation of DPM in mice induced a significant increase in lung tumor incidence, comparable increases were not reported when mice were instilled with extracted DPM (to remove organics). Lung injury was also less in the mice instilled with extracted DPM. Moreover, increases in 8-OHdG in the mice instilled with unextracted DPM correlated very well with increases in tumor rates. In a related study, Ichinose et al. (1997a) intratracheally instilled small doses of DPM, 0.05, 0.1, or 0.2 mg weekly for 3 weeks, in mice fed standard or high-fat diets either with or without β-carotene. High dietary fat enhanced DPM-induced lung tumor incidence, whereas β-carotene, which may act as a free radical scavenger, partially reduced the tumorigenic response. Formation of 8-OHdG was again significantly correlated with lung tumor incidence in these studies, except at the highest dose. Dasenbrock et al. (1996) reported that extracted DPM, intratracheally instilled into rats (15 mg total dose) induced only marginal increases in lung tumor induction, while unextracted DPM was considerably more effective. Although adducts were not measured in this study, it nevertheless provides support for the likelihood that activation of organic metabolites and/or generation of oxygen free radicals from organics are involved in the carcinogenic process.

Additional support for the involvement of particle-associated radicals in tissue damage was provided by the finding that pretreatment with superoxide dismutase (SOD), an antioxidant, markedly reduced lung injury and death due to instillation of DPM. Similarly, Hirafuji et al. (1995) found that the antioxidants catalase, deferoxamine, and MK-447 inhibited the toxic effects of DPM on guinea pig tracheal cells and tissues in vitro.

Although the data presented supported the hypothesis that generation of reactive oxygen species resulting from exposure to DPM is involved in the carcinogenic process, it should be noted that 8-OHdG is efficiently repaired and that definitive proof of a causal relationship in humans is still lacking. It is also uncertain whether superoxide or hydroxyl radicals chemically generated by DPM alone promote 8-OHdG production in vivo and induce lung toxicity, because SOD is extensively located in mammalian tissues. Nevertheless, demonstration that oxygen free radicals can be generated from particle-associated organics, that their presence will induce adduct formation and DNA damage unless repaired, that tumor induction in experimental animals correlates with OhdG adducts, and that treatment with antioxidant limits lung damage, provides strong support for the involvement of oxygen free radicals in the toxicologic and carcinogenic response to DE.

7.4.4. Relationship of Physical Characteristics of Particles to Cancer Induction

The biological potential of inhaled particles is strongly influenced by surface chemistry and character. For example, the presence of trace metal compounds such as aluminum and iron, as well as ionized or protonated sites, is important in this regard (Langer and Nolan, 1994). A major factor is specific surface area (surface area/mg). PMNs characteristically are increased abnormally in the lung by DE exposure, but their presence in the lungs does not appear to be excessive following the pulmonary deposition of even high lung burdens of spherical TiO_2 particles in the 1-2 μm diameter range (Strom, 1984). In these studies lung tumors were detected only at an inhaled concentration of 250 $\mu g/m^3$. In a more recent study in which rats were exposed to TiO_2 in the 15-40 nm size range, inhibition of particle clearance and tumorigenesis were induced at concentrations of 10 mg/m^3 (Heinrich et al., 1995). Comparison of several chronic inhalation studies correlating particle mass and particle surface area retained in the lung with tumor incidence indicated that particle surface area is a much better dosimeter than particle mass (Oberdörster and Yu, 1990; Driscoll et al., 1996). Heinrich et al. (1995) also found that lung tumor rates increased with specific particle surface area following exposure to DE, carbon black, or titanium dioxide, irrespective of particle type. Langer and Nolan (1994) reported that the hemolytic potential of Min-U-Sil15, a silica flour, increased in direct relationship to specific surface area at nominal particle diameters ranging from 0.5 to 20 μm.

Ultrafine particles appear to be more likely to be taken up by lung epithelial cells. Riebe-Imre et al. (1994) reported that CB is taken up by lung epithelial cells in vitro, inducing chromosomal damage and disruption of the cytoskeleton, lesions that closely resemble those present in tumor cells. Johnson et al. (1993) reported that 20-nm polytetrafluoroethylene particles are taken up by pulmonary epithelial cells as well as polymorphonuclear leucocytes, inducing an approximate 4-, 8-, and 40-fold increase in the release of interleukin-1 alpha and beta, inducible nitric oxide synthetase, and macrophage inflammatory protein, respectively.

The carcinogenic potency of diesel particles, therefore, appears to be related, at least to some extent, to their small size and convoluted shape, which results in a large specific particle surface area. Toxicity and carcinogenicity increased with decreasing particle size into the submicron range. For example, Heinrich et al. (1995) have shown that ultrafine titanium dioxide (approximately 0.2 μm diameter) is much more toxic than particles with a 10-fold greater diameter of the same composition used in an earlier study by Lee et al. (1986). This increase in toxicity has been noted with even smaller particles. For example, carbon black particles 20 nm in diameter were shown to be significantly more toxic than 50 nm particles (Murphy et al., 1999). The relationship between particle size and toxicity is of concern because, as noted in Chapter 2, approximately 50%-90% of the number of particles in DE are in the size range from 5 to 50 nm. Other than disruption of the cytoskeleton of epithelial cells, there is little information regarding the means by which particle size influences carcinogenicity as well as noncancer toxicity.

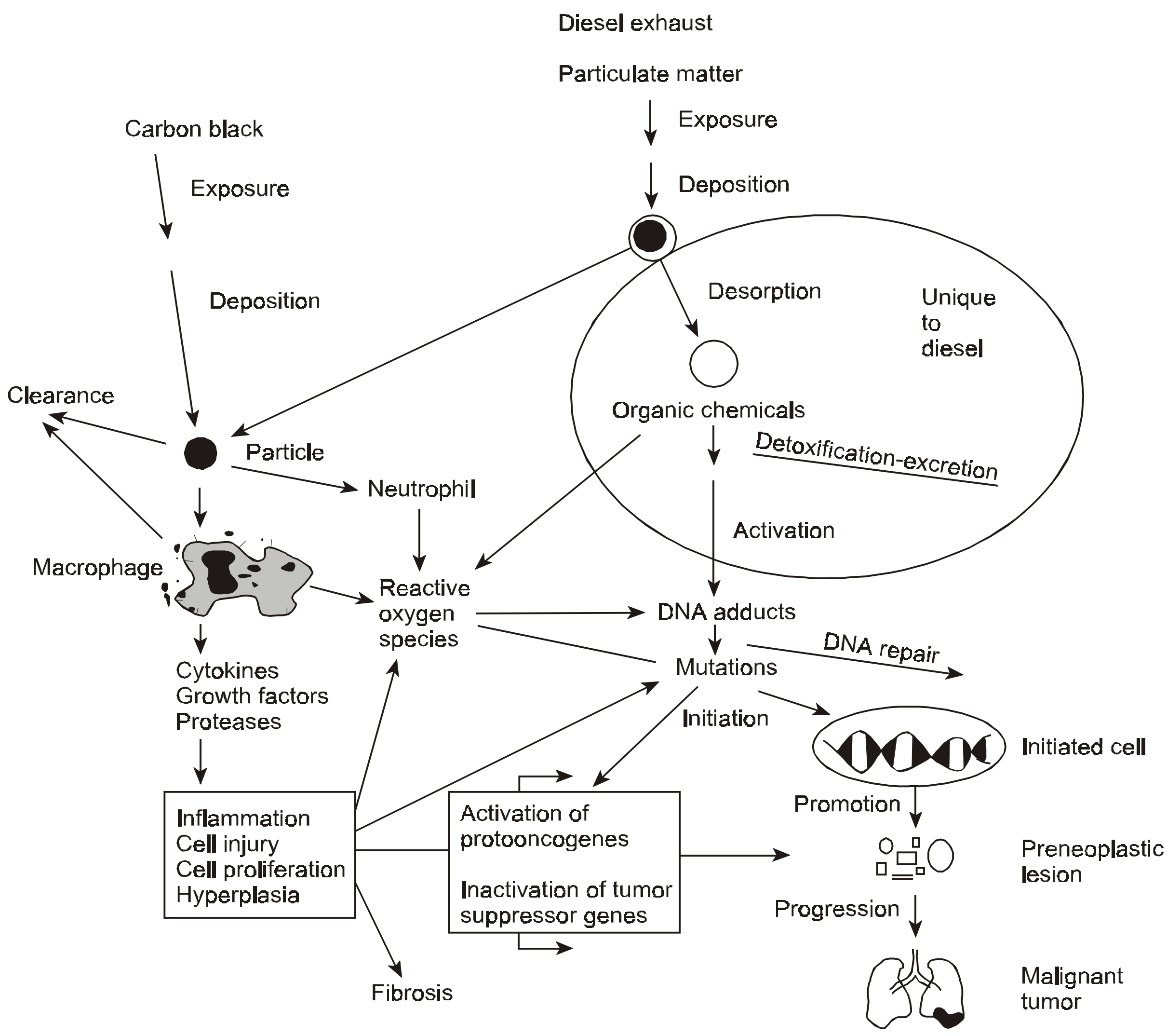
7.4.5. Integrative Hypothesis for Diesel-Induced Lung Cancer

The induction of lung cancer in rats by large doses of carbon black via inhalation (Heinrich et al., 1995; Mauderly et al., 1991; Nikula et al., 1995) or intratracheal instillation (Kawabata et al., 1994; Pott et al., 1994; Dasenbrock et al., 1996) led to the development of the lung particle overload hypothesis. According to this hypothesis the induction of neoplasia by insoluble low- toxicity particles is associated with an inhibition of lung particle clearance and the involvement of persistent alveolar epithelial hyperplasia. Driscoll (1995), Driscoll et al. (1996), and Oberdörster and Yu (1990) outlined a proposed mechanism for the carcinogenicity of DE at high doses that emphasizes the role of phagocytic cells. Following exposure, phagocytosis of particles acts as a stimulant for oxidant production and inflammatory cytokine release by lung phagocytes. It was hypothesized that at high particle exposure concentrations the quantity of mediators released by particle-stimulated phagocytes exceeds the inflammatory defenses of the lung (e.g., antioxidants, oxidant-metabolizing enzymes, protease inhibitors, cytokine inhibitors), resulting in tissue injury and inflammation. With continued particle exposure and/or the persistence of excessive particle burdens, there then develops an environment of phagocytic activation, excessive mediator release-tissue injury and, consequently, more tissue injury, inflammation, and tissue release. This is accompanied by cell proliferation. As discussed in a review by Cohen and Ellwein (1991), conceptually, cell proliferation can increase the likelihood that any oxidant-induced or spontaneously occurring genetic damage becomes fixed in a dividing cell and is clonally expanded. The net result of chronic particle exposures sufficient to elicit inflammation and cell proliferation in the rat lung is an increased probability that the genetic changes necessary for neoplastic transformation will occur. A schematic of this hypothesis has been outlined by McClellan (1997) (see Figure 7-3). In support of this hypothesis, it was reported that concentrations of inhaled CB resulted in increased cytokine expression and inflammatory influx of neutrophils (Oberdörster et al., 1995), increased formation of 8-OhdG (Ichinose et al., 1997b), and increase in the yield of hprt mutants, an effect ameliorated by treatment with antioxidants (Driscoll, 1995; Driscoll et al., 1996). Metabolism of carcinogenic organics to active forms as well as the generation of reactive oxygen species from certain organic species are likely to contribute to the toxic and carcinogenic process.

At low exposure concentrations, the lung particle overload condition is not present and the overload-induced inflammatory effects are not present. Note, however, as discussed in Chapters 5 and 6, that other types of inflammation are present in the rat lung at exposures below those inducing lung particle overload. However, at low exposures, activation of organic carcinogens and generation of oxidants from the organic fraction can still be expected. Actual contribution depends upon elution/bioavailability and the effectiveness of antioxidants. Direct effects of ultrafine diesel particles taken up by epithelial cells are also likely to play a role.

Although high-dose induction of cancer is logically explained by this hypothesis, particle overload has not been clearly shown to induce lung cancer in other species. As noted in the quantitative chapter, the relevance of the rat pulmonary response is therefore problematic. The rat pulmonary noncancer responses to DPM, however, have fairly clear interspecies and human parallels. In response to poorly soluble particles such as DPM, humans and rats both develop an alveolar macrophage response, accumulate particles in the interstitium, and show mild interstitial fibrosis (ILSI, 2000). Other species (mice, hamsters) also have shown similar noncancer pulmonary responses to DPM, but without accompanying cancer response. The rat response for noncancer pulmonary histopathology, however, seems to be more pronounced compared with humans or other species, i.e., rats appear to be more sensitive. Although many critical elements of interspecies comparison, such as the role of airway geometry and patterns of particle deposition, need further elucidation, this basic interspecies similarity and the possible greater sensitivity of pulmonary response seen after longer exposures at high doses make pulmonary histopathology in rats a valid basis for noncancer dose-response assessment.

Figure 7-3. Pathegenesis of lung disease in rats with chronic, high-level exposures to particles.



Source: Modified from McClellan, 1997.

7.4.6. Summary

Recent studies have shown rat lung tumor rates resulting from exposures to nearly organic-free carbon black (CB) particles at high concentrations to be similar to those observed for DE exposures, thus providing strong evidence for a particle overload mechanism for DE-induced pulmonary carcinogenesis in rats. Such a mechanism is also supported by the fact that carbon particles per se cause inflammatory responses and increased epithelial cell proliferation and that AM function may be compromised under conditions of particle overload.

The particle overload hypothesis appears sufficient to account for DE-induced lung cancer in rats. However, there is also biological plausibility for lung cancer induction in humans at concentrations insufficient to induce lung particle overload as seen in rats (Chapter 3, Section 3.4 and ILSI, 2000). The uptake of particles by epithelial cells at ambient or occupational exposure levels, DNA damage resulting from oxygen-free radicals generated from organic molecules, and the gradual in situ extraction and activation of procarcinogens associated with the diesel particles may play a role in this response and provide a basis for the plausibility. The slower particle clearance rates in humans (up to a year or more) may result in greater extraction of organics. This is supported by reports of increased DNA adducts in humans occupationally exposed to DE at concentrations unlikely to induce lung particle overload. Although these modes of action can be expected to function at lung overload conditions also, they are likely to be overwhelmed by inflammatory associated effects.

The evidence to date indicates that caution must be exercised in extrapolating observations made in animal models to humans when assessing the potential for DE-induced pulmonary carcinogenesis. The carcinogenic response and the formation of DNA adducts in rats exposed to DE and other particles at high exposure concentrations may be species-specific and not DPM specific. The likelihood that different modes of action predominate at high and low doses, such as lung particle overload, also renders high-dose extrapolation to lower ambient concentrations uncertain.

7.5. WEIGHT-OF-EVIDENCE EVALUATION FOR POTENTIAL HUMAN CARCINOGENICITY

A carcinogenicity weight-of-evidence evaluation is a synthesis of all pertinent information addressing the question of how likely an agent is to be a human carcinogen. EPA’s 1986 Guidelines for Carcinogen Risk Assessment (U.S. EPA, 1986) provide a classification system for the characterization of the overall weight of evidence for potential human carcinogenicity based on human evidence, animal evidence, and other supportive data. This system includes Group A: *Human Carcinogen*; Group B: *Probable Human Carcinogen*; Group C: *Possible Human Carcinogen*; Group D: *Not Classifiable as to Human Carcinogenicity*; and Group E: *Evidence for Noncarcinogenicity to Humans*.

As part of the guidelines development and updating process, the Agency has developed revisions to the 1986 guidelines to take into account knowledge gained in recent years about the carcinogenic processes. With regard to the weight-of-evidence evaluation for potential human carcinogenicity, EPA's 1996 Proposed Guidelines for Carcinogen Risk Assessment (U.S. EPA, 1996b) and the subsequent revised external review draft (U.S. EPA, 1999) emphasize the need for characterizing cancer hazard, in addition to hazard identification. To express the weight of evidence for potential human carcinogenicity, EPA's proposed 1996 and 1999 guidelines utilize a hazard narrative in place of the 1986 A-E classification system. In order to provide some measure of consistency in using the 1996 and 1999 draft guidelines, standard hazard descriptors are used as part of the hazard narrative. The revised guidelines also stress the importance of considering the mode(s) of action information for making an inference about potential cancer hazard beyond the range of observation, typically encountered at levels of exposure in the general environment. "Mode of action" refers to a series of key biological events and processes that are critical to the development of cancer. This is contrasted with "mechanisms of action," which is defined as a more detailed description of the complete sequence of biological events at the molecular level that must occur to produce a carcinogenic response.

The sections to follow evaluate and weigh the individual lines of evidence and combine all evidence to make an informed judgment about the carcinogenicity hazard of DE. A conclusion in accordance with EPA's 1986 classification system (U.S. EPA, 1986) is provided, as well as a hazard narrative along with appropriate hazard descriptors according to EPA's Proposed Guidelines (U.S. EPA, 1996b, 1999). These sections draw on information reviewed in Chapters 2, 3, 4, and 7.

7.5.1. Human Evidence

Twenty-two epidemiologic studies about the carcinogenicity of workers exposed to DE in various occupations are reviewed in Section 7.2. Exposure to DE has typically been inferred based on job classification within an industry. Increased lung cancer risk, although not always statistically significant, has been observed in 8 out of 10 cohort and 10 of 12 case-control studies within several industries, including railroad workers, truck drivers, heavy equipment operators, and professional drivers. The increased lung cancer relative risks generally range from 1.2 to 1.5, though a few studies show relative risks as high as 2.6. Statistically significant increases in pooled relative risk estimates (1.33 to 1.47) from two independent meta-analyses further support a positive relationship between DE exposure and lung cancer in a variety of DE-exposed occupations.

The generally small increased lung cancer relative risk (less than 2) observed in the epidemiologic studies and meta-analyses potentially weakens the evidence of causality. When a relative risk is less than 2, if confounders (e.g., smoking, asbestos exposure) are having an effect on the observed risk increases, it could be enough to account for the increased risk. With the strongest risk factor for lung cancer being smoking, there is a concern that smoking effects may be influencing the magnitude of the observed increased relative risks. However, in studies for which the effects of smoking were accounted for, increased relative risks for lung cancer prevailed. Though some studies did not have information on smoking, significant confounding by smoking is unlikely because the comparison populations were from the same socioeconomic class. Moreover, when the meta-analysis focused only on the smoking-controlled studies, the relative risks tended to increase.

As evaluated in Section 7.2.4.5, application of the criteria for causality (including the biological plausibility) leads to the conclusion that the increased risks observed in available epidemiologic studies are consistent with a causal association between exposure to DE and occurrence of lung cancer. Overall, the human evidence for potential carcinogenicity for DE is judged to be strong, but less than sufficient for DE to be considered as a human carcinogen because of exposure uncertainties (lack of historical exposure data for workers exposed to DE) and an inability to reach a fully and direct accounting for all possible confounders.

7.5.2. Animal Evidence

DE and its organic constituents, both in the gaseous and particle phase, have been extensively tested for carcinogenicity in many experimental studies using several animal species and with different modes of administration.

Several well-conducted lifetime rat inhalation studies have consistently demonstrated that chronic inhalation exposure to sufficiently high concentrations of DE produced dose-related increases in lung tumors (benign and malignant). However, the lung cancer responses in rats from high-concentration exposures appear to be mediated by impairment of lung clearance mechanisms through particle overload, resulting in persistent chronic inflammation and subsequent pathologic and neoplastic changes in the lung. Overload conditions are not expected to occur in humans as a result of environmental or most occupational exposures to DE. Thus, the rat lung tumor response is not considered relevant to an evaluation of the potential for a human environmental exposure-related hazard (Section 7.4).

The chronic inhalation studies of DE in mice showed equivocal results, whereas negative findings were consistently seen in hamsters. The gaseous phase of DE (filtered exhaust without particulate fraction) was found not to be carcinogenic in rats, mice, or hamsters.

In several intratracheal instillation studies, diesel particulate matter (DPM), carbon black, and the organic DPM extracts which were virtually devoid of PAHs, have been found to produce increased lung tumors in rats. When directly implanted into the rat lung, DPM condensate containing mainly four- to seven-ring PAHs induced increases in lung tumors. In several dermal studies in mice, DPM extracts have also been shown to cause skin tumors and sarcomas in mice following subcutaneous injection.

Available data and hypotheses suggest that both the carbon core and the adsorbed organics have potential roles in inducing lung tumors in the rat, although their relative contribution to the carcinogenic response remains to be determined.

The consistent findings of carcinogenic activity by DPM and the organic extracts of DPM in noninhalation studies (intratracheal instillation, lung implantation, skin painting) contribute to the overall evidence for a human hazard potential for DE. The lack of a tumor response from traditional animal inhalation studies in other rodent species is noted. Without understanding the mode(s) of action of DE's carcinogenicity in humans it is difficult to assess the meaning of nonpositive results from the mouse and hamster inhalation bioassays, and the unusable results from the rat, while having other evidence of carcinogenic potential and plausibility.

It should be noted that the animal studies used DE from engines available in the 1980s, and that present-day engine emissions have different characteristics (e.g., higher elemental carbon content and lesser amounts of adsorbed organics on the carbon particles), with uncertain impact on the outcome of the experimental studies. The same point can be made for the occupational epidemiologic studies.

7.5.3. Other Key Data

Other key data are judged to be supportive of potential carcinogenicity of DE. As discussed in Chapter 2, DE is a complex mixture of hundreds of constituents in either gaseous phase or particle phase. Although present in small amounts, several organic compounds in the gaseous phase (e.g. PAHs, formaldehyde, acetaldehyde, benzene, 1,3-butadiene) are known to exhibit mutagenic and/or carcinogenic activities. PAHs and PAH derivatives, including nitro-PAHs, present on the diesel particle are also known to be mutagenic and carcinogenic. As reviewed in Chapter 4, DPM and DPM organic extracts have been shown to induce gene mutations in a variety of bacteria and mammalian cell test systems. In addition, DE, DPM and DPM extracts have been found to cause chromosomal aberrations, aneuploidy, and sister chromatid exchange in both in vivo and in vitro tests.

There is also suggestive evidence for the bioavailability of the organics from DE (Chapter 3, Section3.5). Elevated levels of DNA adducts in lymphocytes have been reported in workers exposed to DE. In addition, animal studies showed that some of the radiolabeled organic compounds are eluted from DE particles following deposition in the lungs.

7.5.4. Mode of Action

As discussed in Section 7.4, the modes of action of DE-induced carcinogenicity in humans is not understood. It can be suggested that one or multiple modes of action may be involved. These may include: (a) mutagenic and genotoxic events (e.g., direct and indirect effects on DNA and effects on chromosomes) by organic compounds in the gaseous and particle phases; (b) indirect DNA damage via the production of reactive oxygen species (ROS) induced by particle-associated organics; and (c) particle-induced chronic inflammatory response leading to oxidative DNA damage through the release of cytokines, ROS, etc., and an increase in cell proliferation.

The particulate phase or whole DE exposure, as measured by DPM, appears to have the greatest observable contribution to the carcinogenic effects, and both the particle core and the associated organic compounds have demonstrated carcinogenic properties, although a role for the gas-phase components cannot be ruled out. The carcinogenic activity of DE may also be related to the small size of the particles. Moreover, the relative contribution of the possible mode(s) of action may be different at different exposure levels. For example, available evidence from rat studies indicates the importance of the role of the DPM in mediating lung tumor response at high exposure levels. Thus, the role of the adsorbed organic compounds may take on increasing importance at lower exposure levels.

7.5.5. Characterization of Overall Weight of Evidence: EPA's 1986 Guidelines for Carcinogen Risk Assessment

The totality of evidence supports the conclusion that DE is a *probable human carcinogen (Group B1).* This conclusion is based on:

- "Limited"evidence (i.e., strong but less than sufficient evidence for "known human carcinogen"), for a causal association between DE exposure and increased risk of lung cancer among workers in different occupations;
- Evidence of carcinogenicity of DPM in rats and mice by noninhalation routes of exposure (intratracheal instillation, lung implantation, skin painting, and subcutaneous injection); and

- Extensive supporting data including the demonstrated mutagenic and/or chromosomal effects of DE and its organic constituents, suggestive evidence for the bioavailability of the organics from DE, and knowledge of the known mutagenic and/or carcinogenic activity of a number of individual organic compounds present on the particles (e.g,. PAH and derivatives) and in the DE gases (e.g., benzene, 1,3-butadiene, and aldehydes).

7.5.6. Weight-of-Evidence Hazard Narrative: EPA's Proposed Guidelines for Carcinogen Risk Assessment (1996b, 1999)

The combined evidence supports the conclusion that DE is *likely to be carcinogenic to humans* by inhalation and that this hazard applies to environmental exposure conditions. The spectrum of evidence and the inferences drawn provide a substantial case for this hazard potential. The weight of evidence of human carcinogenicity is based on:

- Strong but less than sufficient epidemiologic evidence for a causal association between DE exposure and increased risk of lung cancer among workers in different occupations;
- Evidence of carcinogenicity of DPM in rats and mice by noninhalation routes of exposure (intratracheal instillation, lung implantation, skin painting, and subcutaneous injection); and
- Extensive supporting data including the demonstrated mutagenic and/or chromosomal effects of DE and its organic constituents, suggestive evidence for the local and systemic bioavailability of the organics from DE, and knowledge of the known mutagenic and/or carcinogenic activity of a number of individual organic compounds present on the particles (e.g., PAH and derivatives) and in the DE gases (e.g., benzene, 1,3 butadiene, and aldehydes).

The weight-of-evidence for the lung cancer hazard is considered strong, even though inferences and uncertainties are involved. Major uncertainties include:

- There is scientific debate about the significance of the occupational epidemiologic evidence for a causal association between occupational exposure and increased lung cancer risk. Some experts view the evidence as weak given that most of the relative risk increases are <2.0, whereas others consider the evidence as more than adequate and compelling. With relatively low relative risks (<2.0), the effects of possible confounding exposures or other factors could play a significant role in the risk increases. For example, there is specific concern about whether the effects of smoking, a known cause of lung cancer, has been adequately or fully accounted for in the key studies. In more general terms, the lack of historical exposure data to retrospectively validate estimated DE exposure levels is also a limitation.
- A lack of knowledge about the mode(s) of action of DE lung cancer in humans results in the use of a number of default risk assessment assumptions which, while justifiable by evidence or policy choice, introduce uncertainty. To date, available evidence for the role of DPM, both the adsorbed organics and the carbon core

particle, has been shown only for high exposure conditions in the rat lung. The tumor inducing mode-of-action in the rat lung appears to depend on particle overloading of the lung and subsequent pathology. This sequence is judged not to be relevant for assessing the hazard to humans exposed in the ambient environment. There is virtually no information about the relative role of DE constituents in mediating the carcinogenic effects at lower experimental exposure levels, though hypotheses exist.

While a major uncertainty relates to the incomplete understanding of DE's mode(s) of action for the induction of lung cancer in humans, available data and hypotheses suggest that DE-induced lung carcinogenicity may be mediated by mutagenic and nonmutagenic events from both the particles and the associated organic compounds, although a role for the organics in the gaseous phase cannot be ruled out. Given that there is some evidence for a mutagenic mode of action, a cancer hazard is presumed at environmental exposure levels. This is consistent with EPA's science policy position, which assumes a nonthreshold effect for carcinogens in the absence of definitive data demonstrating a nonlinear or threshold mechanism. It should also be noted that there are not orders of magnitude differences between lower level occupational and higher end environmental exposure levels, in fact, there appears to be exposure overlap. This observation means that an extrapolation of the occupational hazard to lower environmental exposure levels is minimal, and thus, the conclusion of an environmental hazard is supported. Given these circumstances, linear low-dose extrapolation also would be an appropriate default choice in dose-response assessment that is focused on environmental levels of exposure (Chapter 8, Section 8.2). Because of insufficient information, the human carcinogenic potential of DE by oral and dermal exposures cannot be determined.

7.6. EVALUATIONS BY OTHER ORGANIZATIONS

Several organizations have reviewed the relevant data and evaluated the potential human carcinogenicity of DE or its particulate component. The conclusions reached by these organizations are generally comparable to the evaluation made in this assessment using EPA's Carcinogen Risk Assessment Guidelines. A summary of available evaluations conducted by other organizations is provided in Table 7-9.

7.7. CONCLUSION

It is concluded that environmental exposure to DE may present a lung cancer hazard to humans. The particulate phase appears to have the greatest contribution to the carcinogenic effect, both the particle core and the associated organic compounds have demonstrated

Table 7-9. Evaluations of DE as to human carcinogenic potential

Organization	Human data	Animal data	Overall evaluation
NIOSH (1988)	Limited	Confirmatory	Potential occupational carcinogen
IARC (1989)	Limited	Sufficient	Probably carcinogenic to humans
IPCS (1996)	N/A[a]	N/A	Probably carcinogenic to humans
California EPA (1998)	"Consistent evidence for a causal association"	"Demonstrated carcinogenicity"	DPM as a "toxic air contaminant" (California Air Resources Board)
NTP (2000)	"Elevated lung cancer in occupationally exposed groups"	"Supporting animal and mechanistic data"	DPM-Reasonably anticipated to be a carcinogen

[a]Not applicable.

carcinogenic properties, although a role for the DE gas-phase components cannot be ruled out. Using either EPA's 1986 Guidelines for Carcinogen Risk Assessment (U.S. EPA, 1986) or the proposed revisions (U.S. EPA, 1996b, 1999), DE is judged to be a probable human carcinogen, or likely to be carcinogenic to humans by inhalation, respectively. The weight of evidence for potential human carcinogenicity for DE is considered strong, even though inferences are involved in the overall assessment. Major uncertainties of the hazard assessment include the following unresolved issues:

- There has been a considerable scientific debate about the significance of the available human evidence for a causal association between occupational exposure and increased lung cancer risk. Some experts view the evidence as weak given that most of the relative risk increases are <2.0 whereas others consider the evidence as more than adequate and compelling. Additionally, there is debate about whether the effects of smoking have been adequately accounted for in key studies, as well as the lack of historical DE exposure data to retrospectively validate estimated DE exposure levels for the available studies.
- A lack of knowledge about the mode(s) of action for DE lung cancer in humans results in the use of a number of default risk assessment assumptions which, while justifiable by evidence or policy choice, introduce uncertainty. To date, available evidence for the role of DPM, both the adsorbed organics and the carbon core particle, has been shown only for high-exposure conditions in the rat lung. The

tumor-inducing mode of action in the rat lung appears to depend on particle overloading of the lung but this is judged to be not relevant for assessing the human hazard of ambient exposures. There is virtually no information about the relative role of DE constituents in mediating carcinogenic effects at lower experimental or environmental exposure levels. Furthermore, there is only a limited understanding regarding the relationship between DPM particle size and carcinogenicity.

- DE is present in ambient PM (e.g., $PM_{2.5}$ or PM_{10}); however, a cancer hazard for ambient PM has not been identified, as of 1996 (EPA 1996b). An updated evaluation is expected in 2002.

Additional research is needed to address these issues to reduce the uncertainty associated with the potential cancer hazard of exposure to DE.

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8. DOSE-RESPONSE ASSESSMENT: CARCINOGENIC EFFECTS

8.1. INTRODUCTION

Dose-response assessment for carcinogenicity defines the relationship between the exposure/dose of an agent and the degree of carcinogenic response, and evaluates potential cancer risks to humans at exposure/dose levels of interest. Most often, the exposure/dose response of interest is well below the range of observation. As a result, dose-response assessment usually entails an extrapolation from the generally high exposures in studies on humans or laboratory animals to the exposure levels expected from human contact with the agent in the environment. It also includes considerations of the scientific validity of these extrapolations based on available knowledge about the underlying mechanisms or modes of carcinogenic action. The complete sequence of biological events that must occur to produce an adverse effect is defined as "mechanism of action." In cases where only partial information is available, the term "mode of action" is used to refer to the mechanisms for key events that are judged to be sufficient to inform about the shape of the dose-response curve beyond the range of observation.

This chapter evaluates the available exposure/dose-response data and discusses extrapolation issues in estimating the cancer risk of environmental exposure to diesel engine exhaust (DE). It concludes that available data are inadequate to confidently derive a cancer unit risk estimate for DE or its component, diesel particulate matter (DPM). Unit risk is one possible output from a dose-response assessment and is defined as the estimated upper-bound cancer risk at a specific exposure or dose from a continuous average lifetime exposure to a carcinogen (in this case, cancer risk per $\mu g/m^3$ of DPM). In lieu of unit-risk-based quantitative risk estimates, this chapter provides a perspective about potential risk at environmental levels. Subsequent sections of this chapter discuss issues related to dose-response evaluation of human cancer risk for DE exposure, including the target tumor site and underlying mode of action, suitable measures of dose, approaches to low-dose extrapolation, and appropriate data to be used in the dose-response analysis. This is followed by a simple analysis of the possible degree and extent of risk from environmental exposure to DE.

Appendix C provides a summary review of dose-response assessments conducted to date by other organizations and investigators. These risk estimations were performed on the basis of either epidemiologic and/or experimental data. As concluded in Section 8.5, EPA finds that available epidemiologic data are too uncertain to confidently derive a unit risk estimate for DE-induced lung cancer, and that rat data are not suitable for estimating human risk. Nevertheless, a review of dose-response evaluations is provided in the appendix for historical context.

8.2. MODE OF ACTION AND DOSE-RESPONSE APPROACH

According to EPA's 1996 Proposed Guidelines for Carcinogen Risk Assessment (U.S. EPA, 1996), dose-response assessment is performed in two steps: assessment of observed data to derive a point of departure, followed by extrapolation to lower exposures to the extent necessary. Human data are always preferred over animal data, if available, as their use obviates the need for extrapolation across species. Mode-of-action information is important to dose-response evaluation, as it informs about the relevance of animal data to assessment of human hazard and risk, the shape of the dose-response curve at low doses, and the most appropriate measure(s) of exposure/dose and response.

If there are sufficient quantitative data (humans and/or animals) and adequate understanding of the carcinogenic process, the preferred approach is to use a biologically based model for both the range of observation and extrapolation below that range. Otherwise, as a default procedure, a standard mathematical model is used to curve-fit the observed dose-response data to obtain a point of departure, which is the lower 95% confidence limit of the lowest exposure/dose that is associated with a selected magnitude of excesses of cancer risk in human or animal studies. Default approaches for low-dose extrapolation should be consistent with the current understanding of the mode(s) of action. These include approaches that assume linearity or nonlinearity, or both. Linear extrapolation is used when there is insufficient understanding of the modes of action, or the mode-of-action information indicates that the dose-response curve at low dose is, or is expected to be, linear. Linear extrapolation involves the calculation of the slope of the line drawn from the point of departure to zero exposure or dose (i.e., above background). When there is sufficient evidence for a nonlinear mode of action but not enough data to construct a biologically based model for the relationship, a margin of exposure is used as a default approach. A margin-of-exposure analysis compares the point of departure (i.e., the lowest exposure associated with some cancer risk) with the dose associated with the environmental exposure(s) of interest and determines whether or not the exposure margins are adequate. Both default approaches may be used for a tumor response if it is mediated by linear and nonlinear modes of action. The dose-response approaches considered in this chapter follow the principles of EPA's guidelines for carcinogen risk assessment (U.S. EPA, 1986, 1996, 1999).

As reviewed in Chapter 7, there is substantial evidence from combined human and experimental evidence that DE is likely to pose a cancer hazard to humans at anticipated levels of environmental exposure. The critical target organ is the lung. Evidence exists for a causal relationship between risk for lung cancer and occupational exposure to DE in certain occupational workers such as railroad workers, truck drivers, heavy equipment operators, transit workers, etc.

The mechanism(s) by which DE induces lung cancer in humans has not been established. As discussed in Chapter 7, Section 7.4, several modes of action have been postulated on the basis of available mechanistic studies, including direct DNA effects (gene mutations) by the adsorbed organic compounds and the gaseous fractions, indirect DNA effects (e.g., chromosomal aberrations, sister chromatid exchange [SCE], micronuclei) by DE and DPM, oxidative DNA damage by DPM via release of reactive oxygen species (ROS), and particle-induced chronic inflammatory response leading to epithelial cell cytotoxicity and regenerative cell proliferation via release of cytokines, growth factors, and ROS. It is likely that a combination of modes of action contributes to the overall carcinogenic activity of DE, and that the relative contribution of the various modes of action may vary with different exposure levels.

In the absence of a full understanding of the relative roles of DE constituents in inducing lung cancer in humans, and because there is some evidence for a mutagenic mode of action, linear low-dose extrapolation is an appropriate and prudent default choice for modeling dose-response, and if needed, risk extrapolation from high to lower exposures (U.S. EPA, 1986, 1996, 1999). It also should be noted that there are not order of magnitude differences between lower levels of occupational and higher end environmental exposure estimates. In fact, there appears to be exposure overlap. This means that an extrapolation of the occupational hazard to lower environmental exposure levels is minimal. Other individuals and organizations have used either linear risk extrapolation models and/or mechanistically based models to estimate cancer risk from environmental exposure to DE (e.g., IPCS, 1996; Cal EPA, 1998; also see Appendix C). These were examined but not found to provide a compelling basis for unit risk derivation because of database uncertainty and/or recent understandings about the suitability of the rat data for modeling a dose-response at environmental levels of exposure.

For example, there are an observable series of events showing how DE causes lung tumors in the rat under high exposure experimental conditions. Prolonged exposure to high concentrations of a variety of poorly soluble particles including DPM (and its carbon core, devoid of organics) causes lung tumors in rats through a mode of action that involves impairment of lung clearance mechanisms (referred to as "lung overload response"), leading to persistent chronic inflammation, cell proliferation, metaplasia, and ultimately the development of lung tumors (ILSI, 2000). Because this mode of action is not expected to be operative at environmental exposure conditions, the rat lung tumor dose-response data are not considered suitable for predicting human risk at low environmental exposure concentrations.

8.3. USE OF EPIDEMIOLOGIC STUDIES FOR QUANTITATIVE RISK ASSESSMENT

As discussed above, human data are considered more appropriate than animal data in estimating environmental cancer risk for DE. Still, there are many uncertainties in using the available epidemiologic studies that have quantitative exposure data to extrapolate the risk to the general population for ambient-level DE exposure.

8.3.1. Sources of Uncertainty

The greatest uncertainty in estimating DE-induced cancer risk from epidemiologic studies is the lack of knowledge of actual historical exposures for individual workers, particularly for the early years. Reconstruction of historic exposures is based on job exposure categories, industrial hygiene measurements, and assumptions made about exposure patterns.

Another related uncertainty is the choice of markers of exposure to DE. As discussed above, the modes of action for DE-induced lung cancer in humans are not fully understood, and thus the best measure of DE exposure is unknown. Various markers of DPM (e.g., respirable-sized particles, elemental carbon [EC]) have been used as dosimeters for DE. Though EC is more sensitive and more specific than respirable-sized particles, both are considered appropriate dosimeters. Related to the choice of dosimeter, having a relatively constant relationship between the organics (on the particle) and the particle mass would be consistent with a possible mode-of-action role for both the particle and organic components. However, evidence of such a constant historic relationship remains unclear. As discussed in Chapter 2 (Section 2.5.2), it appears that newer model on-road engine exhaust has a lesser quantity of organics adsorbed onto the particle compared to older model engines. On the other hand, with regard to DE in the ambient air, there is significant variation in the amounts of DPM organic components emitted because of aged vehicles in the on-road fleet, driving patterns, and the additional presence of nonroad DE (e.g., marine vessels and locomotives, which generally use older technology than on-road engines).

Another major uncertainty associated with many of the DE epidemiologic studies was the inability to fully control for smoking effects, resulting in possible errors in estimating relative risk increases. Changes in adjustments for smoking could result in considerable changes in relative risk, because smoking has a much larger effect on relative lung cancer risk than is likely for DE. It is difficult to effectively control for a smoking effect in a statistical analysis because cigarette smoke contains an array of biologically active compounds and affects multiple steps of carcinogenesis, thus probably making smokers more susceptible to DE-induced lung cancer than are nonsmokers. A statistical analysis would not be able to adjust for such an effect without having a detailed record of the smoking history of individuals.

A potential uncertainty involves the use of occupational worker data to extrapolate cancer hazard risk to the general population and sensitive subgroups. By sex, age, and general health status, workers are not fully representative of the general population. For example, there is virtually no information to determine whether infants and children or people in poor health respond differently to DE exposure than do workers. Finally, the use of linear low-dose extrapolation may contribute to uncertainty in estimating environmental risks.

8.3.2. Evaluation of Key Epidemiologic Studies for Potential Use in Quantitative Risk Estimates

Among the available epidemiologic studies, only the railroad worker studies and the Teamster truck driver studies have reconstructed quantitative historical exposure data for possible use in deriving a unit risk estimate for DE-induced lung cancer. This section evaluates the strengths and limitations of these data and their suitability for dose-response analysis.

8.3.2.1. *Railroad Worker Studies*

Garshick and colleagues conducted both cohort and case-control studies of lung cancer mortalities among U.S. railroad workers registered with the U.S. Railroad Retirement Board (RRB).

In the cohort study (Garshick et al., 1988), lung cancer mortality was ascertained through 1980 in 55,407 railroad workers, age 40 through 64 in 1959, with at least 10 years of work in selected railroad jobs (39 job titles). The cohort was selected on the basis of job titles in 1959. Industrial hygiene evaluations and descriptions of job activities were used to classify jobs as exposed or unexposed to diesel emissions. Workers with recognized asbestos exposure were excluded from the job categories selected for study. However, a few jobs with some potential for asbestos exposure were included in the cohort. Each subject's work history was determined from a yearly job report filed by his employer with the RRB from 1959 until death or retirement. The year 1959 was chosen as the effective start of DE exposure for this study because by this time 95% of the locomotives in the United States were diesel powered. The author reported statistically significant relative risk increases of 1.57 for the 40-44 year age group and 1.34 for the 45-49 year age group, after exclusion of workers exposed to asbestos and controls for smoking. Age groups were determined by their ages in 1959.

A main strength of the cohort study is the large sample size (55,407), which allowed sufficient power to detect small risks. This study also permitted the exclusion of workers with potential past exposure to asbestos. The stability of job career paths in the cohort ensured that of the workers 40 to 64 years of age in 1959 classified as DE-exposed, 94% of the cases were still in DE-exposed jobs 20 years later.

The main limitation of the cohort study is the lack of quantitative data on exposure to DE. The number of years exposed to DE was used as a surrogate for dose. The dose, based on duration of employment, has inaccuracies because individuals were working on both steam and diesel locomotives during the transition period. It should be noted that the investigators included only exposures after 1959; the duration of exposure prior to 1959 was not known. Other limitations of this study include its inability to examine the effect of years of exposure prior to 1959 and the less-than-optimal latency period for lung cancer expression. No adjustment for smoking was made in this study. For a detailed description of this study please refer to Chapter 7, Section 7.2.1.7.

Garshick and colleagues also conducted a case-control study of railroad workers who died of lung cancer between 1981 and 1982 (Garshick et al., 1987). The author reported statistically significant increased odds ratios (with asbestos exposure accounted for) of 1.41 (95% confidence interval [CI] = 1.06, 1.88) for the ≤64 year age group and 1.64 (95% CI = 1.18, 2.29) for the ≤64 year age group with ≥20 years of exposure when compared with the 0-4 year exposure group. The population base for this case-control study was approximately 650,000 active and retired male U.S. railroad workers with 10 years or more of railroad service who were born in 1900 or later. The cases were selected from deaths with primary lung cancer, which was the underlying cause of death in most cases. Each case was matched to two deceased controls whose dates of birth were within 2.5 years of the date of birth of the case and whose dates of death were within 31 days of the date of death noted in the case. Controls were selected randomly from workers who did not have cancer noted anywhere on their death certificates and who did not die of suicide or of accidental or unknown causes. A total of 1,256 cases and 2,385 controls were selected for the study. Among younger workers, approximately 60% had exposure to DE, whereas among older workers, only 47% were exposed to DE. DE exposure surrogates for workers were similar to those in the cohort study. Asbestos exposure was categorized on the basis of jobs held in 1959, or on the last job held if the subject retired before 1959. Smoking history information was obtained from the next of kin.

The strengths of the case-control study are consideration of confounding factors such as asbestos exposure and smoking; classification of DE exposures by job titles and industrial hygiene sampling; and exploration of interactions between smoking, asbestos exposure, and DE exposure. Major limitations of this study include (a) possible overestimation of cigarette consumption by surrogate respondents; (b) use of the Interstate Commerce Commission (ICC) job classification as a surrogate for exposure, which may have led to misclassification of DE exposure jobs with low intensity and intermittent exposure, such as railroad police and bus drivers, as unexposed; (c) lack of data on the contribution of unknown occupational or environmental exposures and passive smoking; and (d) a suboptimal latency period of 22 years, which may not be long enough to observe a full expression of lung cancer. For a detailed description of this study, please see Chapter 7, Section 7.2.2.4.

As a part of these epidemiologic studies, Woskie et al. (1988a) conducted an industrial hygiene survey in the early 1990s for selected jobs in four small northern railroads. DE exposure was considered as a yes/no variable based on job in 1959 and estimated years of work in a diesel- exposed job as an index of exposure. Thirty-nine job titles were originally identified and were then collapsed into 13 job categories and, for some statistical analyses, into 5 categories (clerks, signal maintainers, engineers/firers, brakers/conductors/hostlers, and shop workers) (Woskie et al., 1988b; Hammond et al., 1988). As discussed below, these exposure estimations were used by Crump et al. (1991) and by Cal EPA (1998) for their dose-response analyses.

8.3.2.1.1. ***Potential for the data to be used for dose-response modeling.*** Both case-control and cohort studies can be used for dose-response analysis if exposure for each worker is available. Control of a smoking effect is important when lung cancer is the disease of interest. However, as discussed previously (see Section 8.3.1), one may not be able to control smoking completely in a dose-response analysis because of the lack of detailed records of the smoking history of individuals.

Garshick et al. (1988) reported a positive relationship of relative risk and duration of exposure by modeling age in 1959 as a covariate in an exposure-response analysis. The positive relationship disappeared when attained age was used instead of age in 1959, and a negative dose-response was observed (Crump et al., 1991). This negative dose-response continued to be upheld in a subsequent reanalysis (Crump, 1999). Garshick (letter from Garshick, Harvard Medical School, to Chao Chen, U.S. EPA, dated August 15, 1991) performed further analysis and reported that the relationship between years of exposure and risk of lung cancer, when adjusted for attained age and calendar year, was flat to negative depending upon which model was used. In contrast, California EPA (Cal EPA, 1998) found a positive dose-response by using age in 1959 but allowing for an interaction term of age and calendar year in the model.

Crump et al. (1991) also found, and Garshick (letter from Garshick, Harvard Medical School, to Chao Chen, U.S. EPA, dated August 15, 1991) confirmed, that in the years 1977-1980 the death ascertainment was not complete. About 20% to 70% of deaths were unaccounted for, depending upon the calendar year. Further analysis, based on job titles in 1959 and limited to deaths occurring through 1976, showed that the youngest workers still had the highest risk of dying of lung cancer.

Extensive statistical analyses were conducted by a panel convened by HEI (1999) to investigate the utility of the railroad worker cohort for use in dose-response based quantitative risk assessment. Seven models were used to test the data, and the models were formed by varying a number of covariates in different combinations. The covariates included employment duration, cumulative exposure with and without correction for background exposure, and three job categories: clerks and signalmen, train workers (which include engineers/firers/brakers/

conductors), and shop workers. The coefficient for each covariate in a model is used to calculate relative risk for the associated covariate. In summary, the panel found that effects of exposure as defined by an exposure-response curve were either flat or negative in all of the models. In these analyses, relative risk for each job category was assumed to be constant with respect to age. Further exploration of the data showed that the relative risk for train workers was not constant. The panel's statistical analyses also revealed the complexity of the data and difficulties of providing an adequate summary measure of effect, probably because calendar year and cumulative exposure are highly correlated, which makes it especially difficult to sort out their separate effects. The difficulty of providing an adequate measure of DE effect was further demonstrated in Table C.3 of the HEI report, in which negative or positive effects for cumulative exposure (with background exposure adjustment) were obtained depending on whether or not job category was included in the model. A similar review of the divergent views about the railroad worker dose response also can be found in Chapter 7, Section 7.2.1.7.

The diverging results about the presence or absence of exposure response for the railroad worker data have become a source of continuing debate about the suitability of these data for estimating DE cancer risk. Although it is difficult to identify the exact reason for the diverging findings, the "age effect" appears to be a main source of uncertainty because age, calendar year, and cumulative exposure are not mutually independent. Therefore, an ideal dose-response analysis would account for the ages when exposure to DE began and terminated, along with the attained age and other covariates for each person, using age-dependent exposure concentration rather than cumulative exposure over lifetime as a dosimeter. This analysis would be possible for the railroad workers if information were available on the ages when exposure began and terminated.

Given the equivocal evidence for positive exposure response, EPA has not derived a unit risk on the basis of the available railroad worker data. This determination should not be construed, however, to imply that the railroad worker studies contain no useful information on lung cancer risk from exposure to DE.

8.3.2.2. *Teamsters Union Trucking Industry Studies*

Steenland et al. (1990) conducted a case-control study of lung cancer deaths in the Central States Teamsters Union to determine the risk of lung cancer among different trucking industry occupations. The study found statistically significant increased odds ratios for lung cancer of 1.89 and 1.64, depending on years of employment. Cases comprised all deaths from lung cancer (1,288). The 1,452 controls comprised every sixth death from the entire file, excluding deaths from lung cancer, bladder cancer, and motor vehicle accidents. Individuals were required to have 20 years tenure in the union to be eligible to claim benefits.

Detailed information on work history and potential confounders such as smoking, diet, and asbestos exposure was obtained by questionnaire. On the basis of interview data and the 1980 census occupation and industry codes, subjects were classified either as nonexposed or as having held other jobs with potential DE exposure. The Teamsters Union work history file did not have information on whether men drove diesel or gasoline trucks, and the four principal occupations were long-haul drivers, short-haul or city drivers, truck mechanics, and dockworkers. Subjects were assigned the job category in which they had worked the longest.

The main strengths of the study are the availability of detailed records from the Teamsters Union, a relatively large sample size, availability of smoking data, and measurement of possible asbestos exposures. Some limitations of this study include possible misclassifications of exposure and smoking habits, as information was provided by next-of-kin and lack of sufficient latency to observe lung cancer excess.

Steenland et al. (1998) conducted an exposure-response analysis by supplementing the data from their earlier case-control study of lung cancer and truck drivers in the Teamsters Union with exposure estimates based on a 1990 industrial hygiene survey of EC exposure (Zaebst et al., 1991), a surrogate for DE in the trucking industry. Available data indicate that exposure to workers in the trucking industry in 1990 averaged 2-27 $\mu g/m^3$ of EC. The 1990 exposure information was used by Steenland as a baseline exposure measurement to reconstruct past exposure (in the period of 1949 to 1983) by assuming that the exposure for workers in different job categories is a function of highway mileages traveled by heavy-duty vehicles and efficiency of the engine over the years.

The industrial hygiene survey by Zaebst et al. (1991) of EC exposures in the trucking industry provided exposure estimates for each job category in 1990. The EC measurements were generally consistent with the epidemiologic results, in that mechanics were found to have the highest exposures and relative risk, followed by long-haul and short-haul drivers. Dockworkers who had the lowest exposures also had the lowest relative risks.

Past exposures were estimated assuming that they were a function of (a) the number of heavy-duty trucks on the road, (b) the particulate emissions (grams/mile) of diesel engines over time, and (c) leaks from truck exhaust systems for long-haul drivers. Estimates of past exposure to EC (as a marker for DE exposure) were made based on the assumption that average 1990 levels for a particular job category could be assigned to all subjects in that category, and that levels prior to 1990 were directly proportional to vehicle miles traveled by heavy-duty trucks and the estimated emission levels of diesel engines. For example, a 1975 exposure level was estimated by the following equation: 1975 level = 1990 level × (vehicle miles 1975/vehicle miles 1990) × (emissions 1975/emissions 1990). Once estimates of exposure for each year of work history were derived for each subject, analyses were conducted by cumulative level of estimated carbon exposure. As with most epidemiologic studies, the endeavors to reconstruct exposures for epidemiologic studies are subject to uncertainties.

8.3.2.2.1. ***Potential for the data to be used for dose-response modeling.*** Steenland et al. (1998) analyzed their case-control data and showed a significant positive trend in lung cancer risk with increasing cumulative exposure to DE. The study by Steenland et al. (1998) could provide a valuable database for calculating unit risk for DE emissions. The strength of this data set is that the smoking histories of workers were obtained to the extent possible. Smoking is especially important in assessing the lung cancer risk due to DE exposure because smoking has much higher relative risk (or odds ratio) of lung cancer than does DE. In the Steenland et al. (1998) study, the overall (ever-smokers vs. nonsmokers) odds ratio for developing lung cancer from smoking is about 7.2, which is about fivefold larger than the 1.4 relative risk increase from a large synthesis of many DE epidemiologic studies. It is possible that a modest change of information on smoking and diesel exposure might alter the conclusion and risk estimate.

Another strength of the Teamster data for use in environmental risk assessment for the general population is that exposures of Teamsters are closer to ambient exposures than are those of railroad workers. The Teamsters Union truck driver case-control workers had cumulative exposure ranging from 19 to 2,440 $\mu g/m^3$-years of EC, with the median and 95th percentile, respectively, of 358 and 754 $\mu g/m^3$-years of EC. The median and 95th percentile of an environmentally equivalent exposure would be 3 and 6 $\mu g/m^3$, respectively.[1] These environmental equivalent exposures for the Teamsters Union truck drivers are close to the estimated ambient exposures of $<1.0\ \mu g/m^3$ to $4.0\ \mu g/m^3$ (see Table 2-31).

Steenland et al. (1998) stated that their risk assessment is exploratory because it depends on estimates about unknown past exposures. An EPA reanalysis of DE exposure for this study is underway. With a revised exposure assessment, a reevaluation of the dose-response would be appropriate. In a recent review, HEI (1999) concluded that the Teamsters studies may be useful for quantitative risk assessment, but significant further evaluation and development are needed. Given the ongoing reanalysis of exposure, EPA will not, at this time, use the Steenland et al. (1998) occupational risk assessment findings to derive equivalent environmental parameters and cancer unit risk estimates.

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[1]The conversion assumes (a) DPM = 40% EC as reported by Steenland et al. (1998), (b) environmental equivalent exposure is approximately = 0.21 × occupational exposure, and (c) 70 $\mu g/m^3$-years is equivalent to a lifetime of exposure at 1 $\mu g/m^3$.

8.3.3. Conclusion

Even though available evidence supports a conclusion that DE is likely to be a human lung carcinogen, the conclusion of the dose-response evaluation is that the available data are not sufficient to confidently estimate a cancer unit risk or unit risk range. The absence of such a cancer unit risk for DE limits the ability to quantify, with confidence, the potential impact of the hazard on exposed populations. Two significant short-term activities are underway to improve the epidemiologic database for dose-response assessment: (1) a follow-up study to correct the undercounting of mortality in the Garshick et al. (1988) railroad worker study, and (2) an EPA-sponsored effort to improve the exposure estimates for Teamsters Union truck drivers (Steenland et al., 1998). EPA will monitor this ongoing research as well as the ongoing NCI-NIOSH study of nonmetal miners and the recently NCI-funded epidemiologic study of truck drivers. As these studies or other new data become publicly available, EPA will reconsider the merit of conducting additional dose-response analysis and unit risk derivation.

8.4. PERSPECTIVES ON CANCER RISK

Although the available data are considered inadequate to confidently estimate a cancer unit risk, this does not mean that there is no information about the possible cancer risk of DE. To examine the significance of the potential cancer hazard from environmental exposure to DE, all relevant epidemiologic and exposure data as well as simple risk assessment tools can be used. Such an approach does not produce confident estimates of cancer unit risk. Rather, these exploratory approaches provide a perspective on the possible magnitude of cancer risk and thus insight about the potential significance of the hazard. This section describes approaches and methods that are used to gauge the magnitude of possible cancer risk from ambient exposure to DE.

The first approach involves examining the differences between the levels of occupational and ambient environmental exposures, while assuming that cancer risk to DE is linearly proportional with cumulative lifetime exposure. Risks to the general public would be low in comparison to occupational risk if the differences in exposure are large (e.g., about three orders of magnitude or more). On the other hand, if the exposure differences are smaller (i.e., within one to two orders of magnitude), environmental risks become more of a concern as they approach the range of workers' risk observed in epidemiologic studies of past occupational exposures. This assumes that the carcinogenic potency of historical and current-day DE is not significantly different, a reasonable assumption, though not without uncertainty.

Table 8-1 shows occupational exposure estimates for some of the occupational groups where increased relative risks of lung cancer (e.g., meta-analyses) have been analyzed. Given that no statistical properties associated with these exposure estimates are known, their use here is

Table 8-1. DPM exposure margins (ratio of occupational ÷ environmental exposures)

Occupational group	Estimated occupational exposure/concentration ----------------------- Environmental equivalent [a]	Exposure margin ratio - average environmental exposure for 0.8 $\mu g/m^3$ of environmental exposure[b]	Exposure margin ratio - high-end environmental exposure for 4.0 $\mu g/m^3$ of environmental exposure[b]	Reference[c]
Public transit workers	15-98 $\mu g/m^3$ --------------------- 3-21 $\mu g/m^3$	4-26	0.8-5	Birch and Cary, 1996
U.S. railroad workers	39-191 $\mu g/m^3$ --------------------- 8- 40 $\mu g/m^3$	10-50	2-10	Woskie et al., 1988b
Fork Lift Operators	7-403 $\mu g/m^3$ ----------------- 1- 85 $\mu g/m^3$	2-106	0.37-21	Groves and Cain, 2000[d]
High end boundary estimate	1200 $\mu g/m^3$ ----------------- 252 $\mu g/m^3$	315	63	see text discussion in Section 8.4

[a] Equivalent environmental exposure = occupational exposure × 0.21, see Chapter 2, Section 2.4.3.1, some values are rounded.
[b] 0.8 $\mu g/m^3$ = average 1990 nationwide on-road exposure estimate from HAPEM model; the companion rural estimate is 0.5 $\mu g/m^3$, and 4 $\mu g/m^3$ is
a high-end estimate. The 1996 nationwide average is 0.7 $\mu g/m^3$, the companion rural estimate is 0.2 $\mu g/m^3$; however, a high-end estimate is not available for 1996. See Chapter 2, Sections 2.4.3.2.1 and 2.4.3.2.2.
[c] See Table 2-27 for more details about Birch and Cary, Woskie.
[d] 403 $\mu g/m^3$ is a 99 percentile estimate of EC/$\mu g/m^3$, the DPM equivalent of the EC measurement can be estimated as DPM = EC x 0.62 to 1.31.

not intended to be precise or to match with specific epidemiologic data, but rather to provide a broad range of possible exposures in the workplace. The purpose is to identify a high- and low-end occupational exposure consistent with the occupational groups of interest and then to compare these to estimates of environmental exposure. Given the special interest in discerning the lower risk magnitude, especially to see if the lower risk might be above or below one in 1 million, a high-end exposure estimate would be used, and as discussed later, the occupational exposure can be arbitrarily increased (e.g., toward an extreme value) to ensure that a low end of risk is identified, consistent with the reported occupational risk increases. Environmental exposure data from on-road vehicle emissions are based on the 1990 nationwide exposure estimates from the HAPEM model (see Chapter 2, Section 2.4.3.2.1). Both average (0.8 $\mu g/m^3$) and high-end exposures (4 $\mu g/m^3$) are used.

In order to compare differences between occupational and environmental exposures, it is necessary to convert occupational exposure to continuous exposure (i.e., environmental equivalent exposure = 0.21 × occupational exposure, see Section 2.4.3.1). Accordingly, Table 8-1 shows equivalent environmental levels and the ratios of occupational to environmental exposures, referred to as exposure margins (EMs). An EM of 1 or less indicates that environmental exposure is comparable to occupational exposure. An EM >1 means that the occupational equivalent exposure is greater than the benchmarked environmental exposure.

Table 8-1 shows that the EMs based on the average nationwide environmental exposure (0.8 $\mu g/m^3$) approach three orders of magnitude. EM's that range from 1 to 10 also can be viewed as showing that adjusted occupational exposures are relatively close to the ambient environmental levels that were chosen as benchmarks. This closeness sets the stage for less uncertainty in hazard and risk extrapolation from the occupational to environmental setting. It also raises a concern that risks to the general public could approach worker risks that were observed in the occupational epidemiologic studies. Table 8-1 is based upon DE exposure estimates from on-road sources only. With the addition of exposure from nonroad sources, the average nationwide-based EM ratios would be lower. For example, using 1996 exposure data for urban populations (Table 2-30), the exposure from on-road sources is 0.5 $\mu g/m^3$, whereas nonroad sources contribute 0.9 $\mu g/m^3$, for a total of 1.4 $\mu g/m^3$. Using this exposure value in place of the EM calculation of Table 8-1 (1990 estimate of 0.8) produces a nearly 43% reduction in the EM ratio. A comparison of EM changes for the high-end on-road plus nonroad exposure is not possible at the present time because the 1996 data have not yet been modeled to obtain a high-end value similar to the 1990 value of 4.0 $\mu g/m^3$.

A second approach to explore the possible cancer risk to the general population from environmental exposure to DE is more quantitative. One begins by examining the risk observed in DE-exposed workers and then making reasoned assumptions as to how these risks can be translated to environmental exposure conditions. Such an approach involves three major assumptions: (1) the excess lung cancer risk as shown in numerous epidemiologic studies and in two meta-analyses is indeed due to DE exposure, (2) the increased lung cancer risk over background is linearly proportional to the lifetime exposure to DE, and (3) the past DE exposure for workers has the same cancer-inducing potential as the current DE in ambient air. Any of these assumptions could have an impact on the possible environmental risk by either increasing or decreasing the risk estimates, including the possibility of a lower or zero risk at environmental levels.

As reviewed in Chapter 7, Section 7.2, numerous epidemiologic studies have shown increased lung cancer risks (i.e., some are deaths, some are cases) among workers in certain occupations. The relative risks or odds ratios range from 1.2 to 2.6. Two independent meta-analyses show smoking-adjusted relative risk increases of 1.35 (Bhatia et al., 1997) and 1.47 (Lipsett and Campleman, 1999). For this analysis, a relative risk of 1.4 is selected as a reasonable estimate. This risk means that the workers faced an extra risk 40% higher than the

5% background lifetime lung cancer risk in the U.S. population.[2] Thus, using the relationship [excess risk = (relative risk-1) × background risk], these DE-exposed workers would have an excess risk of 2% (10^{-2}) (i.e., to develop lung cancer) due to occupational exposure to DE [(1.4 - 1) × (0.05) = 0.02]. The validity of this interpretation depends on an important assumption: that the observed incremental risk of 40% was due to DE exposure alone and not to other unknown extraneous factors. It should be noted, however, that the conclusion about the risk perspective would not be changed even if the incremental risk of 40% were greatly reduced (e.g., to 20%); the conclusion would be changed only if almost all of the incremental risk were due to nondiesel factors.

Next, one would consider the EM (i.e., the EM ratio) between the occupational exposures and general-population environmental exposures. DPM concentrations in the workplace, used as a surrogate for worker exposure, are shown for three occupational worker groups in Table 8-1. These range from 7-403 $\mu g/m^3$ (with an equivalent continuous exposure of 1-85 $\mu g/m^3$). These worker groups are consistent with many of those cited in the meta-analyses. For this exploratory risk estimation approach, we want to intentionally adopt a high-end boundary exposure estimate that is unlikely to be exceeded, so that a lower bounding of the risk would be identified. An occupational boundary exposure of 1,200 $\mu g/m^3$ with its environmental equivalent estimated value of 252 $\mu g/m^3$ has been purposefully adopted to represent a high-end boundary estimate. This happens to be about three times the forklift operator value shown in Table 8-1, and clearly a high-end estimate when Table 2-27 is examined, exclusive of the estimates for miners which are not included in the meta-analyses. It should be noted once again that none of these estimates are intended to be precise.

Table 8-1 shows that the DPM exposure margin ratio between occupational and environmental exposure, using the nationwide average exposure value of 0.8 $\mu g/m^3$, may range from 2 to 315 when the boundary estimate is used, and range from 0.37-63 when 4.0 $\mu g/m^3$ is used as a high-end environmental benchmark exposure. Some of these extreme values will be used, as discussed in the next paragraph.

Risks from environmental exposure depend on the shape of the dose-response curve in the range between occupational and environmental exposures. If lifetime risks in this range were

[2]The background rate of 0.05 is an approximated lifetime risk calculated by the method of lifetable analysis using age-specific lung cancer mortality data and probability of death in the age group taken from the National Health Statistics (HRS) monographs of Vital Statistics of the U.S. (Vol. 2, Part A, 1992). Similar values based on two rather crude approaches also can be obtained: (1) $59.8 \times 10^{-5} / 8.8 \times 10^{-3} = 6.8 \times 10^{-2}$ where 59.8×10^{-5} and 8.8×10^{-3} are, respectively, the crude estimates of lung cancer deaths (including intrathoracic organs, estimated to be less than 105 of the total cases) and total deaths for 1996 reported in Statistical Abstract of the U.S. (Bureau of the Census, 1998, 118th Edition), and (2) 156,900/270,000,000 × 76 = 0.045, where 156,900 is the projected lung cancer deaths for the year 2000 as reported in Cancer Statistics J of the American Cancer Society, Jan/Feb 2000), 270,000,000 is the current U.S. population, and 76 is the expected lifespan.

to fall proportionately with reduced exposure, and if one assumes that past occupational exposures were at the high-boundary end, then the risk from average environmental exposure could be between 10^{-5} and 10^{-4} ($0.02 \div 315 = 6 \times 10^{-5}$). On the other hand, if occupational exposures for different groups were lower, risks from environmental exposure would be higher. For example, if occupational concentrations or exposures were closer to 100 $\mu g/m^3$, a value that is represented in several data sets shown in Table 8-1 (with an equivalent environmental exposure of 21 $\mu g/m^3$ and a corresponding EM of 26), then risks from environmental exposure would approach 10^{-3} ($0.02 \div 26 = 8 \times 10^{-4}$). If lifetime risks were to fall more than proportionately, then risks would be lower. The latter two sources of dose-response uncertainty (i.e., the actual occupational exposures and the shape of the dose-response curve at low exposures) cannot be further defined with currently available information. Use of higher environmental exposures (>0.8 up to 4.0 $\mu g/m^3$) lowers the EM value and increases the estimated risk.

The magnitude of the estimated lifetime cancer risk derived from using a very high-end occupational-to-environmental exposure difference, establishes a reasonable basis to believe that the general population could face possible risks high enough to be of concern. This does not directly address the segments of the population that may be at highest risk: those who are additionally exposed to nonroad sources of DE and children who may be more sensitive to early-life DE exposure, if not in fact, a longer period of potential lifetime exposure.

The analyses presented above are not intended to be precise but are useful in gauging the possible risk range using simple risk exploration methods. Best scientific judgment guided the selection of assumptions and other elements of this analysis which are deemed reasonable and appropriate for identifying possible risks based on the information currently available. These analyses provide a sense of where an upper limit (or "upper bound") of the cancer risk may be. The simple methodologies used are generic and are valid for any increased relative risk data, however, they are not unique to the DE data. These analyses are subject to numerous uncertainties, particularly the lack of actual exposure information in the epidemiologic studies and uncertainties related to the three major underlying assumptions mentioned earlier. Any of these uncertainties could have an impact on the possible risk levels discussed above. Lower risks are possible and one cannot rule out zero risk. The risks could be zero because (a) some individuals within the population may have a high tolerance to exposure from DE and therefore not be susceptible to the cancer risk from environmental exposure, and (b) although evidence of this has not been seen, there could be a threshold of exposure below which there is no cancer risk.

The estimated possible risk ranges (10^{-5} to 10^{-3} as well as lower and zero risk) provide a perspective of the potential significance of the lung cancer hazard. This perspective should not be viewed as a definitive quantitative characterization of risk. The development of risk estimates does not constitute endorsement of their validity as surrogates for cancer unit risk or their suitability for estimating numbers of cancer cases. Further research is needed to more accurately assess and characterize environmental cancer risks of DE.

8.5. SUMMARY AND DISCUSSION

There are numerous published quantitative dose-response assessments to estimate human cancer risk from exposure to DE that use epidemiologic and/or experimental animal data (see Appendix C). These dose-response assessments were considered but failed to present a fully sufficient basis for a confident derivation of a cancer unit risk. This is because of epidemiologic exposure-related database uncertainties and the recent understanding about the lack of relevance of the rat lung cancer response to environmentally exposed humans. The dose-response analysis in this chapter has focused on the feasibility of using the occupational epidemiologic data to develop dose-response relationships and extrapolating them to the presumably lower levels of environmental exposure. Typically, this would result in the derivation of an exposure/dose-specific cancer unit risk. In the absence of an understanding about the mode(s) of action for DE-induced lung cancer in humans, coupled with the consideration that DE contains many mutagenic and carcinogenic constituents, linear low-dose extrapolation is judged to be an appropriate default choice for dose-response analysis, should there be satisfactory data to perform such an analysis.

This chapter specifically evaluated the suitability of using the railroad worker studies (Garshick et al., 1987, 1988) and the Teamster Union truck driver studies (Steenland et al., 1990, 1998) for dose-response analysis. However, because of uncertainties about the exposure response for the railroad workers and exposure uncertainties for the truck drivers, a dose-response-based cancer unit risk estimate for DE is not developed from these data sets at this time.

In the absence of a unit risk to assess environmental cancer risk, some insight about the possible significance of the hazard can be drawn from the available epidemiologic data and exploratory risk evaluation techniques. A discussion of possible risk is presented in the form of a perspective on the possible magnitude of risk from environmental exposure. The perspective discussion notes the small exposure margins and possible overlap between some occupational and environmental exposure levels. This lessens the uncertainty of extrapolating the occupational hazard and observed risk into the environmental setting. Furthermore, based on a more quantitative approach involving the observed lung cancer from occupational exposures and the magnitude of occupational and environmental exposure differences, an exploratory risk analysis shows that environmental cancer risks possibly range from 10^{-5} to nearly 10^{-3}, while a consideration of the numerous uncertainties and assumptions also indicates that lower risk is possible and zero risk cannot be ruled out. These risk findings are only general indicators of the potential significance of the lung cancer hazard and should not be viewed as a definitive quantitative characterization of risk or be used to estimate an exposure-specific population impact, i.e., estimating numbers of cancer deaths. Best scientific judgment guided the selection of assumptions and other elements of the analysis which are deemed reasonable and appropriate for identifying possible risks based on the information currently available. Further research is needed to more accurately assess and characterize environmental cancer risks of DE.

This exploratory risk analysis uses data collected from engines built prior to the mid-1990s. While engine exhaust emissions have been decreasing and exhaust composition has been changing in recent years, particularly for on-road engines, EPA believes that the insight gained from the risk perspective is pertinent to current on-road and nonroad engine use. New and cleaner engines will become available in response to environmental concerns and strict new regulations. As cleaner engines replace a substantial number of existing engines, the risk perspective will need to be reevaluated.

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9. CHARACTERIZATION OF POTENTIAL HUMAN HEALTH EFFECTS OF DIESEL EXHAUST: HAZARD AND DOSE-RESPONSE ASSESSMENTS

9.1. INTRODUCTION

Human health risk assessment entails the evaluation of all pertinent information on the hazardous nature of environmental agents, on the extent of human exposure to them, and on the characterization of the potential risk to an exposed population. The information is typically organized into four components: hazard assessment, dose-response assessment, exposure assessment, and risk characterization. This health assessment document focuses only on the hazard and dose-response assessment components. The overall objectives of this diesel engine exhaust (DE) assessment are:

- to identify and characterize the human health effects, i.e., hazards that may result from environmental exposure to DE;
- to determine whether there is a quantitative exposure/dose-response relationship for DE exposure and the health effect in the range of observation, and if sufficient data are available (1) for noncancer effects to derive estimates of exposure that are believed to be without appreciable risk, and (2) for carcinogenicity to derive an exposure/dose-specific cancer unit risk; and
- to summarize and integrate the findings of the assessment into a characterization and discuss the uncertainties.

This chapter summarizes and integrates the key findings about the nature and characteristics of environmental exposure to DE (Chapter 2), health hazard information (Chapters 3, 4, 5, and 7), and dose-response analyses (Chapters 6 and 8) that are relevant to the potential human health effects associated with current-day environmental exposure to DE. It also discusses the uncertainties associated with the key findings, including critical data and knowledge gaps, key assumptions, and EPA's science policy choices that are used to bridge the data and knowledge gaps.

This assessment is the Agency's first health assessment for DE emissions and was developed to provide information about the potential for DE-related environmental health hazards that could be used in evaluating regulatory initiatives under provisions of the Clean Air Act.

9.2. PHYSICAL AND CHEMICAL COMPOSITION OF DIESEL EXHAUST

As reviewed in Chapter 2, DE is a complex mixture of hundreds of constituents in gas or particle phases. Gaseous components of DE include carbon dioxide, oxygen, nitrogen, water vapor, carbon monoxide, nitrogen compounds, sulfur compounds, and low molecular-weight hydrocarbons and their derivatives. The particulate matter of DE, diesel particulate matter (DPM), is composed of elemental carbon (EC), adsorbed organic compounds, and small amounts of sulfate, nitrate, metals, trace elements, water, and unidentified compounds. Incomplete combustion of fuel hydrocarbons as well as engine oil and other fuel components such as sulfur leads to the formation of DPM. DPM is either directly emitted from diesel-powered engines (primary particulate matter) or is formed from the gaseous compounds emitted by a diesel engine (secondary particulate matter).

DE emissions vary in chemical composition and particle sizes among different engine types, fuel formulations, and within engine types according to operating conditions. As the emissions age in the environment they also change. There also have been changes in DE emissions over time as a result of changes in engine technology and fuel reformulation. The following sections identify and characterize the key components of DE that are of concern in possible health outcomes, and discuss the changes in the composition of DE over time. The latter information is critical for making a scientific judgment about the appropriateness of using epidemiologic and toxicologic findings from past DE exposures to assess hazard and risk from current-day environmental exposures. It should be noted that available animal studies are based on exhaust exposures from various model year on-road diesel engines since 1980, whereas many of the epidemiologic studies refer to exposures from on-road and nonroad diesel engines in use from the 1950s through the mid-1990s.

After emission from the tailpipe, DE undergoes dilution, chemical and physical transformations, and dispersion and transport into the atmosphere. After a day or so in the ambient environment, the exhaust mixture is said to be aging, a recognition of the atmospheric transformation processes, mostly focused on the organics present, though some particle size changes also may occur. The public health impact of DE mixture transformations is not clear, as some atmospheric processes alter chemical forms to a less toxic form whereas others seem to produce a chemical form with increased toxicity (Chapter 2, Section 2.3).

9.2.1. Diesel Exhaust Components of Possible Health Concern

The components of DE that are of health concern for this assessment are the particles (elemental carbon core), the organic compounds adsorbed to the particles, and the organic compounds present in the gas phase. The gaseous oxides of carbon, nitrogen, and sulfur are also of public health interest and the relevant health considerations for these are reviewed separately in EPA's Ambient Air Quality Criteria Documents.

9.2.1.1. *Diesel Particles*

Approximately 80%-95% of DPM mass is in the fine particle size range ($\leq$2.5 micrometers, ambient particulate matter [PM]), with a mean particle aerodynamic diameter of about 0.2 micrometers. Ultrafine particles (<0.1 micrometers), a smaller size component of the fine particles, average about 0.02 micrometers in aerodynamic diameter and account for about 1%-20% of the DPM mass and 50%-90% of the total number of particles in DPM (Chapter 2, Section 2.2.8.3).

Particle size is important for a number of reasons. Particles with aerodynamic diameters >2.5 micrometers (i.e., >$PM_{2.5}$) tend to be retained in the upper portions of the respiratory tract, whereas particles with diameters <2.5 micrometers (i.e., $PM_{2.5}$) are deposited in all areas, especially into the lower portions of the respiratory tract, including the deep lung. These fine and ultrafine particles have a very large surface area per gram mass (Chapter 2, Section 2.2.2), which enables them to adsorb and transport inorganic and organic compounds into the lung (Chapter 3, Section 3.3).

DPM is part of ambient particulate matter (PM). The EPA Emissions Trends Report (U.S. EPA, 2000) indicates that annual nationwide emissions of diesel $PM_{2.5}$ (on-road and nonroad) in 1998 were 77% of all mobile-source emissions in 1998, 23% of the total $PM_{2.5}$ inventory excluding natural and miscellaneous sources, and 6% if the natural and miscellaneous sources are included. Some geographic areas have a higher percentage of DPM in ambient $PM_{2.5}$ because of differences in the number and types of diesel engines present in the area (e.g., on-road engines as well as nonroad engines). For instance, in Manhattan, New York, on-road diesel PM was reported to contribute about 53% of ambient PM_{10} during 3 days in 1993, whereas 1996-1997 studies in the Phoenix and Denver areas showed diesel PM to be 10%-15% of total $PM_{2.5}$ mass (Chapter 2, Section 2.4.2.1).

DPM generally contains a high percentage of EC per unit mass, which can be used as a distinguishing feature from noncombustion sources of $PM_{2.5}$ and, to an extent, other combustion sources. The DPM EC content can range from more than 50% to approximately 75% of the DPM mass depending on age of engine, type of engine (heavy-duty versus light-duty), fuel characteristics, and driving conditions. The organic carbon portion of DPM can range approximately from 19% to 43%, though higher and lower values also have been reported. In comparison, gasoline engine exhaust generally has a reverse pattern of low EC content and a high percentage of organics on the particle mass (see Chapter 2, Table 2-13).

9.2.1.2. *Organic Compounds*

The organic compounds present in the gases and adsorbed onto the particles include a wide spectrum of compounds related to unburned diesel fuel, lube oil, low levels of partial combustion, and pyrolysis products (see Chapter 2, Table 2-19). The organic compounds present in the gaseous phase include alkanes, alkenes, aldehydes, monocyclic aromatic compounds, and polycyclic aromatic hydrocarbons (PAHs). Among the gaseous components of DE, the aldehydes are particularly important because of their potential carcinogenic effects and because they make up an important fraction of the gaseous emissions. Formaldehyde accounts for a majority of the aldehyde emissions (65%-80%) from diesel engines. Acetaldehyde and acrolein are the next most abundant aldehydes. Other gaseous components of DE that are notable for their carcinogenic effects include benzene, 1,3-butadiene, PAHs, and nitro-PAHs (including those with ≤4 rings and nitro-PAHs with 2 and 3 rings). A number of the gaseous compounds (e.g., aldehydes, alkanes, alkenes, NO_x, SO_x) also are known to induce respiratory tract irritation given sufficient exposure (see Chapter 2, Table 2-21). Very small amounts of dioxins have been measured in heavy-duty diesel truck exhaust. These emissions are estimated to represent about 1.2% of the 1995 national dioxin inventory; dioxin emissions from nonroad exhausts have not been estimated (Chapter 2, Section 2.2.7.2).

Organic substances adsorbed onto DPM include C_{14-35} hydrocarbon compounds, PAHs with ≥4 rings, and nitro-PAHs. PAHs and their derivatives comprise <1% of the DPM mass (Chapter 2, Section 2.2.8). Many of these hydrocarbons are known to have mutagenic and carcinogenic properties. California EPA (Cal EPA, 1998) identified at least 19 hydrocarbons present in DE that are known or suspected carcinogens, according to evaluations by the International Agency for Research on Cancer (IARC).

9.2.2. "Fresh" Versus "Aged" Diesel Exhaust

Newly emitted exhaust is termed "fresh," whereas exhaust that is more than 1 or 2 days old is referred to as "aged" because of alterations caused by sunlight and other chemical physical reactions that occur in the atmosphere. The overall toxicological consequence of DE aging is unclear because during aging some compounds in the DE mixture are altered to more toxic forms while others are made less toxic. For example, PAHs present in fresh emissions may be nitrated by atmospheric NO_3 to form nitro-PAHs, thus adding to the existing burden of toxic nitro-PAHs present in fresh exhaust. On the other hand, PAHs present in the gas phase can react with hydroxyl radicals present in the ambient air, leading to a reduced atmospheric lifetime of the original PAHs. Alkanes and alkenes may be converted to aldehydes, and oxides of nitrogen to nitric acid (Chapter 2, Section 2.3).

9.2.3. Changes in Diesel Exhaust Emissions and Composition Over Time

Chapter 2, with its Summary in Section 2.5, provides a full review of emissions trends and a complete characterization of the physical and chemical changes in DE over the years, taking into consideration the lack of consistent analytical and measurement techniques and the variability in emissions based on vehicle mix, driving cycles, engine deterioration, and other factors. Key findings and inferences relevant to the potential health effects of DE are discussed below.

As discussed in Chapter 2, Section 2.2.3, the EPA Emissions Trend Report estimates that DPM_{10} on-road emissions decreased 27% between 1980 and 1998. DPM emission factors (g/mile by model year) from new on-road diesel vehicles decreased on average by a factor of six from the mid-1970s to the mid-1990s. These significant reductions are largely attributable to reductions in three PM components: EC, organic carbon, and sulfate. Limited data are available to assess the changes in emission rates from locomotive, marine, or other nonroad diesel sources over time, although it is estimated that DPM_{10} (≤ 10 µm) emissions from nonroad diesel engines increased 17% between 1980 and 1998 (Chapter 2, Section 2.2.5).

Because of changes in engine technology and fuel composition, the chemical composition of DPM from on-road vehicles has also changed over time. The percentage of soluble organic material associated with DPM decreased by model year from the 1980s to the 1990s, and the proportion of EC is correspondingly higher. PAHs and nitro-PAHs are present in DPM from both new and older diesel engines. There are insufficient data to provide clear insight into the potential for changes in total PAH emissions over time or specific PAHs such as benzo[a]pyrene and 1-nitropyrene. It should be noted that the chemical composition of ambient DPM to which people are currently exposed is determined by a combination of exhaust from older and newer engines as well as on-road and nonroad applications of those engines. Consequently, the decrease in the soluble organic fraction of DPM by model year for on-road engines does not directly translate into a proportional decrease in DPM-associated organic material to which people are exposed. In addition, the contributions from high-emitting and/or smoking diesel engines have not been quantified (Chapter 2, Section 2.5.2).

Because of these uncertainties, the exposure impact of changes in DPM composition over time cannot be confidently characterized. Available data clearly indicate that toxicologically significant organic components of DE (e.g., PAHs, PAH derivatives, nitro-PAHs) were present in DPM and DE in the 1970s and are still present. Even though a significant fraction of ambient DPM (possibly more than 50%) is emitted by nonroad equipment, data are currently inadequate to characterize changes in the chemical composition of DPM from nonroad equipment over time. Given the variation in fuel, engine technology, and in-use operational factors over the years, caution should be exercised in presuming that a decrease in the amount of emissions or emission constituents from older engines to present day in-use engines will result in a decrease in hazard/risk. In meeting the 2007 federal regulations for heavy-duty DE, the exhaust composition will be markedly changed with a consequence that health hazards are expected to be significantly reduced.

9.3. AMBIENT CONCENTRATIONS AND EXPOSURE TO DIESEL EXHAUST

Chapter 2, Section 2.4 provides information on occupational and environmental exposures to DE in order to provide a context for the hazard assessment and dose-response analysis. Highlights of the available information are discussed below.

DE is emitted from a variety of sources, both on-road (e.g., motor vehicles, construction equipment) and nonroad (e.g., farm equipment, railway locomotives, or marine uses). Environmental exposure to DE is generally higher in urban areas than in rural areas. The concentration of DE in the air will vary within any geographic area depending on the number and types of diesel engines in the area and the atmospheric patterns of dispersal. Some important factors that determine the difference between the ambient concentration of DE and the resultant exposure to an individual include the proximity of a person to the DE source and his/her pattern of activity which, for example, includes outdoor versus indoor activities as well as related breathing rates. Certain occupational populations (e.g., transportation and garage workers, heavy-equipment operators, and others who spend considerable time outdoors) can be exposed to much higher levels of DE than the general population. The amount or number of particles delivered and retained in the lung is one factor that could contribute to differential human susceptibility to DPM. For example, children have smaller lungs than adults and thus could have a higher lung burden of inhaled DPM per lung surface area if their activity pattern results in a high breathing frequency.

As DE is a complex mixture of many constituents, environmental concentration measurements and related human exposure is difficult to precisely measure. Even though levels of a number of DE constituents are generally known, it is difficult to quantify the portion that comes from DE since other types of emission sources also may emit the same constituent. Moreover, there is still incomplete knowledge about the relative roles of the relevant DE constituents in mediating the potential health effects of DE. Historically, exposure levels to DPM have been used as a surrogate marker/dosimeter for whole DE. Although uncertainty exists as to whether DPM mass (expressed as $\mu g/m^3$ of DPM) is the most appropriate dosimeter for health effect purposes, it is considered to be a reasonable choice until more definitive information is available about the mechanisms or mode(s) of toxicity action of DE.

Several techniques exist for estimating ambient concentrations of DPM, including chemical mass balance (CMB) source apportionment, dispersion modeling, and using EC as a surrogate for DPM. DPM concentrations reported from CMB and dispersion modeling studies in the 1980s suggest that in urban and suburban areas (Phoenix and Southern California), the annual average DPM concentration ranged from 2 to 13 $\mu g/m^3$. In the 1990s, annual or seasonal average DPM concentrations in suburban or urban locations have ranged from 1.2 to 4.5 $\mu g/m^3$. DPM concentrations at a major bus stop in downtown Manhattan ranged from 13.2 to 46.7 $\mu g/m^3$ over a 3-day period in 1993. In nonurban and rural areas in the 1980s, DPM concentrations were reported to range from 1.4 to 5 $\mu g/m^3$. In the 1990s, nonurban air basins in California were reported to have DPM concentrations ranging from 0.2 to 2.6 $\mu g/m^3$ (Chapter 2, Section 2.4.2).

A comprehensive exposure assessment is not presented in this assessment, though EPA is developing this in an analysis called the National Air Toxics Assessment. Interim exposure estimation based on EPA's Hazardous Air Pollutant Exposure Model (HAPEM-MS3 model), for on-road sources only, suggests that in 1996 annual average DPM exposure in urban areas from only on-road engines was 0.7 $\mu g/m^3$, while in rural areas exposure was 0.3 $\mu g/m^3$. Among 10 urban areas, the 1996 annual average estimated exposure ranged from 0.5 to 1.2 $\mu g/m^3$. A high-end exposure estimate for 1996 is not yet available. Comparable 1990 exposure estimates for on-road sources ranged from 0.9 $\mu g/m^3$ for urban areas to 0.5 $\mu g/m^3$ for rural areas. In 1990 exposure estimates for the most highly exposed individuals (e.g., outdoor workers and children who spend large amounts of time outdoors) were estimated to be up to 4.0 $\mu g/m^3$ (Chapter 2, Section 2.4.3.2, Table 2-29). Nationwide level nonroad emission exposures are estimated to be nearly double those from on-road sources.

Estimates for occupational exposures to DE as DPM mass are generally higher than environmental exposures. Tables 2-27 and 2-28 provide historic exposure estimates for specific worker categories. For example, historic DPM exposure estimates range from 39–191 $\mu g/m^3$ for railroad workers, 4–748 $\mu g/m^3$ for firefighters, 7–98 $\mu g/m^3$ for public transit workers and airport crews, 5–61 $\mu g/m^3$ for mechanics and dock workers, and 2–7 $\mu g/m^3$ for long- and short-haul truck drivers. For a direct comparison of lifetime exposures between an occupational setting (8 hours per day, 5 days per week, for 45 years) and environmental exposure (continuous exposure for 70 years), the occupational estimates are converted to an equivalent environmental lifetime estimate,[1] which is also shown in Table 2-28. A conversion of EC-based measurements to total DPM also may be needed for some estimates. The estimated 70-year lifetime exposures equivalent to those for the occupational groups discussed above range from about 0.4–157 $\mu g/m^3$. These data indicate that some lower-end occupational estimates of DPM, when converted to environmental equivalents, overlap the range of estimated environmental exposures

[1]Environmental equivalent occupational exposure = 0.21 × occupational exposure.

to DPM from on-road emissions (national average in 1990 of 0.8 $\mu g/m^3$, with high-end exposures up to about 4 $\mu g/m^3$). The addition of nonroad emission exposures, when appropriate, makes the case for overlap of occupational and environmental exposure more prevalent.

9.4. HAZARD CHARACTERIZATION

The primary health effects of concern from environmental exposure to DE include effects associated with both acute and short-term exposures as well as chronic exposures. It is recognized that acute exposures may produce transitory physiological symptoms of varied severity as well as exacerbation of allergenic effects from acute and repeated exposures. On the basis of combined human and experimental evidence from chronic exposure studies, noncancer respiratory effects and lung cancer are observed.

The health effects data are based on DE from a variety of engines existing before the mid-1990s. There have been changes in the physical and chemical composition of some DE emissions (on-road vehicle emissions) over time, though there is no definitive information to show that the emission changes portend significant toxicological changes. The mode(s) of action for DE toxicity in humans is not understood, and hence knowledge is lacking about the role of exhaust mixture components in modulating the toxicity. Taken together, these considerations have lead to a judgment that the hazards identified from older technology-based exposures are applicable to current-day exposures. As new and cleaner diesel engines replace a substantial number of existing engines, the general applicability of the older data will need to be reevaluated.

As discussed in Chapter 6 (Section 6.4), it is also reasonable to expect that DPM, being a constituent of ambient fine PM ($PM_{2.5}$), would contribute to the wider spectrum of effects that have been associated with ambient $PM_{2.5}$. Community epidemiologic studies have shown that ambient $PM_{2.5}$ exposure is statistically associated with increased mortality (especially among people over 65 years of age with preexisting cardiopulmonary conditions) and morbidity as measured by increases in hospital admissions, respiratory symptom rates, decrements in lung function, and exacerbation of asthma, and possibly immunological effects in the respiratory system. There continues to be little epidemiologic evidence for an effect of ambient exposure to PM on cancer rates (U.S. EPA, 1996a,b), though U.S. EPA's Criteria Document for Ambient PM (expected to be released in 2002) will examine the question further.

9.4.1. Acute and Short-Term Exposures

The combined human and animal evidence indicates that DE can induce irritation to the eye, nose, and throat, as well as inflammatory responses in the airways and the lung following acute and/or short-term exposure to high concentrations. There also is suggestive evidence for possible immunological and allergenic effects of DE.

9.4.1.1. *Acute Irritation*

DE contains various respiratory irritants in the gas phase and in the particulate phase (e.g., SO_x, NO_x, aldehydes). Acute exposure to DE has been associated with irritation of the eye, nose, and throat, respiratory symptoms (cough and phlegm), and neurophysiological symptoms such as headache, lightheadedness, nausea, vomiting, and numbness or tingling of the extremities. Such symptoms have been described mainly in reports of individuals exposed to DE in the workplace, or in clinical studies in humans exposed acutely to high concentrations of DE. Because of the general lack of validating exposure information in the reports, the role of DE in causing these effects is unknown. An exposure-response relationship for these acute irritation and respiratory symptoms has not been demonstrated (Chapter 5, Section 5.1.1.1).

9.4.1.2. *Respiratory Effects*

Available studies of occupational exposure to DE have not provided evidence for significant decrements of lung function in workers over a work shift or after a short-term exposure period. Short-term and subchronic inhalation studies of DE in animals (rats, mice, hamsters, cats, guinea pigs) showed inflammation of the airways and minimal or no lung function changes. These effects were associated with high DE exposures (up to 6 mg/m^3). Exposure-response relationships have not been established for these responses (Chapter 5, Sections 5.1.1, 5.1.2, and 5.1.3).

9.4.1.3. *Immunological Effects*

Recent human and animal studies show that acute DE exposure episodes can exacerbate immunological reactions to other allergens or initiate a DE-specific allergenic reaction. The effects seem to be associated with both the organic and carbon core fraction of DPM. In human subjects, intranasal administration of DPM has resulted in measurable increases of IgE antibody production and increased nasal mRNA for some proinflammatory cytokines. These types of responses also are markers typical of asthma, though for DE, evidence has not been produced in humans that DE exposure results in asthma. The ability of DPM to act as an adjuvant to other allergens also has been demonstrated in human subjects. For example, co-exposure to DPM and ragweed pollen was reported to significantly enhance the IgE antibody response and cytokine expression relative to ragweed pollen alone. Available animal studies also demonstrate the potential adjuvant effects of DPM with model allergens, e.g., in mouse studies the allergenic reaction to ovalbumin and Japanese cedar pollen (Chapter 5, Sections 5.1.1.1.3 and 5.1.1.1.4).

Additional research is needed to further characterize immunological effects of DE and to determine whether or not the immunological effects constitute a low-exposure hazard. This health endpoint is of considerable public health concern, given the increases in allergic hypersensitivity in the U.S. population (Chapter 5, Section 5.6.2.6).

9.4.2. Chronic Exposure

9.4.2.1. *Noncancer Effects*

Available long-term and cross-sectional human studies have provided evidence for an association between respiratory symptoms (cough and phlegm) and DE exposure, but there was no consistent effect on lung function. DE has been shown in many animal studies of several species to induce lung injury (chronic inflammation and histopathologic changes) following long-term inhalation exposure. DE also has been tested in laboratory animals for other health effects, but no significant effects have been found. Overall, available data lead to the conclusion of a potential chronic respiratory hazard to humans from long-term exposure to DE.

9.4.2.1.1. *Respiratory effects.* A few human studies in various diesel occupational settings suggest that DE exposure may impair pulmonary function, as evidenced by increases in respiratory symptoms and some reductions in baseline pulmonary function consistent with restrictive airway disease. Other studies found no particular effects. The methodologic limitations in available human studies limit their usefulness in drawing any firm conclusions about DE exposure and noncancer respiratory effects (Chapter 5, Section 5.1.1.2).

Available studies in animals, however, provide a large body of evidence demonstrating that prolonged inhalation exposure to high concentrations of DE can result in pulmonary injury. A number of long-term laboratory studies in rats, mice, hamsters, cats, and monkeys found varying degrees of adverse lung pathology including focal thickening of the alveolar walls, replacement of Type I alveolar cells by type II cells, and fibrosis. The rat is the most sensitive animal species to DE-induced pulmonary toxicity (Chapter 5, Sections 5.1.3 and 5.4).

Available mechanistic data, mainly in rats, indicates that the DPM fraction of DE is a controlling factor in the etiology of pulmonary toxicity, although a role for the adsorbed organic compounds on the particles and in the gaseous phase cannot be ruled out. The lung injury appears to be mediated by an invasion of alveolar macrophages that release chemotactic factors that attract neutrophils and additional alveolar macrophages, which in turn release mediators (e.g., cytokines, growth factors) and oxygen radicals. These mediators result in persistent inflammation, cytotoxicity, impaired phagocytosis, clearance of particles, and eventually deposition of collagen by activated fibroblasts. This mode of action seems to be operative for a variety of poorly soluble particles in addition to DPM (ILSI, 2000). Because long-term exposure to DE has been shown to induce exposure-dependent chronic respiratory effects in a wide range of animal species, and the mode of action is deemed relevant to humans, there is a sufficient scientific basis to support a conclusion that humans also could be at hazard for these effects under a chronic exposure condition.

9.4.2.1.2. ***Other noncancer effects***. The negative results from available studies in several animal species (rats, mice, hamsters, rabbits, monkeys) indicate that DE is not likely to pose a reproductive or developmental hazard to humans. There has been some evidence from animal studies indicating possible neurological and behavioral effects, as well as liver effects. These effects, however, are seen at exposures higher than the respiratory effects. Overall, there is insufficient evidence to conclude that a low-exposure hazard exists for these endpoints (Chapter 5, Section 5.1.3.3).

9.4.2.2. ***Carcinogenic Effects***

Many epidemiologic and toxicologic studies have been conducted to examine the potential for DE to cause or contribute to the development of cancer in humans and animals, respectively. In addition, there are some mode-of-action studies that seek to provide an improved understanding about the underlying carcinogenic process and thus contribute to a better understanding of the likelihood of hazard to humans. The available evidence indicates that chronic inhalation of DE is likely to pose a lung cancer hazard to humans. There is insufficient information for an evaluation of the potential cancer hazard of DE by oral and dermal routes of exposure.

9.4.2.2.1. ***Epidemiologic studies.*** Twenty-two epidemiologic studies about the carcinogenicity of workers exposed to DE in various occupations are reviewed in Chapter 7, Section 7.2. Exposure to DE has typically been inferred on the basis of job classification within an industry, with cumulative exposure based on duration of employment or age. Increased lung cancer risk, although not always statistically significant, has been observed in 8 out of 10 cohort studies and 10 of 12 case-control studies within several industries, including railroad workers, truck drivers, heavy-equipment operators, farm tractor operators, and professional diesel vehicle drivers. The increased lung cancer relative risks generally range from 1.2 to 1.5, although a few studies show relative risks as high as 2.6. Statistically significant increases in relative risk, 1.33 to 1.47, are also shown in two independent meta-analyses. The meta-analyses demonstrate the effect of pooling many studies and in this case show the positive relationship between DE exposure and lung cancer across a variety of DE-exposed occupations.

The generally small increases in lung cancer relative risk (1.2 to 1.5, i.e., less than 2) observed in the epidemiologic studies potentially weakens the evidence of causality. This is because with a relative risk of less than 2, if confounders (e.g., smoking, asbestos exposure) were having an effect on the observed risk increases, then it could be enough to account for the increased risk. With the strongest risk factor for lung cancer being smoking, there is a lingering uncertainty as to whether smoking effects may be influencing the magnitude of the observed increased relative risks, in spite of the fact that in key studies the investigating epidemiologists assert that they have effectively controlled for smoking. In studies in which the effects of smoking were controlled, increased relative risks for lung cancer prevailed. While some studies did not have information on smoking, confounding by smoking is judged unlikely to be significant if the comparison populations were from the same socioeconomic class.

As evaluated in Chapter 7 (Section 7.2.4.5), application of the criteria for causality provides a rational basis to conclude that the increased risks observed in available epidemiologic studies are consistent with a causal association between exposure to DE and occurrence of lung cancer. Overall, the human evidence for potential carcinogenicity for DE is judged to be strong but less than sufficient to satisfy the criteria for a “known” human carcinogen because of exposure uncertainties (lack of historical exposure of workers to DE) and residual uncertainty as to whether all confounders have been satisfactorily accounted for. The epidemiologic evidence is inconclusive for DE being associated with other forms of cancer.

9.4.2.2.2. ***Animal studies.*** DE and its organic constituents, both in the gaseous and particle phase, have been extensively tested for carcinogenicity in many experimental studies using several animal species and with different modes of administration. Several well-conducted studies have consistently demonstrated that chronic inhalation exposure to sufficiently high concentrations of DE produced dose-related increases in lung tumors (benign and malignant) in rats. In contrast, chronic inhalation studies of DE in mice showed equivocal results, whereas negative findings were consistently seen in hamsters. The gaseous phase of DE (filtered exhaust without particulate fraction), was found not to be carcinogenic in rats, mice, or hamsters. The available data indicate that among the traditional animal test species, the rat is the most sensitive species to DE. As reviewed in Chapter 7, Section 7.4, the lung cancer response in rats from high-concentration exposures to DE appears to be mediated by impairment of lung clearance mechanisms owing to particle overload, resulting in persistent chronic inflammation and subsequent pathologic and neoplastic changes (i.e., cancer) in the rat lung. Particle overload conditions in the human lung are not expected to occur as a result of environmental or most occupational exposures to DE. Thus, the increased lung tumors in the rat are not an appropriate basis from which to judge the potential for a human hazard or perform a dose-response analysis to derive a cancer unit risk for humans.

In several intratracheal instillation studies, DPM, DPM organic extracts, and carbon black, which is virtually devoid of PAHs, have been found to produce increased lung tumors in rats. When directly implanted into the rat lung, DPM condensate containing mainly four- to seven-ring PAHs induced increases in lung tumors. DPM extracts also have been shown to cause skin tumors in several dermal studies in mice and sarcomas in mice following subcutaneous injection. Overall there are consistent findings of carcinogenic activity by the organic extracts of DPM in noninhalation studies (i.e., intratracheal instillation, lung implantation, skin painting). This contributes to the evidence for a potential human hazard.

9.4.2.2.3. ***Other key data.*** While not as extensive as the human and animal carcinogenicity data, other types of data are judged to be supportive of DE's potential carcinogenicity in humans. As mentioned previously, DE is a complex mixture of hundreds of constituents in either the gaseous phase or particle phase. Although present in small amounts, several organic compounds in the gaseous phase (e.g., PAHs, formaldehyde, acetaldehyde, benzene, 1,3-butadiene) are known to exhibit mutagenic and/or carcinogenic activities. PAHs and PAH derivatives, including nitro-PAHs present on the diesel particle, also are known to be mutagenic and carcinogenic. As reviewed in Chapter 4, DPM and DPM organic extracts have been shown to induce gene mutations in a variety of high-dose bacteria and mammalian cell test systems. DPM and DPM organic extracts also have been shown to induce chromosomal aberrations, aneuploidy, and sister chromatid exchange in both rodent and human in vitro tests.

There also is suggestive evidence for the bioavailability of organic compounds from the DE mixture. Elevated levels of DNA adducts in lymphocytes have been reported in workers exposed to DE. In addition, inhalation studies of animals using radio-labeled materials indicate some elution of organic compounds from DPM after deposition in the lung as measured by their presence in biological tissue and fluids (Chapter 3, Section 3.5).

9.4.2.2.4. ***Modes of carcinogenic action.*** The term "mode of action" refers to a series of key biological events and processes that are critical to the development of cancer. As discussed in Section 9.4.2.2.2, there is an understanding of the modes of action for the DE-induced lung tumors in the rat. However, the modes of action by which DE increases lung cancer risks in humans are unknown, and the evidence in rats is not applicable to environmentally exposed humans.

As discussed in Chapter 7, Section 7.4, it is hypothesized that multiple modes of action could be involved in mediating the carcinogenic effect of DE. These modes of action may include: (a) mutagenic events (e.g., direct effects on DNA and effects on chromosomes) by organic compounds in the gas and particle phase, (b) indirect DNA damage via the production of reactive oxygen species (ROS) induced by particle-associated organics, and (c) particle-induced chronic inflammatory response leading to oxidative DNA damage through the release of cytokines, ROS, etc., and an increase in cell proliferation.

In rats, the particulate phase appears to have the greatest contribution to the carcinogenic effects, and both the particle core and the associated organic compounds have demonstrated carcinogenic properties in one or more test systems. While limited rat data and comparative potency calculations suggest that gas-phase components are not the primary factors in the development of lung cancer, a contributory role of the recognized toxic components cannot be dismissed. The relative importance of the various modes of action may be different at different exposure levels. Evidence from rat studies indicates the importance of the EC component of the DE particle in mediating lung tumor response at high exposure levels. As for the particle-absorbed organics, their inherent toxicity potential gives rise to a hypothesis that they may play a role in low or high exposures to DE.

9.4.2.2.5. ***Weight-of-evidence evaluation.*** Chapter 7, Section 7.5, provides an evaluation of the overall weight of evidence for human carcinogenicity in accordance with EPA's Guidelines for Carcinogen Risk Assessment (U.S. EPA, 1986, 1996a, 1999). The totality of evidence supports the conclusion that DE is a *probable human carcinogen (Group B1)* by inhalation exposure using the criteria in the 1986 guidelines. A cancer hazard narrative for DE also is provided in accordance with the revised draft 1996/1999 guidelines, which concludes that DE *is likely to be carcinogenic to humans* by inhalation from environmental exposures. The common bases for either conclusion include the following lines of evidence:

- strong but less than sufficient evidence for a causal association between DE exposure and increased lung cancer risk among workers in varied occupations where exposure to DE occurs;
- extensive supporting data including the demonstrated mutagenic and/or chromosomal effects of DE and its organic constituents, and knowledge of the known mutagenic and/or carcinogenic activity of a number of individual organic compounds present with particles and in the DE gases;
- evidence of carcinogenicity of DPM and the associated organic compounds in rats and mice by noninhalation routes of exposure; and
- suggestive evidence for the bioavailability of DE organics from DE in humans and animals.

A notable uncertainty in the characterization of the potential cancer hazard of DE at low levels of environmental exposure is the incomplete understanding of about its mode(s) of action for the induction of lung cancer in humans. Available data suggest that DE-induced lung carcinogenicity may be mediated by mutagenic and nonmutagenic events by both the particles and the associated organic compounds, and that a role for the organics in the gaseous phase cannot be ruled out. Given that there is some evidence for a mutagenic mode of action, a cancer hazard is presumed possible at environmental levels of exposure. This is consistent with EPA's science policy position that assumes a nonthreshold effect for carcinogens with a mutagenic component in the absence of definitive data demonstrating a threshold or nonlinear mechanism. Additional support for an environmental hazard also comes from a comparison of the estimated environmental levels to the estimated occupational exposure levels where risk is seen. Given that there is only a minimal margin between environmental and occupational exposure ranges, if not an overlap, the extrapolation of observable hazard from the occupational setting to the ambient environment is relatively confident. Because of insufficient information, the human carcinogenic potential of DE by oral and dermal exposures cannot be determined.

Several organizations previously have reviewed available relevant data and evaluated the potential human carcinogenicity of DE or the particulate component (DPM) of DE. Similar conclusions were reached by various organizations (see Table 7-9). For example, some organizations have concluded that DE is probably carcinogenic to humans (IARC, 1989; IPCS, 1996), or reasonably is anticipated to be a carcinogen (NTP, 2000).

Overall, the weight of evidence for potential human carcinogenicity for DE is considered strong, even though inferences are involved. Uncertainties are present, however, and include the following unresolved issues.

First, there has been a considerable scientific debate about the significance of the available human evidence for a causal association between occupational exposure and increased lung cancer risk. Some experts view the evidence as weak and/or inconsistent while others consider the evidence compelling. This is due to a lack of consensus about whether the effects of smoking and other potential confounders have been adequately accounted for in key studies, and the lack of agreed-upon historical DE exposure data for the available studies.

Second, while the mode of action for DE-induced lung tumors in rats from high exposure is sufficiently understood, the mode of action for the DE lung cancer risk in humans is not known. To date, available evidence for the role of both the adsorbed organics and the carbon core particle has only been shown under high-exposure experimental animal test conditions. There is virtually no information about the relative role of DE constituents in mediating carcinogenic effects at the low-exposure levels.

Additional research is needed to address these issues to reduce the uncertainty associated with the potential cancer hazard of exposure to DE.

The relevance of this hazard characterization to current ambient DE exposures hinges on recognizing that the health effects data are derived from engine technologies and fuels that existed in the past, and that some changes in the DE exhaust mixture have occurred and can be expected in the future. Although decreases in amount and changes in composition of DE emissions have occurred over time for on-road engines, a change is slow to manifest in the environment because, for example, vehicular fleet turnover is slow and the change is slow to dominate across an engine fleet. Available studies have not focused on the potential toxicological effect of the emission changes. There is no compelling evidence at present to show that past and present exhaust characteristics are so toxicologically dissimilar as to render the current use of the assessment's findings outdated.

9.5. DOSE-RESPONSE ASSESSMENT

In assessments of estimated human health risks, human data from environmental exposures are always preferred over animal data, if available, as their use obviates the need for extrapolation across species, e.g., from animals to humans. However, for most environmental agents, available health effects information is generally limited to occupational exposures in studies of humans (e.g., workers) or high experimental exposures to laboratory animals. For the agents with high-exposure data compared to environmental exposure levels of interest, dose-response assessment is performed in two steps: assessment of data in the observable range to derive a point of departure (which usually is the lowest exposure or dose that induces some, minimal, or no apparent effects), followed by extrapolation to lower exposures to the extent necessary. Extrapolation to low exposures is ideally based on the understanding of mode(s) of toxic action of the agent which allows the development and use of a mode of action specific exposure-response model. In the absence of sufficient data, default methods and models are used to extrapolate to the lower exposure levels.

For DE, there is sufficient evidence to conclude that acute or short-term inhalation exposure at relatively high levels can cause irritant effects to the eye, nose, and throat, respiratory symptoms, and neurophysiological symptoms such as headache, nausea, etc., however, no quantitative data are available to derive an estimate of human exposure that is not likely to elicit irritant and inflammatory effects in humans.

There is also sufficient evidence to support the conclusion that DE has the potential to cause cancer and noncancer effects of the lung from long-term inhalation exposure. Chapters 6 and 8 provide dose-response analyses related to the noncancer and cancer hazards to humans, respectively, from lifetime exposure to DE. A dose-response analysis to estimate the expected response at environmental exposure levels has less uncertainty the closer the animal test or estimated human epidemiologic-related exposures are to the environmental levels of interest. With increasing exposure margins (EM), and thus a greater range of extrapolation, the uncertainty about the shape of the dose-response curve in the region of low-dose extrapolation increases and the possibility of a zero risk cannot be ruled out.

9.5.1. Evaluation of Risk for Noncancer Health Effects

As discussed previously (Section 9.4.2.1), the evidence for potential chronic noncancer health effects of DE is based primarily on findings from chronic animal inhalation studies showing a spectrum of dose-dependent chronic inflammation and histopathological changes in the lung in several animal species including rats, mice, hamsters, and monkeys. A limited number of epidemiologic investigations of workers exposed to DE have not provided consistently clear evidence of significant chronic respiratory effects associated with DE exposure. On the other hand, the relatively large epidemiologic database for ambient PM shows a clear relationship between respiratory effects and ambient fine PM that is partially composed of DPM. The specific role of DPM or any other source-related constituent of ambient PM in causing the observed respiratory effects has not been defined.

The approach taken in this assessment to estimate a level of DE in the air to which humans may be exposed throughout their lifetime without an appreciable risk of deleterious effects is to derive a reference concentration (RfC) for DE based on the consistent data for respiratory inflammation in the rat studies. This approach assumes that humans would respond to DE similarly to the tested animals under similar exposure conditions. An uncertainty of this approach stems from the circumstance that animal studies have used high DE exposures, and the animal results must be translated to humans as well as to lower exposure levels since the potential chronic health effects of DE in humans at environmental exposure levels cannot be ascertained from the available DE human data.

It also is relevant to recognize that DPM is a component of ambient fine PM and that there is a relative wealth of human effects data for ambient PM showing a similarity of certain adverse health effects for DPM and ambient fine PM. This allows one to reasonably expect that the $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) would provide a measure of protection from DPM, reflecting DPM's current and approximate proportion to $PM_{2.5}$. Ambient $PM_{2.5}$ has been shown to be statistically associated with increased mortality (especially among people over 65 years of age with preexisting cardiopulmonary conditions) and morbidity, as measured by increases in hospital admissions, respiratory symptom rates, and decrements in lung function with both long- and short-term changes in ambient $PM_{2.5}$ concentrations.

9.5.1.1. *Chronic Reference Concentrations for Diesel Exhaust*

An inhalation Reference Concentration (RfC) is based upon long-term data, i.e., chronic exposure, and can be derived from either human or animal data. An RfC is correctly defined as "an estimate of a continuous inhalation exposure to the human population, including sensitive subgroups, with uncertainty spanning perhaps an order of magnitude, that is likely to be without appreciable risks of deleterious noncancer effects during a lifetime." The RfC methodology assumes that there is an exposure threshold below which effects will not occur. The RfC is not a bright line; rather, as the long-term human exposure increases above the RfC, the margin of protection decreases.

With the absence of DE exposure-response data in humans, this assessment derives an RfC for DE based on dose-response data from four chronic inhalation studies in rats (Mauderly et al., 1987; Ishinishi et al., 1988; Heinrich et al., 1995; Nikula et al., 1995). All of these studies used DPM (expressed as $\mu g/m^3$) as a measure of DE exposure. The pulmonary effects, including inflamation and histopathologic lesions, were considered to be the critical noncancer effects. As shown in Table 6-2, the no-observable-adverse-effects levels (NOAELs), the lowest-observable-adverse-effects levels (LOAELs), and the adverse effects levels (AELs) for lung inflammation and histopathologic changes were identified for the first three studies. For the Nikula et al. study, lower 95% confidence estimates of the concentrations of DPM associated with a 10% incidence ($BMCL_{10}$) of chronic pulmonary inflammation and fibrosis were derived since NOAEL's were not observed. For all four studies, human equivalent concentrations (HECs) corresponding to the animal NOAEL, LOAEL, AEL, and $BMCL_{10}$ were then computed using a dosimetry model developed by Yu et al. (1991) as described in Chapter 6, Section 6.5.2, and Appendix A. The dosimetry model accounts for species differences (rat to human) in respiratory exchange rates, particle deposition efficiency, differences in particle clearance rates at high and low doses, and transport of particles to lymph nodes. The purpose is to identify the highest HEC value with no apparent effect, i.e., $NOAEL_{HEC}$.

The highest $NOAEL_{HEC}$ associated with no apparent effect is 144 $\mu g/m^3$ from the Ishinishi et al. (1988) study; this then becomes the point of departure for deriving an RfC. To obtain the RfC, this point of departure was divided by two types of uncertainty factors (UF): a factor of 3 recognizes interspecies (i.e., rat to human) extrapolation uncertainties, and a factor of 10 reflects uncertainties about interindividual human variation in sensitivity. An evaluation of the interspecies extrapolation issues for dosimeteric and pharmacodynamic equivalence between rats and humans showed that although some adjustments could be accounted for, there remained a residual uncertainty, and thus an uncertainty of 3 out of a possible factor of 10 is used. In the absence of mechanistic or specific data, a default value of 10 is considered appropriate to account for possible human variability in sensitivity, particularly for children and people with preexisting respiratory conditions. The spectrum of the population that may have a greater susceptibility cannot be better characterized until there is additional knowledge about mode of action. The resulting RfC for DE is 5 $\mu g/m^3$ of DPM.

Overall, the confidence level in the RfC is considered medium in a range of low to high confidence. A principal uncertainty of the RfC analysis is the reliance on animal data to predict human risk. The critical effects, chronic inflammation, and pathologic changes, which are well characterized in four animal species, are considered relevant to humans. Collective evidence for all poorly soluble particles, including DPM, indicates that the rat is the most sensitive laboratory animal species tested to date. Although in general the rat is thought to be more sensitive to lung injury than humans to poorly soluble particles (ILSI, 2000), it is not clear that this is the case specifically for diesel. We must recall that DE is a mixture of not just carbon particles but also various organics, both on the particles and in gases. In addition, differences in particle deposition, retention, and clearance mechanisms have been largely but perhaps not completely addressed by the use of the rat-to-human dosimetry model. The use of rat data is not likely to grossly underestimate the human risk for pulmonary noncancer health effects. In terms of the potential for other critical health effects, there is growing evidence suggesting that DE can exacerbate allergenic effects to known sensitizers, while also evoking production of biochemical markers typically associated with asthma. Some work in this area indicates that humans may be as sensitive as rats and mice to the immunologic effects (Chapter 6, Section 6.3.4). This database is currently lacking key exposure-response data, but may in the future provide an alternative basis for RfC derivation. It also should be noted that the ambient PM health effects data show a broader array of adverse human health concerns (e.g., cardiovascular effects, as well as acute exposure effects). With DPM being a ubiquitous component of ambient PM, there is an uncertainty about the adequacy of the existing DE noncancer database to identify all of the pertinent DE-caused noncancer health hazards.

9.5.1.2. *Risks Based on Ambient $PM_{2.5}$*

As discussed in Chapter 6 (Section 6.4), in 1997 EPA established an annual NAAQS for $PM_{2.5}$, at a level of 15 $\mu g/m^3$ to provide protection against adverse health effects associated with both long- and short-term exposures to ambient fine PM. DPM is a typical constituent of ambient fine PM (generally about 10% of $PM_{2.5}$ with some examples up to 36%).[2] Given the

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[2]"A qualitative comparison of adverse effects of exposure to DPM and ambient fine PM shows that the respiratory system is adversely affected in both cases, though a wider spectrum of adverse effects has been identified for ambient fine PM. In contrast to the diesel PM database, there is a wealth of human data for fine PM noncancer effects which indicates that the health effects from fine PM do not have a discernable threshold at this time."

similarity of health concerns for respiratory inflammation and pulmonary health effects from both DPM and fine particles, it is reasonable to expect that DPM contributes to some of the health effects associated with $PM_{2.5}$. Current knowledge is insufficient, however, to describe the relative potencies of DPM and the other components of $PM_{2.5}$. As long as the percentage of DPM to total ambient $PM_{2.5}$ remains in similar proportion, protective levels for $PM_{2.5}$ would be expected to offer a measure of protection from effects associated with DPM.

9.5.1.3. *Conclusions*

This assessment estimates an exposure air level of DE (as measured by DPM) to which humans may be exposed throughout their lifetime without experiencing any adverse noncancer health effects. The approach taken applies the RfC method using data specific to DE to produce an RfC of 5 $\mu g/m^3$ of DPM on the basis of four chronic inhalation studies of DE in rats and a composite uncertainty factor of 30. In addition, this assessment also recognizes the relative wealth of data regarding health effects associated with ambient PM and presumes that a health protective level for $PM_{2.5}$ also would be expected to provide a measure of protection from DPM, a constituent part of $PM_{2.5}$. The $PM_{2.5}$ standard of 15 $\mu g/m^3$ as an annual average thus is expected to provide a measure of protection from DPM noncancer health effects, reflecting DPM's current approximate proportion to $PM_{2.5}$.

9.5.2. Evaluation of Cancer Risks

As discussed in Section 9.4.3, the combined weight of evidence indicates that DE has the potential to pose a cancer hazard to humans at anticipated levels of environmental exposure. The target organ of DE-induced carcinogenicity is the lung. Strong evidence exists for a causal relationship between risk for lung cancer and occupational exposure to DE in certain occupational workers such as railroad workers, truck drivers, heavy-equipment operators (e.g., shipyard, diesel farm equipment, and construction), and transit workers. The evidence, however, was less than sufficient to confidently characterize DE as carcinogenic to humans, and instead the assessment concludes that DE is likely to be a human carcinogen. It also has been shown unequivocally in several studies that DE can cause benign and malignant lung tumors in rats in a dose-related manner following chronic inhalation exposure to high concentrations; however, this response is not thought applicable to predict a hazard to humans exposed at lower environmental levels. The mechanism(s) by which DE would induce lung cancer in humans has not been established, but available data suggest that mutagenic and nonmutagenic modes of action are possible. Hence, for estimating DE cancer risk at low environmental exposures, linear low-dose extrapolation would be considered an appropriate default assumption, which is consistent with EPA's science policy position that in the absence of an understanding of modes of carcinogenic action, a nonthreshold effect is to be presumed (U.S. EPA, 1986, 1996a). This same assumption has been used by other organizations/risk assessors who have previously used either linear risk extrapolation models or mechanistically based models to estimate cancer risk from environmental exposure to DE (e.g., WHO-IPCS, 1996; Cal EPA, 1998; also see Appendix C).

Dose-response assessment is based on either human or animal data, although human data are always preferred if available. Several quantitative assessments have been conducted by organizations and investigators on the basis of both occupational data and rat data (see Appendix C). However, more recent evidence indicates that DE causes tumors in the rat lung via a mode of action that involves impairment of lung clearance mechanisms (referred to as "lung overload response") associated with high exposures. This lung overload response is not expected in humans exposed to environmental levels (nor is it expected to occur in many occupational exposures), and thus the rat lung tumor dose-response data are not considered suitable for predicting human risk at low environmental exposures. Given that the rat data are not appropriate for estimating cancer risk to humans, this assessment focuses on using the occupational epidemiologic data for estimating environmental risk of DE to humans.

Even though occupational data are considered most relevant for use in dose-response assessment, uncertainties exist, including the following issues:

- the use of DPM (expressed as $\mu g/m^3$) as a surrogate dosimeter for DE exposure, given that the relative roles of various constituents in mediating carcinogenic effects and the mode of carcinogenic action are still unknown;
- the representativeness of occupational populations for the general population and vulnerable subgroups, including infants and children and individuals with preexisting diseases, particularly respiratory conditions;
- the lack of actual DE exposure data for workers in the available epidemiologic studies;
- possible confounders (smoking and asbestos exposure) that could contribute to the observed lung cancer risk in occupational studies of DE if the control for these confounders is not adequate; and
- whether or not an exposure-response relationship for occupational lung cancer risk can be estimated for DE.

Chapter 8, Section 8.3, provides a discussion of these uncertainties, along with an evaluation of the suitability of available occupational studies for a derivation of a cancer unit risk estimate for DE. Unit risk is defined as the estimated upper-bound cancer risk at a specific exposure or dose from a continuous average lifetime exposure of 70 years (in this case, cancer risk per $\mu g/m^3$ of DPM).

Among the occupational studies, the railroad worker studies (Garshick et al., 1987, 1988) and the Teamsters Union truck driver studies (Steenland et al., 1990, 1998) are considered to have the best available exposure data for possible use in establishing exposure-response relationships and deriving a cancer unit risk. There have been different views on the suitability of these studies for estimating environmental cancer risks (e.g., Cal EPA, 1998; HEI, 1995, 1999). Given the equivocal evidence for the presence or absence of an exposure-response relationship for the study of railroad workers, and exposure uncertainties for the study of truck drivers, it is judged that available data are too uncertain at this time for the development of a confident quantitative dose-response analysis and subsequent derivation of cancer unit risk for DE.

In the absence of a cancer unit risk to assess population cancer risk, this assessment provides a "perspective" about the possible magnitude of risk in the population from environmental exposure to DE. One approach to estimating the possible magnitude of risk involves simply noting that risks to the general public would be low in comparison with occupational risk if the differences in the lower environmental exposures compared to the higher occupational exposures are large. If the differences are small, the environmental risks would approach the workers' risk observed in studies of past occupational exposures. A comparison of environmental equivalent occupational and ambient environmental exposures showed that for certain occupations, there is a potential for overlap between environmental exposure and the estimated environmental equivalent occupational exposure, while in other cases the environmental exposures could be up to about 100-fold lower than the occupational levels (see Table 8-1). For the exposure overlap case, one can infer that the environmental risk could be the same as, or approach, the risk magnitudes observed in the occupational studies. In the 100-fold lower case, the environmental risk could be about 100-fold lower than the observed risk magnitudes in the occupational studies. Risks to the general public are of potential concern when a significant risk is seen in the occupational setting and the difference between occupational and ambient exposure may overlap or is relatively small (within one to two orders of magnitude).

A second approach, which is related to the first approach but more quantitative, is to estimate possible ranges of lung cancer risk from occupational exposures to DE, and then use a proportional relationship of exposure differences (e.g., EMs) to scale the occupational risk to the environmental exposure setting. Given the range of observed relative risks or odds ratios of lung cancer in a number of occupational studies, a relative risk increase of 1.4 was selected as a reasonable estimate of occupational risk for the purpose of this analysis. The relative risk of 1.4

means that the workers faced an extra risk that is 40% higher than the approximate 5% background lifetime lung cancer risk in the U.S. population. Using the relationship [*excess risk = (relative risk-1)* × *background risk*], 2% of these DE-exposed workers (i.e., 10^{-2} risk) would have been at risk (and developed lung cancer) attributable to occupational exposure to DE.

Using a nationwide average environmental exposure (0.8 μg/m^3 DPM), and assuming (a) the excess lung cancer risk from occupational exposure is about 10^{-2}; and (b) the past occupational exposures were no higher than about 1,200 μg/m^3 (equivalent to an environmental equivalent EM of 315, connoting a relatively large EM), the environmental cancer risk would fall between 10^{-4} and 10^{-5}. The selection of 1,200 μg/m^3 is a very high value intentionally selected to illustrate a high-end exposure boundary and thus a lower bounding of risk calculated by this exploratory approach. On the other hand, if occupational exposures for some groups were lower, for example, closer to 100 μg/m^3 (equivalent to an environmental equivalent EM of 26, connoting a smaller EM), the environmental risk would be higher and approach 10^{-3}. The selection of 100 μg/m^3 is purposefully toward the lower end of the reported occupational exposure range which spans 7–403 μg/m^3 in Table 8-1. The risk estimates are attended by numerous uncertainties; their inclusion in this document does not constitute Agency endorsement of their validity as a surrogate for cancer unit risk; the range of values is not useful for estimating numbers of cancer cases; and the range of possible risk from environmental exposures also could be lower and a zero risk cannot be ruled out.

These types of exploratory analyses are not intended to be precise or provide a definitive characterization of cancer risk but are useful in illustrating and gauging the possible range of risk based on applying reasonable judgment. The analyses provides a sense of where an upper limit (or "upper bound") of the risk may be. These analyses are subject to uncertainties, particularly the lack of actual exposure information for the occupational epidemiologic studies and the use of public-health-conservative risk assessment assumptions. The possible risks also could be lower and a zero risk cannot be ruled out because (a) some individuals in the population may have a high tolerance to exposure from DE and therefore not be susceptible to cancer from environmental exposure, and (b) although not reported, there could be a threshold of exposure below which there is no cancer risk. Given these circumstances, we refer to this risk analysis as a "perspective" on possible risks. Best scientific judgment guided the selection of assumptions and other elements of this analysis which are deemed reasonable and appropriate for identifying possible risks based on the information currently available. Further research is needed to more accurately assess and characterize environmental cancer risks from DE.

9.6. SUMMARY AND CONCLUSIONS

The available health effects data show that acute (short-term episodic exposure) and chronic (long-term) exposure to DE can pose hazards to humans and that environmental exposures, in some cases, may have a risk.

At relatively high acute exposures, DE can cause acute irritation to the eye and upper respiratory airways and symptoms of respiratory irritation which may be temporarily debilitating. Evidence also shows that DE has immunological toxicity that can induce allergic responses (some of which are also typical of asthma) and/or exacerbate existing respiratory allergies. While the hazard potential is important for these acute and short exposure-related effects, quantitative dose-response estimates for these effects could not be developed because of the lack of exposure-response information.

It is concluded that long-term exposure to low levels of DE poses a hazard for chronic inflammation and pathological changes in the human lung. A level of human lifetime exposure thought to be without appreciable risk for lung damage is estimated to be 5 $\mu g/m^3$ of DPM, this being a calculated RfC value for DE. Because DPM is a constituent of ambient $PM_{2.5}$ and there is some similarity in potential adverse effects from DE and $PM_{2.5}$, it is expected that a measure of protection from health effects associated with DE is provided by the 1997 annual $PM_{2.5}$ NAAQS, set at a level of 15 $\mu g/m^3$.

DE is considered to pose a human lung carcinogenicity hazard, which is expressed in a weight-of-evidence conclusion that DE is judged to be a “probable” human carcinogen, or is “likely to be carcinogenic in humans by inhalation” at environmental or higher exposure conditions. Because of uncertainty in the available exposure-response data, a cancer unit risk/cancer potency for DE has not been derived. One should note that the closeness of the high-end environmental exposures and low-end estimates of occupational exposure suggest less uncertainty in the extrapolation of hazard and possible risk to the environmental setting. Exploratory analyses using public health conservative assumptions provides a perspective on the possible range of lung cancer risk from environmental exposure to DE. Best scientific judgment guided the selection of assumptions and other elements of this analysis which are deemed reasonable and appropriate for identifying possible risks based on the information currently available. These analyses indicate that lifetime cancer risk may exceed 10^{-5} and could be as high as 10^{-3} or nearly so, though considering the assumptions used and the uncertainties, lower risk is possible and a zero risk cannot be ruled out. This range of values is attended by numerous uncertainties, the inclusion of the range in this assessment does not constitute Agency endorsement of their validity as surrogates for cancer unit risk values, and the range is not suitable for estimating numbers of cancer cases. These risk findings should not be viewed as a definitive characterization of risk.

Even though the evidence for potential human health hazards for DE is convincing and persuasive, uncertainties exist because of the use of assumptions to bridge data and knowledge gaps about human exposures to DE and the underlying mechanisms by which DE may cause the observed toxicities in humans and animals. A notable uncertainty of this assessment is how the physical and chemical nature of DE emissions has changed over the years because the toxicological and epidemiologic observations are based on older engines and their emissions, yet the desire is to focus on the potential health hazards related to exposure from present-day or future emissions. There have been changes in the physical and chemical composition of some DE emissions (on-road vehicle emissions) over time, though there is no definitive information to show that the emission changes portend significant toxicological changes. The mode(s) of action for DE toxicity in humans is not understood, and hence knowledge is lacking about the role of exhaust mixture components in modulating the toxicity. Taken together, these considerations have lead to a judgment that the hazards identified from older technology-based exposures are applicable to current-day exposures. As new and cleaner diesel engines replace a substantial number of existing engines, the general applicability of the conclusions in this assessment will need to be reevaluated.

Other uncertainties include the assumptions that health effects observed at high doses may be applicable to low doses, and that toxicologic findings in laboratory animals are predictive of human responses. Also, the available data are not sufficient to demonstrate the absence or presence of an exposure/dose-response threshold in humans for DE toxicity at environmental exposures. Again, this is due in part to the lack of understanding of how DE may cause adverse health effects in exposed humans and laboratory animals. Although there are hypotheses about the specific mechanisms by which DE might cause cancer and other toxicities, no specific biological pathways or specific constituents of DE have been firmly established as responsible for low-dose effects. The assumptions used in this assessment, i.e., the presence of a biological threshold for chronic respiratory effects based on cumulative dosage and the absence of a threshold for lung cancer stemming from subtle and irreversible effects, are considered prudent and reasonable default choices.

The characterization of health hazards and risks contained in this document assumes that the potential DE health hazards are relevant for long-term exposures, up to and including lifetime exposures, and would apply to a wide spectrum of individuals but not necessary those that would have significant differential susceptibility. There is no DE-specific information that provides direct insight into the question of differential susceptibility within the general human population or vulnerable subgroups, for example, children or the elderly. Although default approaches to account for interindividual variation have been included in the derivation of the noncancer effects RfC (i.e., use of an uncertainty factor of 10), this may or may not adequately protect certain subgroups that could be more vulnerable. Differential susceptibility to DPM among individuals in the population would be due to differences in dosimetry (i.e., differences in retained particle mass or number in the lung) and/or differences in respiratory system tissue response sensitivity. From the dosimetry perspective, we understand that age, gender, and disease status can influence deposition in the lung and other areas of the respiratory tract (U.S. EPA, 1996b, Section 10.7.7). For example, given that DE chronic toxicity is focused on the respiratory system, vulnerable subgroups might include those individuals who predispose their lungs to increased particle retention (e.g., smoking, high particulate burdens from nondiesel sources) or those having existing respiratory or lung inflammation, repeated respiratory infections, or chronic bronchitis or asthma. For children, there is also the hypothesis of possible increased sensitivity to exposure, given the ongoing processes of development from birth to maturation, of the respiratory and immune systems.

Despite the uncertainties regarding intraspecies variability, the default approach of using an uncertainty factor of 10 in the derivation of the noncancer effects RfC to account for possible interindividual variation in the toxic response to DE exposure is appropriate and reasonable given the lack of DE-specific data.

Variation in DE exposure is another source of uncertainty. Because of variation in human activity patterns and their proximity to DE sources of emissions, different population subgroups could potentially receive higher or lower exposure to DE. The highest exposed are clearly occupational subgroups whose job brings them very close to DE sources, such as diesel engine vehicle drivers and workers, diesel powered machinery operators, some underground miners, etc. High exposures in the general population would be to those living very near or having time outdoors in proximity to DE sources as well as those engaged in activities that cause high breathing rates where DE is present. Accordingly, where appropriate, analyses in this assessment have included possible high-end DE exposures in addition to the lower nationwide average exposure estimates.

Lastly, this assessment considers only potential heath effects from exposures to DE alone. DE exposure could be additive or synergistic to concurrent exposures to other air pollutants. For example, there is evidence that DPM that has been altered by being in the presence of ambient ozone significantly increases the rat lung inflammatory effect compared to DPM that was not subjected to ozone (Madden et al., 2000). This observation suggests a hypothesis that inflammation-related noncancer hazards of airborne DPM may be worsened by the increasing presence of ozone in the ambient air. Other concerns include the possible impacts for children and adults on the exacerbation of existing allergens resulting from DE exposure. However, in the absence of more definitive data demonstrating interactive effects from combined exposures to DE and other pollutants, it is not possible to further address these issues at this time.

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Appendix A

Calculation of Human Equivalent Continuous Exposure Concentrations (HECs)

A.1. INTRODUCTION

As discussed in Chapter 3, the lung burden of diesel particulate matter (DPM) during exposure is determined by both the amount and site of particle deposition in the lung and, subsequently, by rates of translocation and clearance from the deposition sites. Mathematical models have often been used to complement experimental studies in estimating the lung burdens of inhaled particles in different species under different exposure conditions. This appendix presents a mathematical model that simulates the deposition and clearance of DPM in the lungs of rats and humans of Yu et al.(1991) also published as Yu and Yoon (1990).

Diesel particles are aggregates formed from primary spheres 15-30 nm in diameter. The aggregates are irregularly shaped and range in size from a few molecular diameters to tens of microns. The mass median aerodynamic diameter (MMAD) of the aggregates is typically 0.2 µm and is polydisperse with a geometric standard deviation of around 2.3. The organics adsorbed onto the aggregates normally account for 10% to 30% of the particle mass. However, the exact size distribution of DPM and the specific composition of the adsorbed organics depend upon many factors, including engine design, fuels used, engine operating conditions, and the thermodynamic process of exhaust. The physical and chemical characteristics of DPM have been reviewed extensively by Amann and Siegla (1982) and Schuetzle (1983).

Four mechanisms deposit DPM within the respiratory tract during exposure: impaction, sedimentation, interception, and diffusion. The contribution from each mechanism to deposition, however, depends upon lung structure and size, the breathing condition of the subject, and particle size distribution. Under normal breathing conditions, diffusion is the most dominant mechanism and the other three mechanisms play minor roles.

Once DPM is deposited in the respiratory tract, both the carbonaceous core and the adsorbed organics will be removed from the deposition sites by mechanical clearance, provided by mucociliary transport in the ciliated conducting airways as well as macrophage phagocytosis and migration in the nonciliated airways, and dissolution. As the carbonaceous core or soot of DPM is insoluble, it is removed from the lung primarily by mechanical clearance, whereas the adsorbed organics are removed principally by dissolution (Chapter 3).

A.2. PARTICLE MODEL

To develop a mathematical model that simulates the deposition and clearance of DPM in the lung, an appropriate model for diesel particles must be introduced. For the deposition study, an equivalent sphere model developed by Yu and Xu (1987) was used to simulate the dynamics and deposition of DPM in the respiratory tract by various mechanisms. For the clearance study, a diesel particle is assumed to be composed of three different material components according to their characteristic clearance rates: (1) a carbonaceous core of approximately 80% of the particle mass; (2) absorbed organics of about 10% of particle mass, which are slowly cleared from the lung; and (3) adsorbed organics quickly cleared from the lung, accounting for the remaining 10% of particle mass. The presence of two discrete organic phases in the particle model is suggested by observations that the removal of particle-associated organics from the lung exhibits a biphasic clearance curve (Sun et al., 1984; Bond et al., 1986), as discussed in Chapter 3. This curve represents two major kinetic clearance phenomena: a fast- phase organic washout with a half-time of a few hours, and a slow phase with a half-time that is a few hundred times longer. The detailed components involved in each phase are not known. It is possible that the fast phase consists of organics that are leached out primarily by diffusion mechanisms while the slow phase might include any or all of the following components: (a) organics that are "loosened" before they are released, (b) organics that have become intercalated in the carbon core and whose release is thus impeded, (c) organics that are associated for longer periods of time because of hydrophobic interaction with other organic-phase materials, (d) organics that have been ingested by macrophages and as a result effectively remain in the lung for a longer period of time because of metabolism by the macrophage (metabolites formed may interact with other cellular components), and (e) organics that have directly acted on cellular components, such as the formation of covalent bonds with DNA and other biological macromolecules to form adducts.

The above distinction of the organic components is general and made to account for the biphasic clearance of DPM; it does not specifically imply the actual nature of the adsorbed organics. For aerosols made of pure organics, such as benzo(*a*)pyrene (BaP) and nitropyrene (NP) in the same size range of DPM, Sun et al. (1984) and Bond et al. (1986) observed a nearly monophasic clearance curve. This might be explained by the absence of intercalative phenomena (a) and of hydrophobic interaction imposed by a heterogeneous mixture of organics (b). The measurement of a pure organic might also neglect that quantity which has become intracellularly (c) or covalently bound (d).

A.3. COMPARTMENTAL LUNG MODEL

The model of Yu et al. (1991) comprises three principal compartments involved in deposition and clearance: tracheobronchial (T or TB), alveolar (A), and lung-associated lymph node (L), as shown in Figure A-1. The outside compartments blood (B) and GI tract (G) and nasopharyngeal or head (H) are also represented. The alveolar compartment in the model is obviously the most important for long-term retention studies. However, for short-term consideration, retentions in other lung compartments may also be significant. The presence of these lung compartments and the two outside compartments in the model therefore provides a complete description of all clearance processes involved.

In Figure A-1, $r_H^{(i)}$, $r_T^{(i)}$, and $r_A^{(i)}$ are, respectively, the mass deposition rates of DE material component i (i=1 [core], 2 [slowly cleared organics], and 3 [rapidly cleared organics]) in the head, tracheobronchial, and alveolar compartments; and $\lambda_{XY}^{(i)}$ represents the transport rate of material component i from any compartment X to any compartment Y. Let the mass fraction of material component i of a diesel particle be f_i. Then

$$r_H^{(i)} = f_i \, r_H \, , \tag{A-1}$$

$$r_T^{(i)} = f_i \, r_T \, , \tag{A-2}$$

$$r_A^{(i)} = f_i \, r_A \, , \tag{A-3}$$

where r_H, r_T, and r_A are, respectively, the total mass deposition rates of DPM in the H, T, and A compartments, determined from the equations:

$$r_H = c(TV)(RF)(DF)_H \, , \tag{A-4}$$

$$r_T = c(TV)(RF)(DF)_T \, , \tag{A-5}$$

$$r_A = c(TV)(RF)(DF)_A \quad . \tag{A-6}$$

In Equations A-4 to A-6, c is the mass concentration of DPM in the air, TV is the tidal volume, RF is the respiratory frequency, and $(DF)_H$, $(DF)_T$, and $(DF)_A$ are, respectively, the deposition fractions of DPM in the H, T, and A compartments over a respiratory cycle. The values of $(DF)_H$, $(DF)_T$, and $(DF)_A$, which vary with the particle size, breathing conditions, and lung architecture, were determined from the deposition model of Yu and Xu (1987).

The differential equations for $m_{XY}^{(i)}$, the mass of material component i in compartment X as a function of exposure time t, can be written as

Head (H)

$$\frac{dm_H^{(i)}}{dt} = r_H^{(i)} - \lambda_{HG}^{(i)} m_H^{(i)} - \lambda_{HB}^{(i)} m_H^{(i)} , \tag{A-7}$$

Tracheobronchial (T)

$$\frac{dm_T^{(i)}}{dt} = r_T^{(i)} + \lambda_{AT}^{(i)} m_A^{(i)} - \lambda_{TG}^{(i)} m_T^{(i)} - \lambda_{TB}^{(i)} m_T^{(i)} , \tag{A-8}$$

Alveolar (A)

$$\frac{dm_A^{(i)}}{dt} = r_A^{(i)} - \lambda_{AT}^{(i)} m_A^{(i)} - \lambda_{AL}^{(i)} m_A^{(i)} - \lambda_{AB}^{(i)} m_A^{(i)} , \tag{A-9}$$

Lymph nodes (L)

$$\frac{dm_L^{(i)}}{dt} = \lambda_{AL}^{(i)} m_A^{(i)} - \lambda_{LB}^{(i)} m_L^{(i)} . \tag{A-10}$$

Equation A-9 may also be written as

$$\frac{dm_A^{(i)}}{dt} = r_A^{(i)} - \lambda_A^{(i)} m_A^{(i)} , \tag{A-11}$$

where

$$\lambda_A^{(i)} = \lambda_{AT}^{(i)} + \lambda_{AL}^{(i)} + \lambda_{AB}^{(i)} . \tag{A-12}$$

is the total clearance rate of material component i from the alveolar compartment. In Equations A-7 to A-10, we have assumed vanishing material concentration in the blood compartment to calculate diffusion transport.

The total mass of the particle-associated organics in compartment X is the sum of $m_X^{(2)}$ and $m_X^{(3)}$ the total mass of DPM in compartment X is equal to

$$m_X = m_X^{(1)} + m_X^{(2)} + m_X^{(3)} \tag{A-13}$$

The lung burdens of diesel soot (core) and organics are defined, respectively, as

$$m_{Lung}^{(1)} = m_T^{(1)} + m_A^{(1)} , \qquad \text{(A-14)}$$

and

$$m_{Lung}^{(2)+(3)} = m_T^{(2)} + m_A^{(2)} + m_T^{(3)} + m_A^{(3)} . \qquad \text{(A-15)}$$

Because the clearance of diesel soot from compartment T is much faster than from compartment A, $m_T^{(1)} < m_A^{(1)}$ a short time after exposure, Equation A-14 leads to

$$m_{Lung}^{(1)} \cong m_A^{(1)} . \qquad \text{(A-16)}$$

Solution to Equations A-7 to A-10 can be obtained once all the transport rates $\lambda_{XY}^{(i)}$ are known. When $\lambda_{XY}^{(i)}$ are constant, which is the case in linear kinetics, Equations A-7 to A-10 will have a solution that increases with time at the beginning of exposure but eventually saturates and reaches a steady-state value. This is the classical retention model developed by the International Commission of Radiological Protection (ICRP, 1979). However, as discussed in Chapter 3, data have shown that when rats are exposed to DPM at high concentration for a prolonged period, long-termed clearance is impaired. This is the so-called overload effect, observed also for other insoluble particles. The overload effect cannot be predicted by the classical ICRP model. Soderholm (1981) and Strom et al. (1987, 1988) have proposed a model to simulate this effect by adding a separate sequestering compartment in the alveolar region. In the present approach, a single compartment for the alveolar region of the lung is used and the overload effect is accounted for by a set of variable transport rates $\lambda_{AT}^{(i)}$, $\lambda_{AL}^{(i)}$, and $\lambda_A^{(i)}$ which are functions of m_A. The transport rates $\lambda_A^{(i)}$ and $\lambda_{AL}^{(i)}$ in Equations A-7 to A-10 can be determined directly from experimental data on lung and lymph node burdens, and $\lambda_{AT}^{(i)}$ and $\lambda_{AB}^{(i)}$ from Equation A-12.

A.4. SOLUTIONS TO KINETIC EQUATIONS

Equation A-11 is a nonlinear differential equation of $m_A^{(i)}$ with known function of $\lambda_A^{(i)}$. For diesel soot, this equation becomes

$$\frac{dm_A^{(1)}}{dt} = r_A^{(1)} - \lambda_A^{(1)}(m_A)m_A^{(1)} \ . \tag{A-17}$$

Because clearance of the particle-associated organics is much faster than diesel soot, $m_A^{(2)}$ and $m_A^{(3)}$ constitute only a very small fraction of the total particle mass (less than 1%) after a long exposure, and we may consider $\lambda_A^{(1)}$ as a function of $m_A^{(1)}$ alone. Equation A-17 is then reduced to a differential equation with $m_A^{(1)}$ the only dependent variable.

The general solution to Equation A-17 for constant $r_A^{(1)}$ at any time, t, can be obtained by the separation of variables to give

$$\int_0^{m_A^{(1)}} \frac{dm_A^{(1)}}{r_A^{(1)} - \lambda_A^{(1)} m_A^{(1)}} = t \ . \tag{A-18}$$

If $r_A^{(1)}$ is an arbitrary function of t, Equation A-17 needs to be solved numerically such as by a Runge-Kutta method. Once $m_A^{(1)}$ is found, the other kinetic equations A-7 to A-10 for both diesel soot and the particle-associated organics can be solved readily, as they are linear equations. The solutions to these equations for constant $r_H^{(i)}$, $r_T^{(i)}$, and $r_A^{(i)}$ are given below:

Head (H)

$$m_H^{(i)} = r_H^{(i)}/\lambda_H^{(i)} + (m_{H0}^{(i)} - r_H^{(i)})/\lambda_H^{(i)}) \ \exp\ (-\lambda_H^{(i)}\ t) \tag{A-19}$$

$$where \quad \lambda_H^{(i)} = \lambda_{HG}^{(i)} + \lambda_{HB}^{(i)} \tag{A-20}$$

Tracheobronchial (T)

$$m_T^{(i)} = \exp\left(-\lambda_T^{(i)}\, t\right) \int_0^t \left(r_T^{(i)} + \lambda_{AT}^{(i)}\ m_A^{(i)} \right) \exp\left(\lambda_T^{(i)}\, t\right) dt + m_{T0}^{(i)} \qquad \text{(A-21)}$$

$$where\ \ \lambda_T^{(i)} = \lambda_{TG}^{(i)} + \lambda_{TB}^{(i)} \qquad \text{(A-22)}$$

Lymph nodes (L)

$$m_L^{(i)} = \exp(-\lambda_{LB}^{(i)}\, t) \int_0^t \lambda_{AL}^{(i)} m_A^{(i)} \exp(\lambda_{LB}^{(i)}\, t)\ dt + m_{L0}^{(i)}) \qquad \text{(A-23)}$$

In Equations A-19 to A-23, $m_{XO}^{(i)}$ represents the value of $m_X^{(i)}$ at t = 0.

In the sections to follow, the methods of determining $r_H^{(i)}$, $r_T^{(i)}$ and $r_A^{(i)}$ or $(DF)_H$, $(DF)_T$, and $(DF)_A$ $r_H^{(DF)}$, $r_T^{(DF)}$ and $r_A^{(DF)}$ as well as the values of $\lambda_{XY}^{(i)}$ in the compartmental lung model are presented.

A.5. DETERMINATION OF DEPOSITION FRACTIONS

The mathematical models for determining the deposition fractions of DPM in various regions of the respiratory tract have been developed by Yu and Xu (1986, 1987) and are adopted in this report. Yu and Xu consider DPM as a polydisperse aerosol with a specified mass median aerodynamic diameter (MMAD) and geometrical standard deviation σ_g. Each diesel particle is represented by a cluster-shaped aggregate within a spherical envelope of diameter d_e. The envelope diameter d_e is related to the aerodynamic diameter of the particle by the relation

$$\frac{d_e}{d_a} = \varphi^{-1/2} \left(\frac{C_a}{C_e}\right)^{1/2)} \left(\frac{\zeta}{\zeta_o}\right)^{1/2} \qquad \text{(A-24)}$$

where ζ is the bulk density of the particle in g/cm^3, ζ_0 = 1 g/cm^3; φ is the packing density, which is the ratio of the space actually occupied by primary particles in the envelope to the overall envelope volume; and C_x is the slip factor given by the expression:

$$C_x = 1 + 2\frac{\lambda}{d_x}\left[1.257 + 0.4 \exp -\left(\frac{0.55 d_x}{\lambda}\right)\right] \quad \text{(A-25)}$$

in which $\lambda \cong 8 \times 10^{-6}cm^3$ is the mean free path of air molecules at standard conditions. In the diesel particle model of Yu and Xu (1986), ζ has a value of 1.5 g/cm^3 and a φ value of 0.3 is chosen based upon the best experimental estimates. As a result, Equation A-24 gives d_e/d_a = 1.35. In determining the deposition fraction of DPM, d_e is used for diffusion and interception according to the particle model.

A.5.1. Deposition in the Head

Particle deposition in the naso- or oropharyngeal region is referred to as head or extrathoracic deposition. The amount of particles that enters the lung depends upon the breathing mode. Normally, more particles are collected via the nasal route than by the oral route because of the nasal hairs and the more complex air passages of the nose. Since the residence time of diesel particles in the head region during inhalation is very small (about 0.1 s for human adults at normal breathing), diffusional deposition is insignificant and the major deposition mechanism is impaction. The following empirical formulas derived by Yu et al. (1981) for human adults are adopted for deposition prediction of DPM:

For mouth breathing:

$$(DF)_{H,\ in} = 0,\ for\ d_a^2 \leq 3000 \quad \text{(A-26)}$$

$$(DF)_{H,\ in} = -1.117 + 0.324\ \log(d_a^2 Q),\ for\ d_a^2 Q > 3000 \quad \text{(A-27)}$$

$$(DF)_{H,\ ex} = 0, \quad \text{(A-28)}$$

and for nose breathing:

$$(DF)_{H,\ in} = -0.014 + 0.023\ \log(d_a^2 Q),\ for\ d_a^2 Q \leq 337 \quad \text{(A-29)}$$

$$(DF)_{H,\ in} = -0.959 + 0.397\ \log(d_a^2 Q),\ for\ d_a^2 Q > 337 \qquad \text{(A-30)}$$

$$(DF)_{H,\ ex} = 0.003 + 0.033\ \log(d_a^2 Q),\ for\ d_a^2 Q \le 215 \qquad \text{(A-31)}$$

$$(DF)_{H,\ ex} = -0.851 + 0.399\ \log(d_a^2 Q),\ for\ d_a^2 Q > 215 \qquad \text{(A-32)}$$

where $(DF)_H$ is the deposition efficiency in the head, the subscripts in and ex denote inspiration and expiration, respectively, d_a is the particle aerodynamic diameter in μm, and Q is the air flowrate in cm^3/sec.

Formulas to calculate deposition of diesel particles in the head region of children are derived from those for adults using the theory of similarity, which assumes that the air passage in the head region is geometrically similar for all ages and that the deposition process is characterized by the Stokes number of the particle. Thus, the set of empirical equations from A-26 through A-32 are transformed into the following form:

For mouth breathing:

$$(DF)_{H,\ in} = 0,\ for\ d_a^2 Q \le 3000 \qquad \text{(A-33)}$$

and for nose breathing:

$$(DF)_{H,\ in} = -1.117 + 0.972\ logK + 0.324\ \log(d_a^2 Q),\ for\ d_a^2 Q > 3000 \qquad \text{(A-34)}$$

$$(DF)_{H,\ ex} = 0. \qquad \text{(A-35)}$$

$$(DF)_{H,\ in} = -\ 0.014 + 0.690\ \log\ K + 0.023\ \log(d_a^2 Q),\ for\ d_a^2 Q \le 337 \qquad \text{(A-36)}$$

$$(DF)_{H,\ in} = -0.959 + 1.191\ \log\ K + 0.397\ \log\ (d_a^2 Q),\ \text{for}\ d_a^2 Q > 337 \qquad \text{(A-37)}$$

$$(DF)_{H,\ ex} = 0.003 + 0.099\ \log\ K + 0.033\ \log(d_a^2 Q),\ \text{for}\ d_a^2 Q \le 215 \qquad \text{(A-38)}$$

where K is the ratio of the linear dimension of the air passages in the head region of adults to that of children, which is assumed to be the same as the ratio of adult/child tracheal diameters.

$$(DF)_{H,\ ex} = 0.851 + 1.197 \log K + 0.399 \log(d_a^2 Q), \text{ for } d_a^2 Q > 215 \qquad \text{(A-39)}$$

For rats, the following empirical equations are used for deposition prediction of DPM in the nose:

$$(DF)_{H,\ in} = (DF)_{H,\ ex} = 0.046 + 0.009 \log(d_a^2 Q), \text{ for } d_a^2 Q \leq 13.33 \qquad \text{(A-40)}$$

A.5.2. Deposition in the Tracheobronchial and Alveolar Regions

The deposition model adopted for DPM is the one previously developed for monodisperse (Yu, 1978) and polydisperse spherical aerosols (Diu and Yu, 1983). In the model,

$$(DF)_{H,\ in} = (DF)_{H,\ ex} = -0.522 + 0.514 \log(d_a^2 Q), \text{ for } d_a^2 Q > 13.33 \qquad \text{(A-41)}$$

the branching airways are viewed as a chamber model shaped like a trumpet (Figure A-2). The cross-sectional area of the chamber varies with airway depth, x, measured from the beginning of the trachea. At the last portion of the trumpet, additional cross-sectional area is present to account for the alveolar volume per unit length of the airways. Inhaled diesel particles that escape capture in the head during inspiration will enter the trachea and subsequently the bronchial airways (compartment T) and alveolar spaces (compartment A).

Assuming that the airways expand and contract uniformly during breathing, the equation for the conservation of particles takes the form:

$$\beta(A_1 + A_2)\frac{\partial c}{\partial x} + Q\,\frac{\partial c}{\partial x} = -\,Qc\eta \qquad \text{(A-42)}$$

where c is the mean particle concentration at a given x and time t; A_1 and A_2 are, respectively, the summed cross-sectional area (or volume per unit length) of the airways and alveoli at rest; η is the particle uptake efficiency per unit length of the airway; β is an expansion factor, given by:

$$\beta = 1 + \frac{V_t}{V_l} \qquad \text{(A-43)}$$

and Q is the air flow rate, varying with x and t according to the relation

$$\frac{Q}{Q_o} = 1 - \frac{V_x}{V_l} \tag{A-44}$$

where Q_0 is the air flow rate at x = 0. In Equations A-43 and A-44, V_t is the volume of new air in the lungs and V_x and V_ℓ are, respectively, the accumulated airway volume from x = 0 to x, and total airway volume at rest.

Equation A-42 is solved using the method of characteristics with appropriate initial and boundary conditions. The amount of particles deposited between location x_1 and x_2 from time t_1 to t_2 can then be found from the expression

$$DF = \int_{t_1}^{t_2} \int_{x_1}^{x_2} Qc\eta \, dx dt \tag{A-45}$$

For diesel particles, η is the sum of those due to the individual deposition mechanisms described above, i.e.,

where η_I, η_S, η_P, and η_D are, respectively, the deposition efficiencies per unit length of the

$$\eta = \eta_I + \eta_S + \eta_P + \eta_D \tag{A-46}$$

airway due to impaction, sedimentation, interception, and diffusion. On the basis of the particle model described above, the expressions for η_I, η_S, η_P, and η_D are obtained in the following form:

$$\eta_I = \frac{0.768}{L}(St)\theta. \tag{A-47}$$

$$\eta_S = \frac{2}{\pi L}[2\epsilon \sqrt{1 - \epsilon^{(2/3)}} - \epsilon^{1/3}\sqrt{1 - \epsilon^{2/3}} + \sin^{-1} \epsilon^{1/3}] \tag{A-48}$$

$$\eta_P = \frac{4}{3\pi L}(\Gamma - \frac{\Gamma^3}{32}) \tag{A-49}$$

$$\eta_D = \frac{1}{L}[1 - 0.819\exp(-14.63\Delta) - 0.0976\exp(-89.22\Delta) - 0.0325\exp(-228\Delta) - 0.0509\exp(-125\Delta^{2/3})] \quad \text{(A-50)}$$

$$\eta_D = \frac{4}{L}\Delta^{1/2}(1 - 0.444\Delta^{1/2}) \quad \text{(A-51)}$$

for Reynolds numbers of the flow smaller than 2000, and for Reynolds numbers greater than or equal to 2000, where $ST=d_a^2u/(18\mu R)$ is the particle Stokes number, $\theta = L/(8R)$, $\in = 3\mu u_s L/(32uR)$, $\Gamma = d_e/R$, and $\Delta = DL/(4R^2u)$. In the above definitions u is the air velocity in the airway; μ is the air viscosity; L and R are, respectively, the length and radius of the airway; $u_s = C_a d_a^2/(18\mu)$ is the particle settling velocity; and $D = C_e kT(3\pi\mu d_e)$ is the diffusion coefficient with k denoting the Boltzmann constant and T the absolute temperature. In the deposition model, it is also assumed that η_I and $\eta_P = 0$ for expiration, while η_D and η_S have the same expressions for both inspiration and expiration.

During the pause, only diffusion and sedimentation are present. The combined deposition efficiency in the airway, E, is equal to:

$$E = 1 - (1 - E_S)(1 - E_D) . \quad \text{(A-52)}$$

where E_D and E_S are, respectively, the deposition efficiencies due to the individual mechanisms of diffusion and sedimentation over the pause period. The expression for E_D and E_S are given by

$$E_D = 1 - \sum_{i=1}^{3}\frac{4}{\alpha_i}\exp(-\alpha_i^2\tau_D)\left(1 - \sum_{i=1}^{3}\frac{4}{\alpha_i^2}\right)\exp\left[-\frac{4\tau_D^{1/2}}{\pi^{1/2}\left(1 - \sum_{i=1}^{3}\frac{4}{\alpha_i^2}\right)}\right] \quad \text{(A-53)}$$

where $\tau_D = D\tau/R^2$ in which τ is the pause time and α_1, α_2, and α_3 are the first three roots of the equation:

$$J_o(\alpha) = 0 . \quad \text{(A-54)}$$

in which J_o is the Bessel function of the zero_{th} order, and:

$$E_S = 1.1094\tau_S - 0.1604\tau_S^2, \; for\; 0 < \tau_S \le 1. \quad \text{(A-55)}$$

and

$$E_S = 1 - 0.0069\tau_S^{-1} - 0.0859\tau_S^{-2} - 0.0582\tau_S^{-3}, \quad for\ \tau_S > 1, \tag{A-56}$$

where $\tau_S = u_S\tau/2R$.

The values of $(DF)_T$ and $(DF)_A$ over a breathing cycle are calculated by superimposing DF for inspiration, deposition efficiency E during pause, and DF for expiration in the tracheobronchial airways and alveolar space. It is assumed that the breathing cycle consists of a constant flow inspiration, a pause, and a constant flow expiration, each with a respective duration fraction of 0.435, 0.05, and 0.515 of a breathing period.

A.5.3. Lung Models

Lung architecture affects particle deposition in several ways: the linear dimension of the airway is related to the distance the particle travels before it contacts the airway surface; the air flow velocity by which the particles are transported is determined by the cross-section of the airway for a given volumetric flowrate; and flow characteristics in the airways are influenced by the airway diameter and branching patterns. Thus, theoretical prediction of particle deposition depends, to a large extent, on the lung model chosen.

A.5.3.1. *Lung Model for Rats*

Morphometric data on the lung airways of rats were reported by Schum and Yeh (1979). Table A-1 shows the lung model data for Long Evans rats with a total lung capacity of 13.784 cm^3. Application of this model to Fischer rats is accomplished by assuming that the rat has the same lung structure regardless of its strain and that the total lung capacity is proportional to the body weight. In addition, it is also assumed that the lung volume at rest is about 40% of the total lung capacity and that any linear dimension of the lung is proportional to the cubic root of the lung volume.

A.5.3.2. *Lung Model for Human Adults*

The lung model of mature human adults used in the deposition calculation of DPM is the symmetric lung model developed by Weibel (1963). In Weibel's model, the airways are assumed to be a dichotomous branching system with 24 generations. Beginning with the 18th generation, increasing numbers of alveoli are present on the wall of the airways, and the last three generations are completely aleveolated. Thus, the alveolar region in this model consists of all the airways in the last seven generations. Table A-2 presents the morphometric data of the airways of Weibel's model adjusted to a total lung volume of 3000 cm^3.

A.5.3.3. *Lung Model for Children*

The lung model for children in the diesel study was developed by Yu and Xu (1987) on the basis of available morphometric measurements. The model assumes a lung structure with dichotomous branching of airways, and it matches Weibel's model for a subject when evaluated at the age of 25 years, the age at which the lung is considered to be mature. The number and size of airways as functions of age t (years) are determined by the following equations.

A.5.3.3.1. ***Number of airways and alveoli.*** The number of airways $N_i(t)$ at generation i for age t is given by

$$N_i(t) = 2^i, \qquad \text{for } 0 \le i \le 20 \qquad \text{(A-57)}$$

$$\begin{cases} N_{21}(t) = N_r(t), \\ N_{22}(t) = N_{23}(t) = 0. \end{cases} \qquad \text{for } N_r(t) \le 2^{21} \qquad \text{(A-58)}$$

$$\begin{cases} N_{21}(t) = 2^{21}, \\ N_{22}(t) = N_r(t) - 2^{21}, \\ N_{23}(t) = 0, \end{cases} \qquad \text{for } 2^{21} < N_r(t) \le 2^{22} \qquad \text{(A-59)}$$

$$\begin{cases} N_{21}(t) = 2^{21}, \\ N_{22}(t) = 2^{22}, \\ N_{23}(t) = N_r(t) - 2^{21} - 2^{22} \end{cases} \qquad \textit{for } N_r(t) > 2^{21} + 2^{22}, \qquad \text{(A-60)}$$

where $N_r(t)$ is the total number of airways in the last three airway generations. The empirical equation for N_r which best fits the available data is

$$N_r(t) = \begin{cases} 2.036 \times 10^7(1 - 0.926e^{-0.15}t), & t \le 8 \\ 1.468 \times 10^7, & t > 8 \end{cases} \qquad \text{(A-61)}$$

Thus, $N_r(t)$ increases from approximately 1.5 million at birth to 15 million at 8 years of age and remains nearly constant thereafter. Equations A-58 to A-60 also imply that in the last three generations, the airways in the subsequent generation begin to appear only when those in the preceding generation have completed development.

The number of alveoli as a function of age can be represented by the following equation according to the observed data:

$$N_A(t) = 2.985 \times 10^8(1 - 0.919e^{-0.45}t) \tag{A-62}$$

The number of alveoli distributed in the unciliated airways at the airway generation level is determined by assuming that alveolization of airways takes place sequentially in a proximal direction. For each generation, alveolization is considered to be complete when the number of alveoli in that generation reaches the number determined by Weibel's model.

A.5.3.3.2. ***Airway size.*** Four sets of data are used to determine airway size during postnatal growth: (a) total lung volume as a function of age; (b) airway size as given by Weibel's model; (c) the growth pattern of the bronchial airways; and (d) variation in alveolar size with age. From these data, it is found that the lung volume, LV(t) at age t, normalized to Weibel's model at 4800 cm^3 for an adult (25 years old), follows the equation

$$LV(t) = 0.959 \times 10^5(1 - 0.998e^{-0.002}t) \quad (cm^3). \tag{A-63}$$

The growth patterns of the bronchial airways are determined by the following equations

$$D_i(t) - D_{iw} = \alpha_i[H(t) - H(25)], \tag{A-64}$$

$$L_i(t) - L_{iw} = \beta_i[H(t) - H(25)], \tag{A-65}$$

where $D_i(t)$ and $L_i(t)$ are, respectively, the airway diameter and length at generation i and age t, D_{iw} and L_{iw} the corresponding values for Weibel's model, α_i and β_i are coefficients given by

$$\alpha_i = 3.26 \times 10^{-2}\exp[-1.183 \ (i+1)^{0.5}] \tag{A-66}$$

$$\beta_i = 1.05 \times 10^{-6} \exp \ [10.1] \ (i+1)^{-0.2}] \tag{A-67}$$

and H(t) is the body height, which varies with age t in the form

$$H(t) = 1.82 \times 10^2(1 - 0.725e^{-0.14}t) \ (cm). \tag{A-68}$$

For the growth patterns of the airways in the alveolar region, it is assumed that

$$\frac{D_i}{D_{iw}} = \frac{L_i}{L_{iw}} = \frac{D_a}{D_{aw}} = f(t), \quad for \ 17 \le i \le 23 \tag{A-69}$$

where D_a is the diameter of an alveolus at age t, D_{aw} = 0.0288 cm is the alveolar diameter for adults in accordance with Weibel's model, and f(t) is a function determined from

$$f(t) = \sqrt[3]{\frac{\{LV(t) - \sum_{i=0}^{16} \frac{\pi}{4} D_i^2(t)\ L_i(t) N_i(t)\}}{\{\sum_{i=17}^{23} \frac{\pi}{4} D_{iw}^2 L_{iw} N_i(t) + \frac{5\pi}{36} D_{aw}^3 N_A(t)\}}} \tag{A-70}$$

A.6. TRANSPORT RATES

The values of transport rates $\lambda_{XY}^{(i)}$ for rats have been derived from the experimental data of clearance for diesel soot (Chan et al., 1981; Strom et al., 1987, 1988) and for the particle-associated organics (Sun et al., 1984; Bond et al., 1986; Yu et al., 1991). These values are used in the present model of lung burden calculation and are listed below:

$$\lambda_{HG}^{(i)} = 1.73 \ (i = 1,2,3) \tag{A-71}$$

$$\lambda_{HB}^{(1)} = \lambda_{TB}^{(1)} = \lambda_{LB}^{(1)} = \lambda_{AB}^{(i)} = 0.00018 \tag{A-72}$$

$$\lambda_{HB}^{(2)} = \lambda_{TB}^{(2)} = \lambda_{LB}^{(2)} = \lambda_{AB}^{(2)} = 0.0129 \tag{A-73}$$

$$\lambda_{HB}^{(3)} = \lambda_{TB}^{(3)} = \lambda_{LB}^{(3)} = \lambda_{AB}^{(3)} = 12.55 \tag{A-74}$$

$$\lambda_{TG}^{(i)} = 0.693 \qquad (i = 1,2,3) \tag{A-75}$$

$$\lambda_{AL}^{(1)} = 0.00068\ [1 - \exp(-0.046 m_A^{1.62})] \tag{A-76}$$

$$\lambda_{AL}^{(i)} = \frac{1}{4}\lambda_{AB}^{(i)} \qquad (i = 2,3) \tag{A-77}$$

$$\lambda_{AT}^{(i)} = 0.012\ \exp(-0.11 m_A^{1.76}) + 0.00068\ \exp(-0.046 m_A^{1.62}) \quad (i = 1,2,3) \tag{A-78}$$

$$\lambda_{A}^{(1)} = \lambda_{AL}^{(1)} + \lambda_{AT}^{(1)} + \lambda_{AB}^{(1)} = 0.012\ \exp(-0.11 m_A^{1.76}) + 0.00086 \tag{A-79}$$

$$\lambda_{A}^{(2)} = \lambda_{AL}^{(2)} + \lambda_{AT}^{(2)} + \lambda_{AB}^{(2)} = 0.012\ \exp(-0.11 m_A^{1.76}) + 0.00068\ \exp(-0.046 m_a^{1.62}) + 0.0161 \tag{A-80}$$

$$\lambda_{A}^{(3)} = \lambda_{AL}^{(3)} + \lambda_{AT}^{(3)} + \lambda_{AB}^{(3)} = 0.012\ \exp(-0.11 m_A^{1.76}) + 0.00068\ \exp(-0.046 m_A^{1.62}) + 15.7 \tag{A-81}$$

where $\lambda_{XY}^{(i)}$ is the unit of day^{-1}, and $m_A \cong m_A^{(1)}$ is the particle burden (in mg) in the alveolar compartment.

Experimental data on the deposition and clearance of DPM in humans are not available. To estimate the lung burden of DPM for human exposure, it is necessary to extrapolate the transport rates $\lambda_{XY}^{(i)}$ from rats to humans. For organics, it is assumed that the transport rates are the same for rats and humans. This assumption is based upon the observation of Schanker et al. (1986) that the lung clearance of inhaled lipophilic compounds appears to depend only on their lipid/water partition coefficients and is independent of species. In contrast, the transport rates of diesel soot in humans should be different from those of rats, since the alveolar clearance rate, λ_A, of insoluble particles at low lung burdens for human adults is approximately seven times that of rats (Bailey et al., 1982).

No data are available on the change of the alveolar clearance rate of insoluble particles in humans due to excessive lung burdens. It is seen from Equation A-79 that $\lambda_A^{(1)}$ for rats can be written in the form

$$\lambda_A^{(1)} = a \exp(-b m_A^c) + d \qquad \text{(A-82)}$$

where a, b, c, and d are constants. The right-hand side of Equation A-82 consists of two terms, representing, respectively, macrophage-mediated mechanical clearance and clearance by dissolution. The first term depends upon the lung burden, whereas the second term does not. To extrapolate this relationship to humans, we assume that the dissolution clearance term is independent of species and that the mechanical clearance term for humans varies in the same proportion as in rats under the same unit surface particulate dose. This assumption results in the following expression for $\lambda_A^{(1)}$ in humans

$$\lambda_A^{(1)} = \frac{a}{P} \exp[-b(m_A/S)^c] + d \qquad \text{(A-83)}$$

where P is a constant derived from the human/rat ratio of the alveolar clearance rate at low lung burdens and S is the ratio of the pulmonary surface area between humans and rats. Equation A-83 implies that rats and humans have equivalent amounts of biological response in the lung to the same specific surface dose of inhaled DPM.

From the data of Bailey et al. (1982), a value of $\lambda_A^{(1)} = 0.00169$ day^{-1} is obtained for humans at low lung burdens leading to P = 14.4. A value for S of 148 is reported from the data of the anatomical lung model of Schum and Yeh (1979) for rats and Weibel's model for human adults. For humans less than 25 years old, the model assumes the same value for P, but S is computed from the data of the lung model for young humans (Yu and Xu 1987). The value of S for different ages is shown in Table A-3.

The equations for other transport rates that have a lung-burden-dependent component are extrapolated from rats to humans in a similar manner. The following lists the values of $\lambda_{XY}^{(i)}$ (in day^{-1}) for humans used in the present model calculation:

$$\lambda_{HG}^{(1)} = 1.73 \quad (i = 1,2,3) \qquad \text{(A-84)}$$

$$\lambda_{HB}^{(1)} = \lambda_{TB}^{(1)} = \lambda_{LB}^{(1)} = \lambda_{AB}^{(1)} = 0.00018 \quad \text{(A-85)}$$

$$\lambda_{HB}^{(2)} = \lambda_{TB}^{(2)} = \lambda_{LB}^{(2)} = \lambda_{AB}^{(2)} = 0.0129 \quad \text{(A-86)}$$

$$\lambda_{HB}^{(3)} = \lambda_{TB}^{(3)} = \lambda_{LB}^{(3)} = \lambda_{AB}^{(3)} = 12.55 \quad \text{(A-87)}$$

$$\lambda_{TG}^{(i)} = 0.693 \qquad (i = 1,2,3) \quad \text{(A-88)}$$

$$\lambda_{AL}^{(1)} = 0.00068 \ \{1 - 0.0694 \ \exp[-0.046(m_A/S)^{1.62}]\} \quad \text{(A-89)}$$

$$\lambda_{AL}^{(i)} = \frac{1}{4}\lambda_{AB}^{(i)} \qquad (i = 2, 3) \quad \text{(A-90)}$$

$$\lambda_{AT}^{(i)} = 0.0694 \ \{0.012 \ \exp[-0.11(m_A/S)^{1.76}] + 0.00068 \ \exp[-0.046(m_A/S)^{1.76}]\} \ (i = 1, 2, 3) \quad \text{(A-91)}$$

$$\lambda_{A}^{(1)} = \lambda_{AL}^{(1)} + \lambda_{AB}^{(1)} + \lambda_{AT}^{(1)} = 0.0694 \ \{0.012 \ \exp[-0.11(m_A/S)^{1.76}]\} + 0.00086 \quad \text{(A-92)}$$

$$\lambda_{A}^{(2)} = \lambda_{AL}^{(2)} + \lambda_{AT}^{(2)} + \lambda_{AB}^{(2)} = \quad \text{(A-93)}$$

$$0.0694\{0.012 \ \exp[-0.11(m_A/A)^{1.76}] +$$

$$0.00068 \ \exp[-0.046(m_A/S)^{1.76}]\} + 0.016 \quad \text{(A-94)}$$

A.7. RESULTS

A.7.1. Simulation of Rat Experiments

To test the accuracy of the model, simulation results are obtained on the retention of DPM in the rat lung and compared with the data of lung burden and lymph node burden obtained by Strom et al. (1988). A particle size of 0.19 µm MMAD and a standard geometric deviation, σ_g, of 2.3 (as used in Strom's experiment) are used in the calculation.

The respiratory parameters for rats are based on their weight and calculated using the following correlations of minute volume, respiratory frequency, and growth curve data.

$$\text{Minute volume} = 0.9W\ (\text{cm}^3/\text{min}) \qquad \text{(A-95)}$$

$$\text{Respiratory frequency} = 475W^{-0.3}\ (1/\text{min}) \qquad \text{(A-96)}$$

where W is the body weight (in grams) as determined from the equation

$$W = 5+537T/(100+T),\ \text{for}\ T \geq 56\ \text{days} \qquad \text{(A-97)}$$

in which T is the age of the rat measured in days.

Equation A-95 was obtained from the data of Mauderly (1986) for rats ranging in age from 3 mo to 2 years old; Equation A-96 was obtained from the data of Strom et al. (1988); and Equation A-97 was determined from the best fit of the experimental deposition data. Figures A-3 and A-4 show the calculated lung burden of diesel soot ($m_A^{(1)} + m_T^{(1)}$) and lymph node burden, respectively, for the experiment by Strom et al. (1988) using animals exposed to DPM at 6 mg/m^3 for 1, 3, 6, and 12 weeks; exposure in all cases was 7 days/week and 20 h daily. The solid lines represent the calculated accumulation of particles during the continuous exposure phase and the dashed lines indicate calculated post-exposure retention. The agreement between the calculated and the experimental data for both lung and lymph node burdens during and after the exposure periods was very good.

Comparison of the model calculation and the retention data of particle-associated BaP in rats obtained by Sun et al. (1984) is shown in Figure A-5. The calculated retention is shown by the solid line. The experiment of Sun et al. consisted of a 30-min exposure to diesel particles coated with [^3H] benzo[a]pyrene *([^3H] - BaP)* at a concentration of 4 to 6 µg/m^3 of air and followed by a post-exposure period of over 25 days. The fast and slow phase of *([^3H] - BaP)* clearance half-times were found to be 0.03 day and 18 days, respectively. These correspond to $\lambda_{AO}^{2} = 0.0385\ \text{day}^{-1}$ and $\lambda_{AO}^{(3)} = 23.1\ \text{day}^{-1}$ in our model, where $\lambda_{AO}^{(i)}$ is the value of $\lambda_{XY}^{(i)}$ at $m_A \rightarrow 0$. Figure A-5 shows that the calculated retention is in excellent agreement with the experimental data obtained by Sun et al. (1984).

A.7.2. Predicted Burdens in Humans

Selected results of lung burden predictions in humans are shown in Figures A-6 to A-9. The particle conditions used in the calculation are 0.2 µm MMAD with σ_g = 2.3, and the mass fractions of the rapidly and slowly cleared organics are each 10% $(f_1 = f_2 = 0.1)$. Figures A-6 and A-7 show, respectively, the lung burdens per unit concentration of diesel soot and the associated organics in human adults for different exposure patterns at two soot concentrations, 0.1 and 1 mg/m^3. The exposure patterns used in the calculation are (a) 24 h/day and 7 days week; (b) 12 h/day and 7 days/week; and (c) 8 h/day and 5 days/week, simulating environmental and occupational exposure conditions. The results show that the lung burdens of both diesel soot and the associated organics reached a steady-state value during exposure. Because of differences in the amount of particle intake, the steady-state lung burdens per unit concentration were highest for exposure pattern (a) and lowest for exposure pattern (b). Also, increasing soot concentration from 0.1 to 1 mg/m^3 increased the lung burden per unit concentration. However, the increase was not noticeable for exposure pattern (c). The dependence of lung burden on the soot concentration is caused by the reduction of the alveolar clearance rate at high lung burdens discussed above.

Figures A-8 and A-9 show the effect of age on lung burden, where the lung burdens per unit concentration per unit weight are plotted versus age. The data of lung weight at different ages are those reported by Snyder (1975). The exposure pattern used in the calculation is 24 h/day and 7 days/week for a period of 1 year at the two soot concentrations, 0.1 and 1 mg/m^3. The results show that, on a unit lung weight basis, the lung burdens of both soot and organics are functions of age, and the maximum lung burdens occur at approximately 5 years of age. Again, for any given age, the lung burden per unit concentration is slightly higher at 1 mg/m^3 than at 0.1 mg/m^3.

A.8. PARAMETRIC STUDY OF THE MODEL

The deposition and clearance model of DPM in humans, presented above, consists of a large number of parameters that characterize the size and composition of diesel particles, the structure and dimension of the respiratory tract, the ventilation conditions of the subject, and the clearance half-times of the diesel soot and the particle-associated organics. Any single or combined changes of these parameters from their normal values in the model would result in a change in the predicted lung burden. A parametric study has been conducted to investigate the effects of each individual parameter on calculated lung burden in human adults. The exposure pattern chosen for this study is 24 h/day and 7 days/week for a period of 10 years at a constant soot concentration of 0.1 mg/m^3. The following presents two important results from the parametric study.

A.8.1. Effect of Ventilation Conditions

The changes in lung burden due to variations in tidal volume and respiratory frequency are depicted in Figures A-10 and A-11. Increasing any one of these ventilation parameters increased the lung burden, but the increase was much smaller with respect to respiratory frequency than to tidal volume. This small increase in lung burden was a result of the decrease in deposition efficiency as respiratory frequency increased, despite a higher total amount of DPM inhaled. The mode of breathing has only a minor effect on lung burden because switching from nose breathing does not produce any appreciable change in the amount of particle intake into the lung (Yu and Xu, 1987). All lung burden results presented in this report are for nose breathing.

A.8.2. Effect of Transport Rates

Transport rates have an obvious effect on the retention of DPM in the lung after deposition. Because we are mainly concerned with the long-term clearance of diesel soot and the associated organics, only the effects of two transport rates, $\lambda_A^{(1)}$ and $\lambda_A^{(2)}$, are studied. Experimental data of $\lambda_A^{(1)}$ from various diesel studies in rats have shown that $\lambda_A^{(1)}$ can vary by a factor of two or higher. We use a multiple of 0.5 to 2 for the uncertainty in $\lambda_A^{(1)}$ and $\lambda_A^{(2)}$ to examine the effect on lung burden. Figures A-12 and A-13 show respectively, the lung burden results for diesel soot and the associated organics versus the multiples of $\lambda_A^{(1)}$ and $\lambda_A^{(2)}$ used in the calculation. As expected, increasing the multiple of $\lambda_A^{(1)}$ reduced the lung burden of diesel soot with practically no change in the organics burden (Figure A-12), while just the opposite occurred when the multiple of $\lambda_A^{(2)}$ was increased (Figure A-13).

A.9. OPERATIONAL DERIVATION OF HUMAN EQUIVALENT CONCENTRATIONS (HECs)

The model of Yu et al. (1991) is ordered into two parts; one part parameterized on the physiology and anatomy of a 300 g rat and the other part parameterized on the physiology and anatomy of a 25 year old human male. The sequence of steps taken to calculate the human equivalent continuous concentrations (the HECs), outlined in Table A-4, were as follows:

- The exposure scenario of the rats was entered into the rat portion of the model and the model ran to obtain the output of lung burden in mg DPM/ rat lung at the time of the sacrifice of the rats.
- The output of mg DPM/ rat lung was normalized to mg DPM/ cm^2 of rat lung tissue based on a total pulmonary surface area of 4090 cm^2.

- The normalized rat lung burdens were used to calculate the corresponding lung burden based on the pulmonary surface area of 627,000 cm^2. This operation yielded mg DPM / lung of a 25 year old human male.
- Various air concentrations were run in an iterative fashion with the human portion of the model under a continuous exposure scenario of 24 h/day, 7d/wk for 70 years with ventilatory parameters set at 0.926 L for tidal volume and 15 breaths per minute as the respiratory frequency to yield a total daily pulmonary volume of 20 m^3. This was continued until the output (mg DPM/lung) was matched to the mg DPM /human lung obtained from the normalized rat lung burden; the concentration from the model that matched this lung burden was termed the human equivalent continuous concentration, the HEC. The human modeling runs did not consider the preadult status of airway and alveoli number discussed above but rather were ran for 1 to 70 years with adult (25 years of age) parameters mentioned above.

These HEC values address kinetic issues of DPM deposition and retention in the lung by humans. As noted above, these values do not reflect the kinetic variability that may exist in the human population exposed to DPM which includes men and women, young and old. However, the limited parametric analysis of the model clearly shows variability of those parameters most determinative in humans (e.g., tidal volume, respiration rate, and rates of clearance of particles from the airways) were mirrored in the corresponding output of the model (lung burden of DPM). One interpretation of this parallel in parameter-output is that the variability in the physiological characteristics of humans reflects the variability in the model such that, for example, a small tidal volume would be reflected with a decreased lung burden of DPM. Variability among humans of these key parameters such as tidal volume do vary but within an order of magnitude. This would mean that the DPM dose received by different individuals in the population from the same concentration would indeed vary within the extremes of these determinative parameters.

Table A-1. Lung model for rats at total lung capacity

Generation number	Number of airways	Length (cm)	Diameter (cm)	Accumulative volume[a] (cm)
1	1	2.680	0.340	0.243
2	2	0.715	0.290	0.338
3	3	0.400	0.263	0.403
4	5	0.176	0.203	0.431
5	8	0.208	0.163	0.466
6	14	0.117	0.134	0.486
7	23	0.114	0.123	0.520
8	38	0.130	0.112	0.569
9	65	0.099	0.095	0.615
10	109	0.091	0.087	0.674
11	184	0.096	0.078	0.758
12	309	0.073	0.070	0.845
13	521	0.075	0.058	0.948
14	877	0.060	0.049	1.047
15	1,477	0.055	0.036	1.414
16[b]	2,487	0.035	0.020	1.185
17	4,974	0.029	0.017	1.254
18	9,948	0.025	0.016	1.375
19	19,896	0.022	0.015	1.595
21	39,792	0.020	0.014	2.003
22	79,584	0.019	0.014	2.607
25	318,336	0.017	0.014	7.554
24	636,672	0.017	0.014	13.784

[a]Including the attached alveoli volume (number of alveoli = 3×10^7, alveolar diameter = 0.0086 cm).
[b]Terminal bronchioles.

Table A-2. Lung model by Weibel (1963) adjusted to 3000 cm^3 lung volume

Generation number	Number of airways	Length (cm)	Diameter (cm)	Accumulative volume[a] (cm)
0	1	10.260	1.539	19.06
2	2	4.070	1.043	25.63
2	4	1.624	0.710	28.63
3	8	0.650	0.479	29.50
4	16	1.086	0.385	31.69
5	32	0.915	0.299	33.75
6	64	0.769	0.239	35.94
7	128	0.650	0.197	38.38
8	256	0.547	0.159	41.13
9	512	0.462	0.132	44.38
10	1,024	0.393	0.111	48.25
11	2,048	0.333	0.093	53.00
12	4,096	0.282	0.081	59.13
13	8,192	0.231	0.070	66.25
14	16,384	0.197	0.063	77.13
15	32,768	0.171	0.056	90.69
16[b]	65,536	0.141	0.051	109.25
17	131,072	0.121	0.046	139.31
18	262,144	0.100	0.043	190.60
19	524,283	0.085	0.040	288.16
20	1,048,579	0.071	0.038	512.94
21	2,097,152	0.060	0.037	925.04
22	4,194,304	0.050	0.035	1,694.16
23	8,388,608	0.043	0.035	3,000.00

Table A-3. Ratio of pulmonary surface areas between humansand rats as a function of human age

Age (year)	Surface area
0	4.99
1	17.3
2	27.6
3	36.7
4	44.7
5	51.9
6	58.5
7	64.6
8	70.4
9	76.0
10	81.4
11	86.6
12	91.6
13	96.4
14	101
15	106
16	110
27	115
28	119
19	123
20	128
21	132
22	136
23	140
24	144
25	148

Table A-4. Human equivalent continuous concentrations (HECs) calculated with the model of Yu et al. (1991) from long-term repeated exposure rat studies of DPM exposure

Study	Exposure conditions[a]	Rat exposure concs (mg/m^3)	mg DPM/ rat lung (modeled)[b]	mg DPM/cm^2 rat&human lung[b,c]	mg DPM/ human lung[c]	HEC (mg/m^3)[c]
Mauderly et al., 1987a	7 h/day, 5 days/wk, 130 wk[d]	0.35	0.28	6.85E-5	43	0.038
Mauderly et al., 1987a	7 h/day, 5 days/wk, 130 wk	3.47	20.23	4.95E-3	3101	1.375
Mauderly et al., 1987a	7 h/day, 5 days/wk, 130 wk	7.08	44.52	1.09E-2	6825	3.05
Ishinishi et al., 1988 (LD[c])	16 h/day, 6 days/wk, 130 wk	0.11	0.24	5.87E-5	37	0.032
Ishinishi et al., 1988 (LD)	16 h/day, 6 days/wk, 130 wk	0.41	1.00	2.45E-4	153	0.128
Ishinishi et al., 1988 (LD)	16 h/day, 6 days/wk, 130 wk	1.18	18.45	4.51E-3	2828	1.25
Ishinishi et al., 1988 (LD)	16 h/day, 6 days/wk, 130 wk	2.32	39.89	9.75E-3	6115	2.75
Ishinishi et al., 1988 (HD)	16 h/day, 6 days/wk, 130 wk	0.46	1.15	2.81E-4	176	0.144
Ishinishi et al., 1988 (HD)	16 h/day, 6 days/wk, 130 wk	0.96	12.94	3.16E-3	1984	0.883
Ishinishi et al., 1988 (HD)	16 h/day, 6 days/wk, 130 wk	1.84	31.22	7.63E-3	4786	2.15
Ishinishi et al., 1988 (HD)	16 h/day, 6 days/wk, 130 wk	3.72	64.67	1.58E-2	9914	4.4
Nikula et al., 1995	16 h/day, 5 days/wk, 100 wk	2.44	28.64	7.00E-3	4391	1.95
Nikula et al., 1995	16 h/day, 5 days/wk, 100 wk	6.3	76.15	1.86E-2	11674	5.1
Heinrich et al., 1995	18 h/day, 5 days/wk, 104 wk	0.84	3.83	9.4E-4	587	0.33
Heinrich et al., 1995	18 h/day, 5 days/wk, 104 wk	2.5	34.4	8.4E-3	5274	2.35
Heinrich et al., 1995	18 h/day, 5 days/wk, 104 wk	6.98	97.8	2.4E-2	14993	6.7

[a] These are entered into the program as hrs/day, days/week for the total number of weeks exposed and the last week of exposure before evaluation (as this would affect clearance). The parameters for the rat were based on a body weight which was set in the program at 300g.
[b] These values were obtained with the rat portion of the model and are noted as lung burden, in mg DPM /lung of a 300 g rat, at the final week of the exposure scenario. These outputs were then normalized to cm^2 of the rat lung, at 4090 cm^2 total (Xu and Yu, 1987).
[c] Preparatory to using the human portion of the model, the mg DPM/cm^2 value from above was used to project the mg DPM that would be present in the adult human lung based on a total lung surface area of 627,000 cm^2 (Xu and Yu, 1987). Various air concentrations were then entered into the human model as 70 years continuous exposure scenarios and ran iteratively until the output (in mg DPM / lung at age 70) matched this mg DPM/human lung, i.e., the total lung burden. This matching air concentration is, by definition, the human equivalent continuous concentration (HEC).
[d] weeks = (months of exposure) × 4.33.

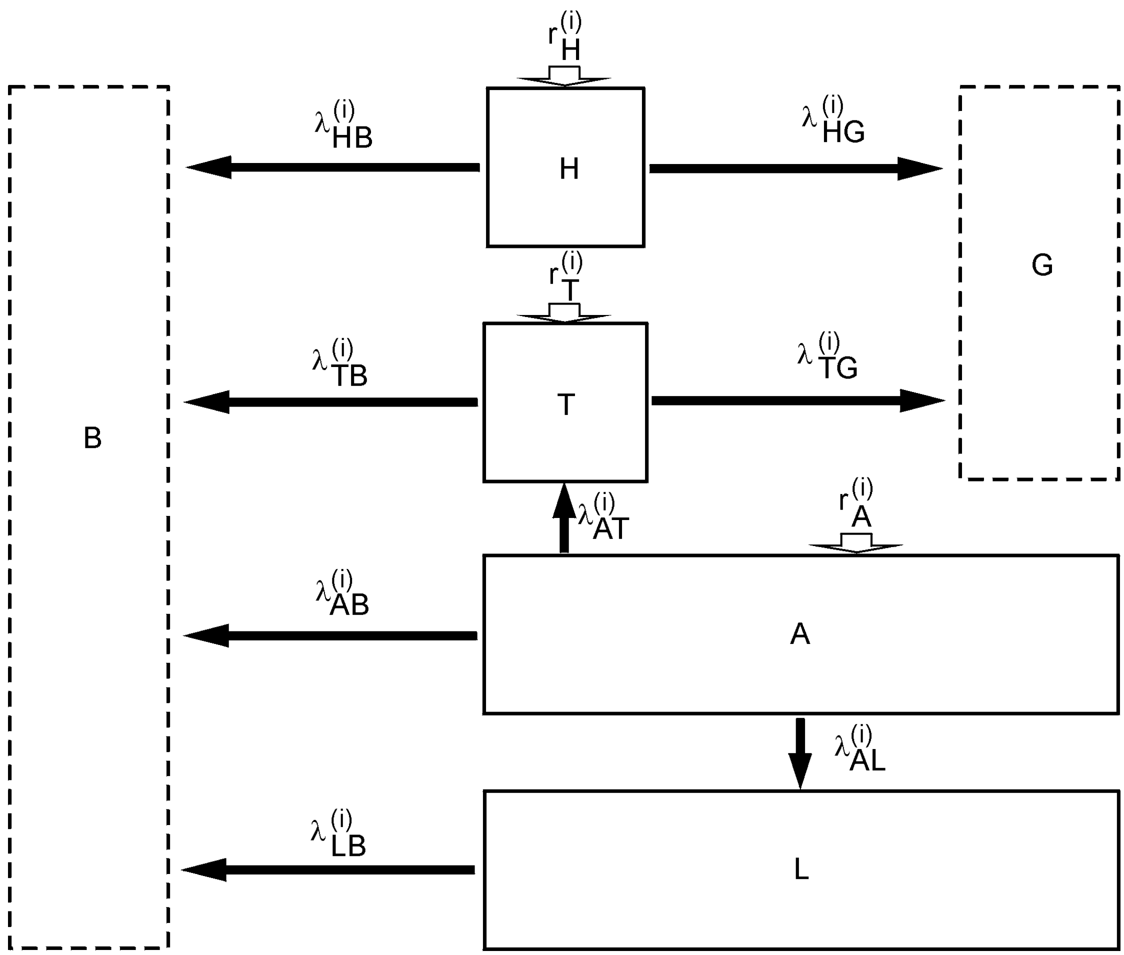

Figure A-1. Compartmental model of DPM retention.

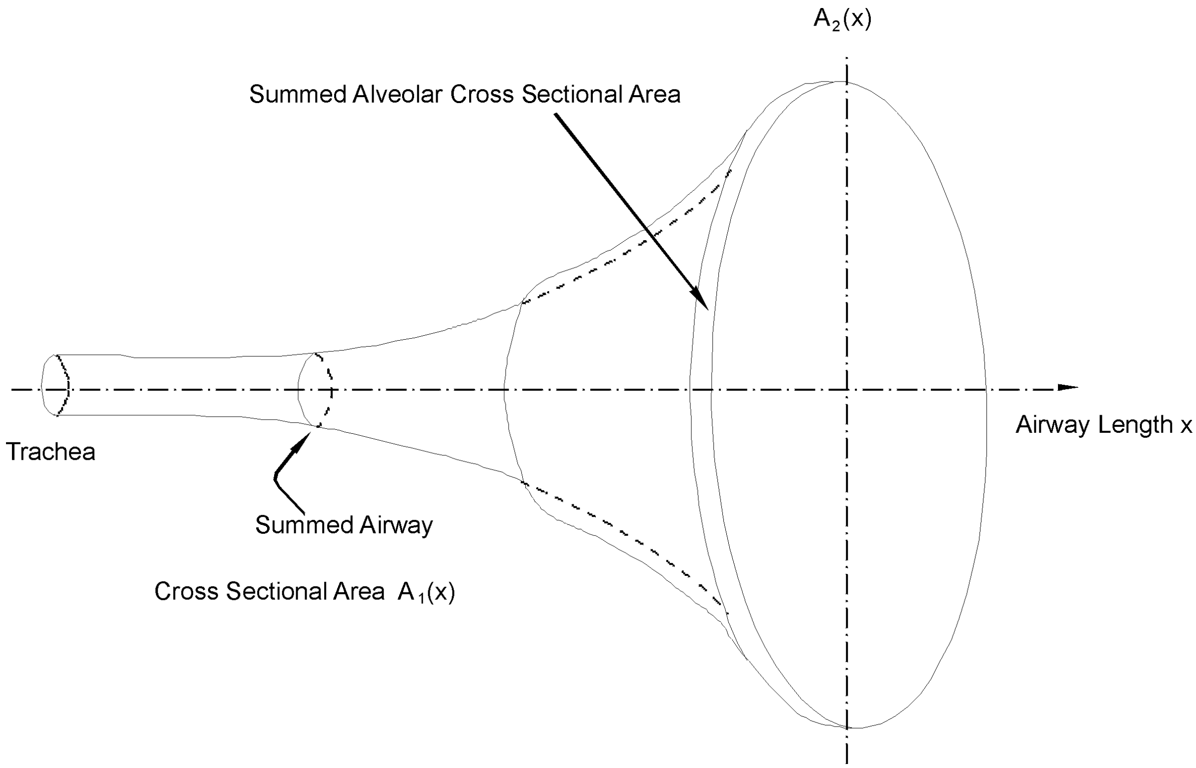

Figure A-2. Trumpet model of lung airways.

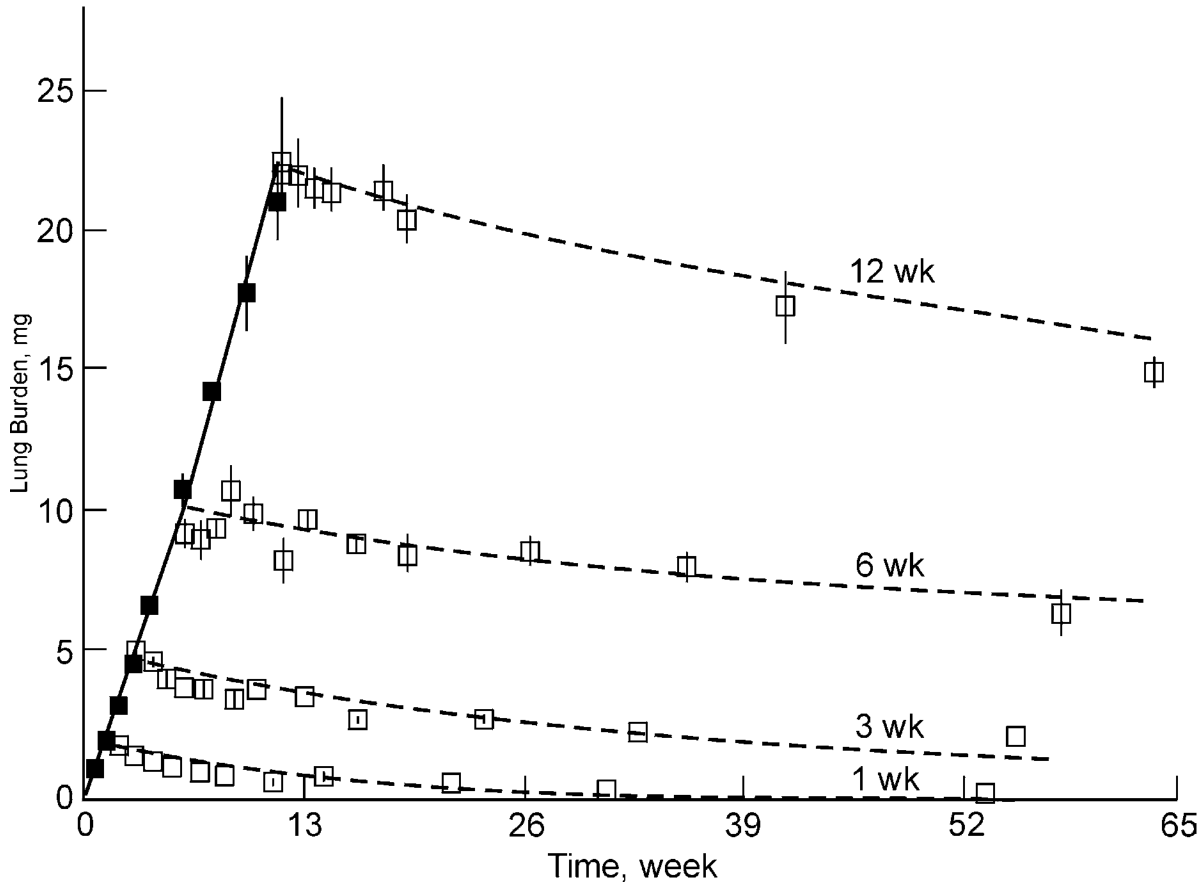

Figure A-3. The experimental and predicted lung burdens of rats to DPM at a solid and dashed concentration of 0.6 mg/m^3 for different exposure spans. Lines are, respectively, the predicted burdens during exposure and post-exposure. Particle characteristics and exposure pattern are explained in the text. The symbols represent the experimental data from Strom et al. (1988).

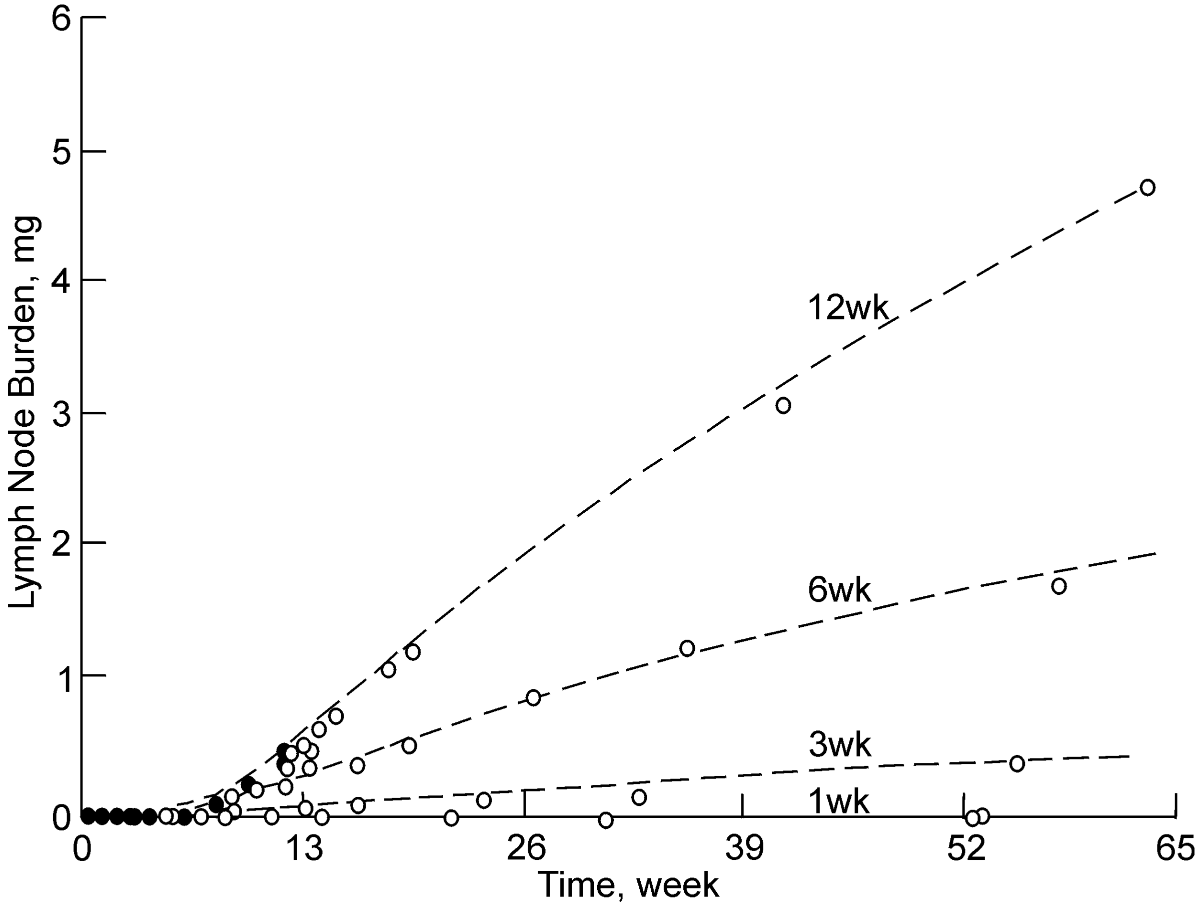

Figure A-4. Experimental and predicted lymph node burdens of rats exposed to CEPs at a concentration of 6.0 mg/m^3 for different exposure spans. The solid and dashed lines are, respectively, the predicted burdens during exposure and post-exposure. Particle characteristics and exposure pattern are explained in the text. The symbols represent the experimental data from Strom et al. (1988).

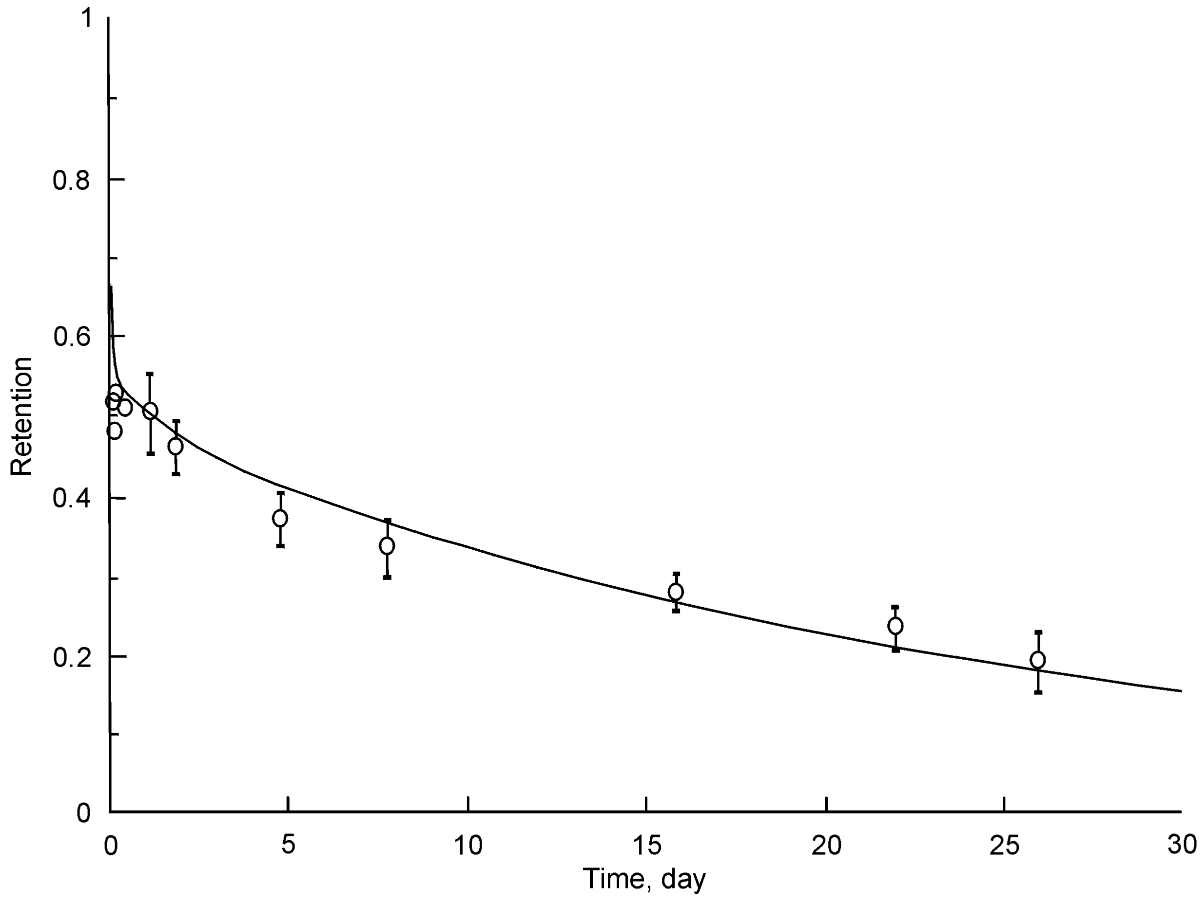

Figure A-5. Comparison between the calculated lung retention (solid line) and the experimental data obtained by Sun et al. (1984) for the particle-associated BaP in rats.

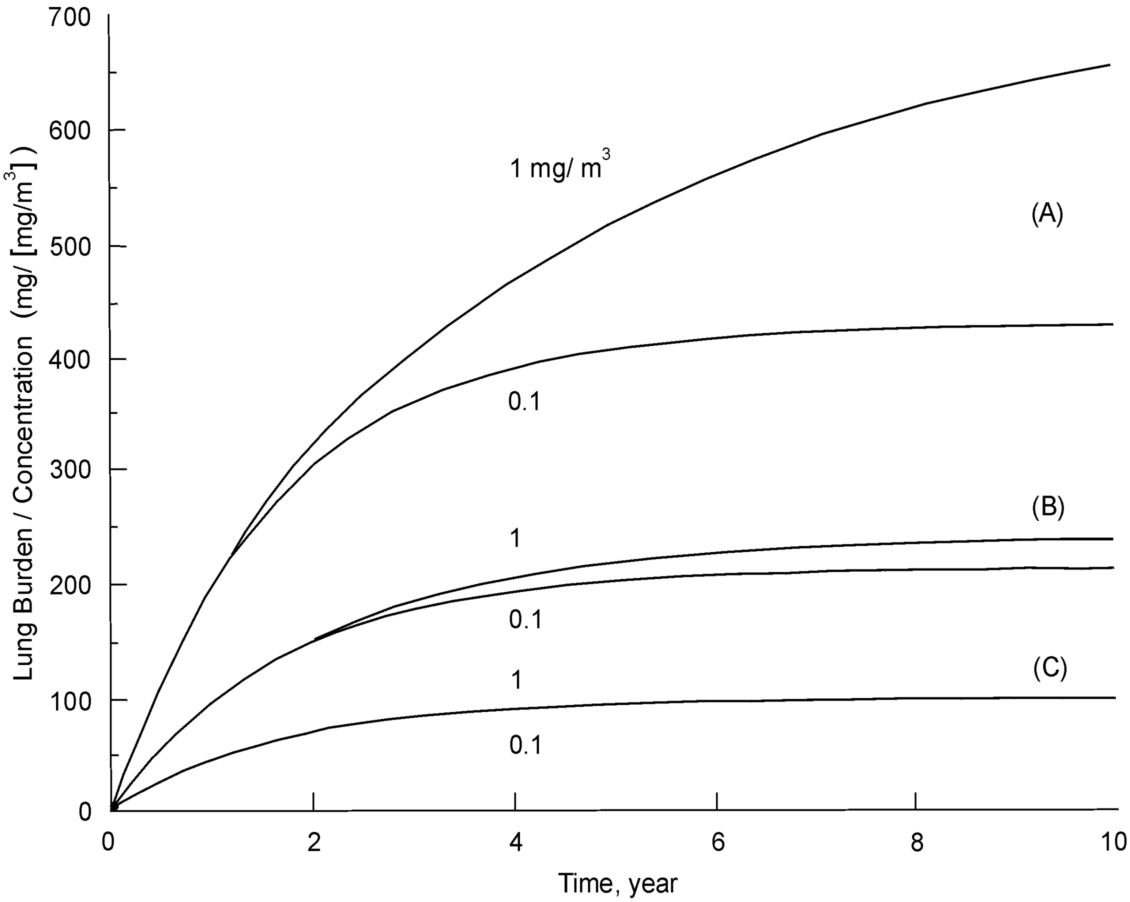

Figure A-6. Calculated lung burdens of diesel soot per unit exposure concentration in human adults exposed continuously to DPM at two different concentrations of 0.1 and 1.0 mg/m^3. Exposure patterns are (a) 24 h/day and 7 days/week, (b) 12 h/day and 7 days/week, and (c) 8 h/day and 5 days/week.

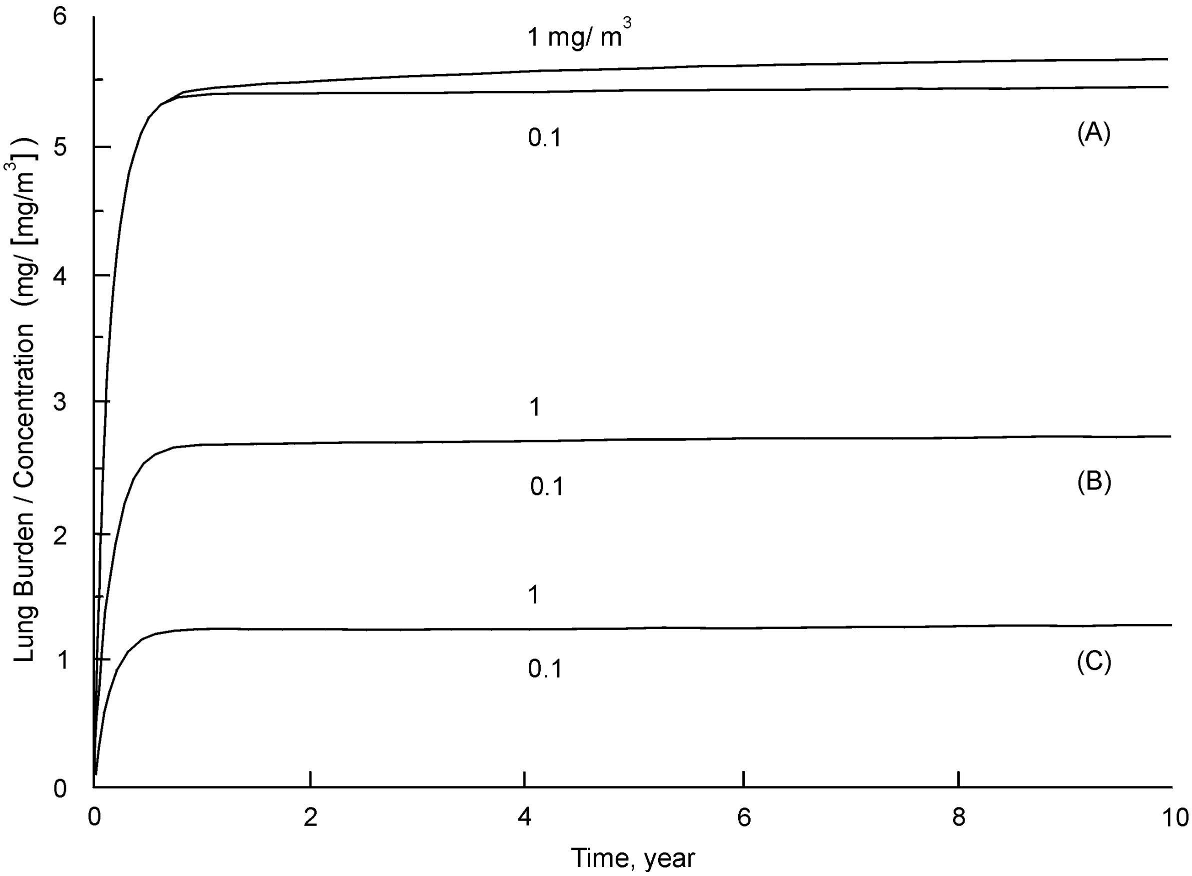

Figure A-7. Calculated lung burdens of the particle-associated organics per unit exposure concentration in human adults exposed continuously to DPM at two different concentrations of 0.1 and 1.0 mg/m^3. Exposure patterns are (a) 24 h/day and 7 days/week, (b) 12 h/day and 7 days/week, and (c) 8 h/day and 5 days/week.

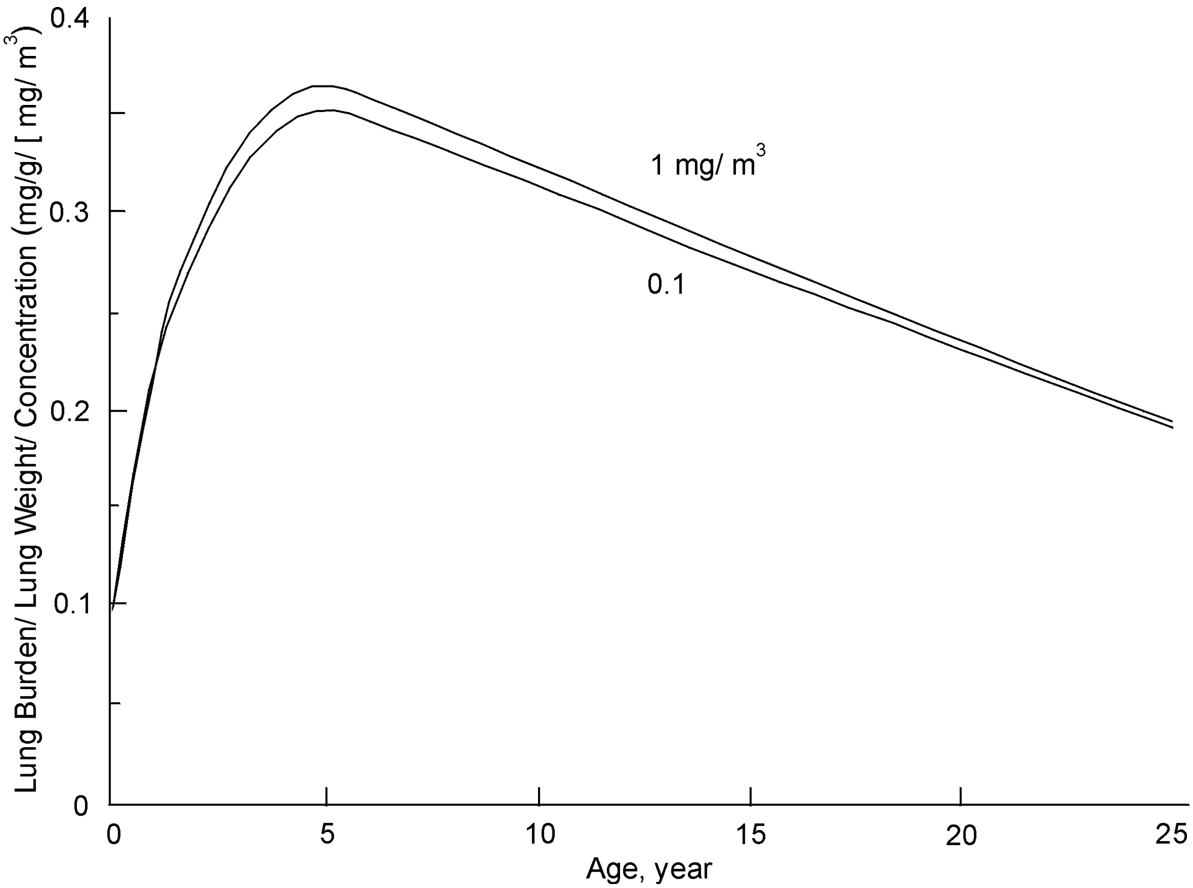

Figure A-8. Calculated lung burdens of diesel soot per gram of lung per unit exposure concentration in humans of different ages exposed continuously for 1 year to DPM of two different concentrations of 0.1 and 1.0 mg/m^3 for 7 days/week and 24 h daily.

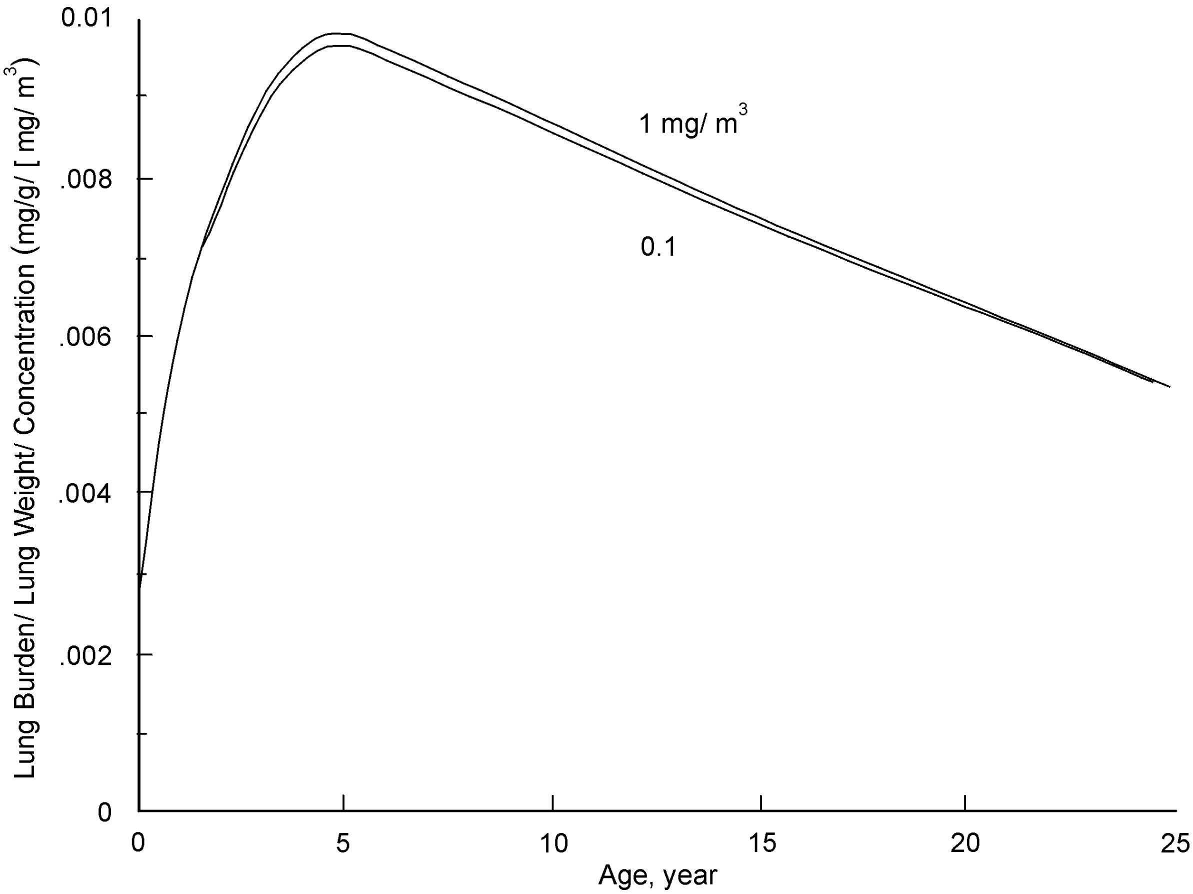

Figure A-9. Calculated burdens of the particle-associated organics per gram of lung per unit exposure concentration in humans of different ages exposed continuously for 1 year to DPM of two different concentrations of 0.1 and 1.0 mg/m^3 for 7 days/week and 24 h daily.

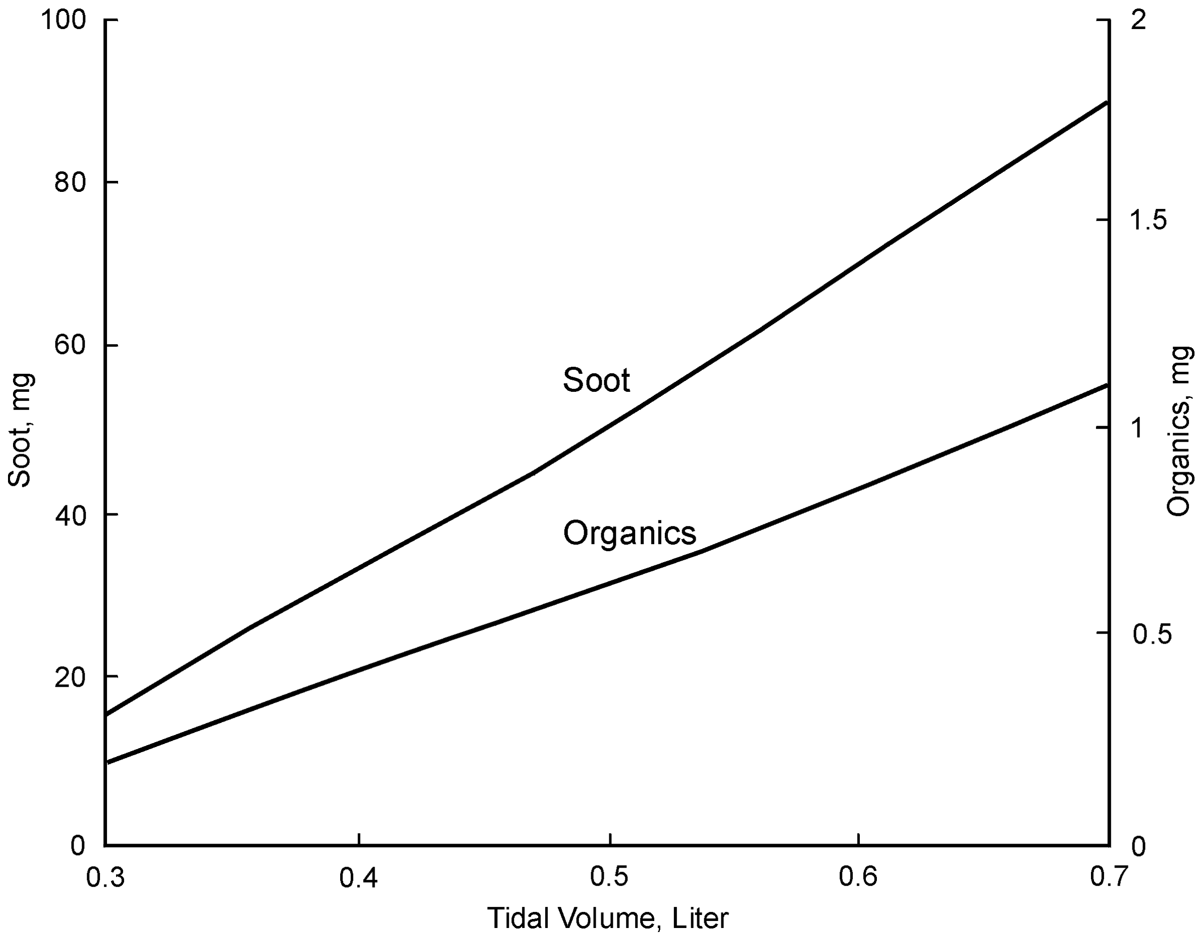

Figure A-10. Calculated lung burdens in human adults versus tidal volume in liters for exposure to DPM at 0.1 mg/m^3 for 10 years at 7 days/week and 24 h daily. Parameters used in the calculation are: (a) MMAD=0.2 µm, σ_g=2.3, f_2=0.1, f_3=0.1; (b) respiratory frequency = 14 min^{-1}; and (c) lung volume = 3000 cm^3.

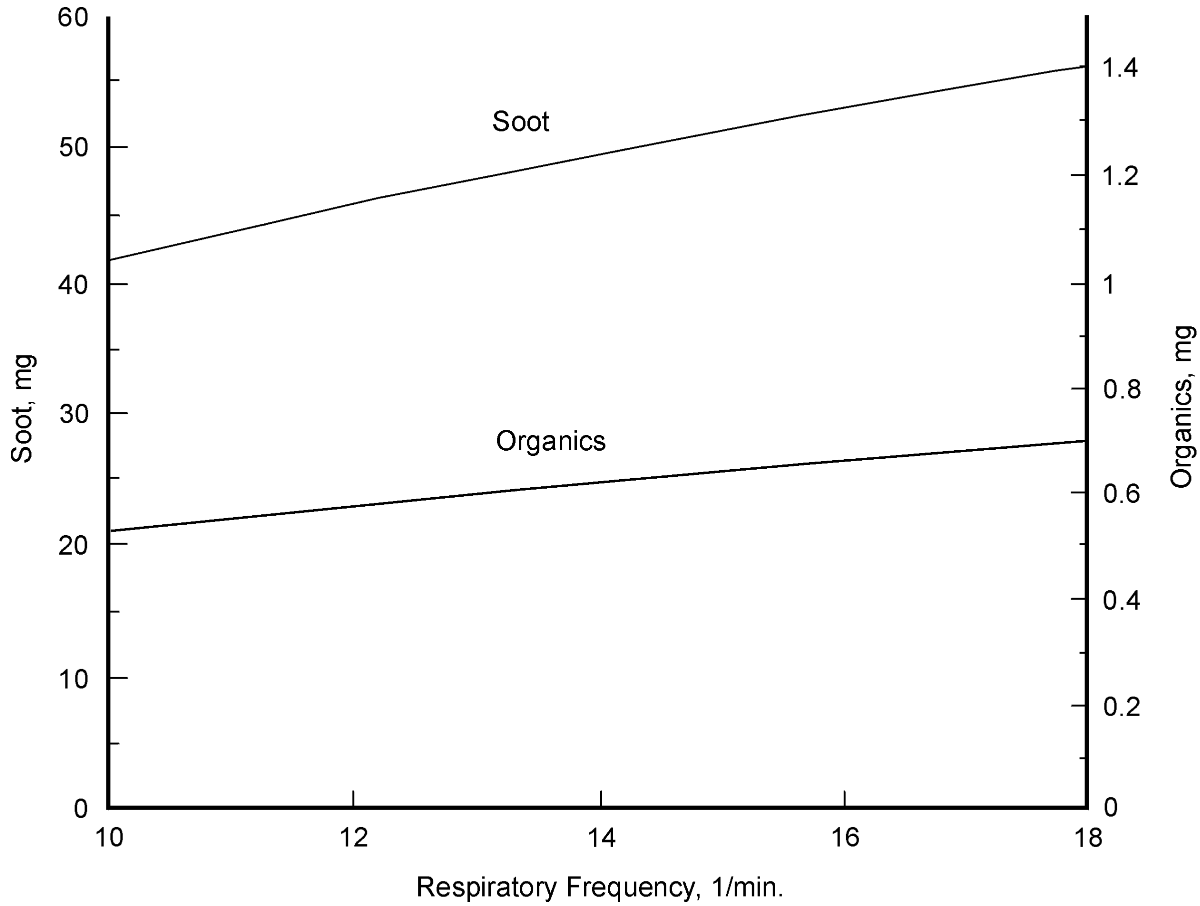

Figure A-11. Calculated lung burdens in human adults versus respiratory frequency in *bpm* for exposure to DPM at 0.1 mg/m^3 for 10 years at 7 days/week and 24 h daily. Parameters used in the calculation are: (a) MMAD=0.2 µm, σ_g=2.3, f_2=0.1, f_3=0.1; (b) tidal volume = 500 cm^3, and (c) lung volume = 3200 cm^3.

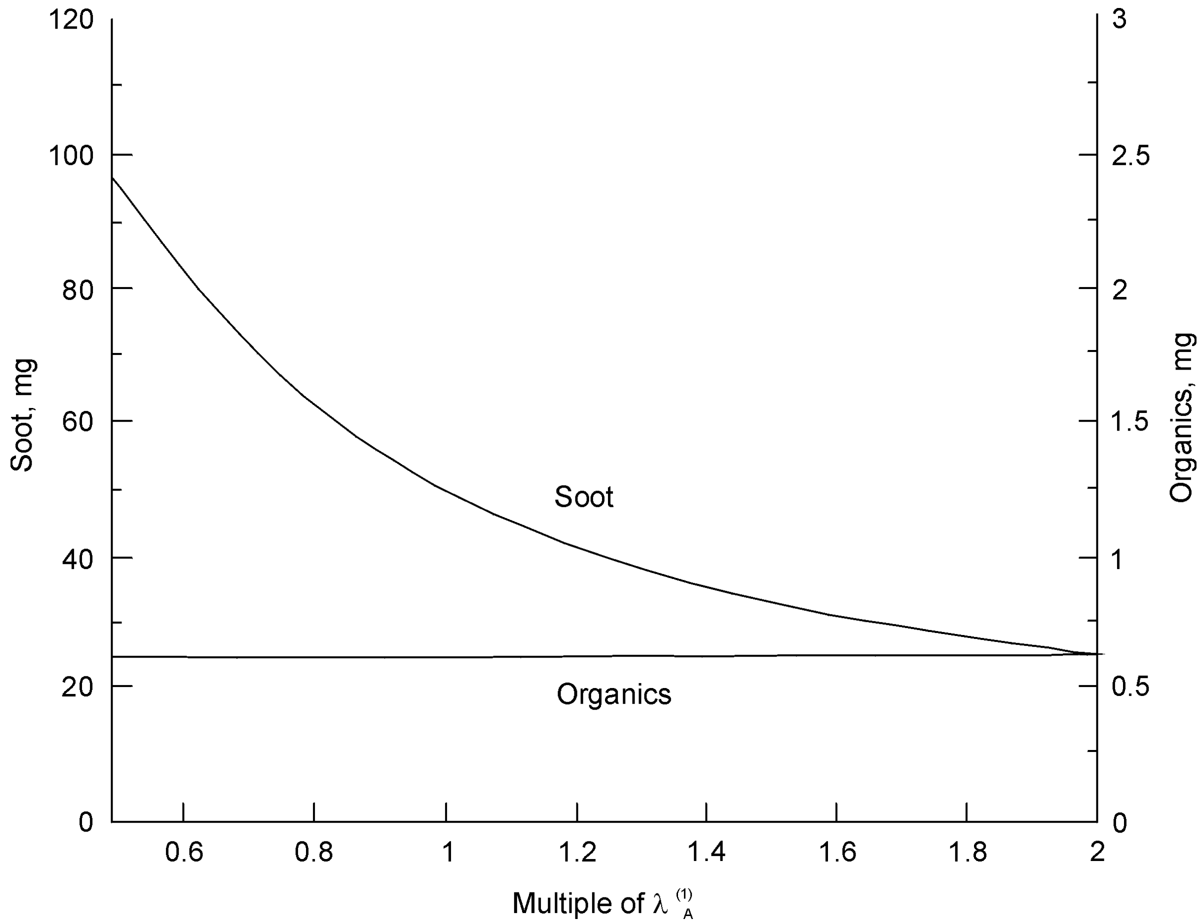

Figure A-12. Calculated lung burdens in human adults versus multiple of $\lambda_A^{(1)}$ for exposure to DPM at 0.1 mg/m_3 for 10 years at 7 days/week and 24 h daily. Parameters used in the calculation are: (a) MMAD=0.2 µm, σ_g=2.3, f_2=0.1, f_3=0.1; (b) tidal volume = 500 cm^3, respiratory frequency = 14 min^{-1}; and (c) lung volume = 3200 cm^3.

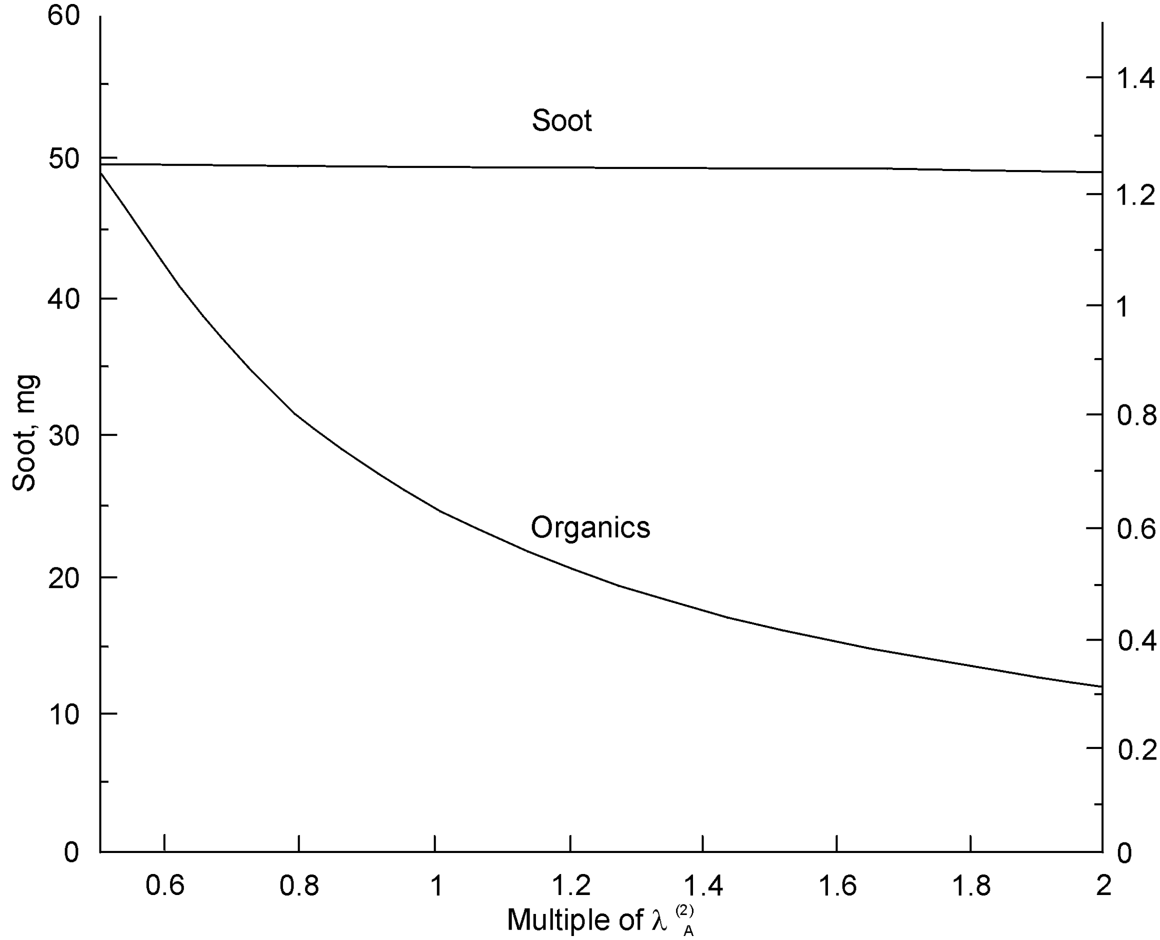

Figure A-13. Calculated lung burdens in human adults versus multiple of $\lambda_A^{(1)}$ for exposure to DPM at 0.1 mg/m^3 for 10 years at 7 days/week and 24 h daily. Parameters used in the calculation are: (a) MMAD=0.2 µm σ_g=2.3, f_2=0.1, f_3=0.1; (b) tidal volume = 500 cm^3, respiratory frequency = 14 min$^{-1;}$ and (c) lung volume = 3200 cm^3.

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Appendix B

Benchmark Concentration Analysis of Diesel Data

B-1. INTRODUCTION TO BENCHMARK

The benchmark dose or benchmark concentration approach, hereafter referred to as the BMC approach, is an alternate to the N/LOAEL option for deriving effect levels. The BMC is currently undergoing extensive consideration by the Agency with promulgation of software and guidelines for application of this methodology (U.S. EPA, 2000). The BMC approach involves fitting a dose-response function to dose and effect information from a single study to derive the best fit of those data. This "best fit"is statistically termed the maximum likelihood estimate but is referred to in the benchmark terminology as the BMC curve. The curve defining the corresponding lower 95% confidence limit of this "best fit"estimate is termed the BMCL curve. This BMCL curve is used to predict the dose that will result in a level of response that is defined *a priori* as the benchmark response "x", $BMCL_x$. In the analyses below, for example, the benchmark response for a 10% increase in incidence[1] of chronic inflammation is defined as a $BMCL_{10}$; the corresponding 10% increase as determined from the BMC curve would be termed the BMC_{10}. This $BMCL_{10}$ would be derived by first using the data and the programs to determine the BMC and BMCL curves. The concentration corresponding to a 10% increase in incidence would then be determined directly from the BMCL. The $BMCL_{10}$ then would be used as the representative value for the effect level or point of departure in the dose-response assessment.

The latest version of the Agency Benchmark Dose Software (BMDS Version 1.2; U.S. EPA, 2000) was used to analyze data on chronic inflammation and pulmonary histopathology present in the chronic studies that were amenable to benchmark analysis. At this time, the Agency BMDS offers sixteen different models total that are appropriate for the analysis of dichotomous data (gamma, logistic, probit, Weibull, log-logistic, multistage, log-probit, quantal-linear, quantal-quadratic), continuous data (linear, polynomial, power, Hill) and nested developmental toxicology data (NLogistic, NCTR, Rai & Van Ryzin). Results from all models include a reiteration of the model formula and model run options chosen by the user, goodness-of-fit information, a graphical presentation for visual inspection and the concentration estimate for the response at the designated $BMCL_x$, as well as the corresponding BMC_x. More details on the modeling results are described and presented in the analysis on dichotomous data following.

The U.S. EPA benchmark dose (BMD/C) methods guidance has not been finalized at this time to provide definitive procedures and criteria (U.S. EPA 1995). Therefore, in this document provisional criteria for minimum data to perform a benchmark analysis are designated such that (1) complete quantitative information on the response of interest should be available (e.g.,

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[1]For increases in incidence "extra risk" is used which is response incidence (inc) normalized to the background (BG) incidence; response – BG/1-BG.

incidence as number affected / total, means with variability) and that (2) at least two exposure levels with responses that differ from those of the controls are provided, and (3) a benchmark response of 10% is employed such that outcomes are $BMCL_{10}$s. A response of 10% is at or near the limit of sensitivity in most long-term bioassays as determined from both the typical number of animals used in bioassays and a low spontaneous background rate (e.g., 0.1%) for a given effect (Haseman, 1984; Haseman et al., 1989).

B-2. DIESEL DATA FOR BENCHMARK ANALYSIS

Using the criteria set forth in Section B-1 and the information about the critical effects that have been identified (pulmonary inflammation, pulmonary histopathology including indicators of fibrotic changes such as increases in alveolar-capillary wall thickness) the following rat chronic studies identified in Chapter 6 were analyzed for information suitable for BMC analysis: Ishinishi et al. (1986, 1988), Mauderly et al. (1987a,b; 1988); Heinrich et al. (1986, 1995), and Nikula et al. (1995).

Results from this analysis yielded only a few data sets from a single study, that of Nikula et al. (1995), that could be used for BMC analysis. The basis for not including data from the other studies varied. Information on pulmonary histopathology in the studies of Ishinishi et al. (1986, 1988), for example, was supplied only in narrative form with no quantitative information given. A similar situation was found for those reports of the ITRI study; Wolff et al. (1987) reports on clearance alterations due to DPM exposure; Henderson et al. (1988) does give information on hydroxyproline but only in graphical form; the 1988 study of Mauderly et al. deals with pulmonary function as a function of DPM lung loading; the 1987a reference of Mauderly et al. discusses tumor prevalence only and the Mauderly 1987b reference reports on diesel exhaust in developing lung to a single exposure concentration of DPM with no dose-response information available. Those reports on the General Motor study contain extensive information relating not to the critical effects, but mostly to precursors of inflammation such as levels of polymorphonuclear neutrophils and lymphocytes in bronchoalveolar lavage from DPM exposed rats (Strom, 1984) and guinea pigs (Barnhart et al., 1981) as well as information on collagen biosynthesis (Misiorowski et al., 1980) all of which is presented in graphical rather than tabular form amenable for benchmark analysis. The information on noncancer histopathology reported by Heinrich et al. (1995) is in text form only and this author's 1986 study deals primarily with clearance and mortality. Nikula et al. (1995), however, do present extensive quantitative dose-response information (incidence / dichotomous data) on several measures of the critical effect including chronic inflamation (presence of focal aggregates of neutrophils), focal fibrosis with epithelial hyperplasia (nodular fibrosis rimmed by hyperplasia), and septal fibrosis (interstitial fibrosis within alveolar septa) although the study had but 2 exposure concentrations both of which are different from the controls, a minimal number on which benchmark analysis should be performed.

B-3. BENCHMARK ANALYSIS OF DIESEL DATA

These data from Nikula et al. (1995) were extracted, HEC concentrations calculated using the model of Yu et al. (1991; Appendix A), and analyzed using all 9 applicable models for dichotomous data. Because the benchmark models were ran with the HEC, general from the model of Yu et al. (1991), the $BMCL_{10s}$ are also HECs. The results and data are presented in Table B-1. Results were evaluated based on the nature of the data set, visual inspection of the graphical output, and on the goodness-of-fit parameters, including p values and the AIC. When p values were generated for model fits, values for p that were less than 0.1 were considered to reflect a minimal fit to the data and were disqualified from further consideration. However, the small set of only 3 data points was often matched by the number of parameters fitted in several of the models such that the outcome of the model exactly fit the data and thus no p value is generated; these model fits are often referred to as being overparameterized, and are indicated as "NA" in Table B-1. Values for p that were less than 0.1 were considered to reflect a minimal fit to the data. The AIC (Akaike Information Coefficient; Akaike, 1973; Stone, 1998) is a parameter generated for the models in U.S. EPA (2000) that allows for a general comparison among models run on the same data set. The AIC is defined as -2 log L + 2 p where log L is the log likelihood of the fitted model, and p is the number of parameters estimated; smaller values indicate better fits.

The overall results of this mathematical analysis is reasonable in a biologically mechanistic sense in that chronic inflammation is more prevalent and apparently occurs at lower concentrations (i.e., has lower $BMCL_{10}$ values) than does focal fibrosis. The information on septal fibrosis were not interpretable as the data were not amenable (no or zero background and then total incidence) to any meaningful benchmark or other dose-response analysis. The most sensitive endpoint, chronic inflammation, is therefore the most sensitive benchmark concentration followed by focal fibrosis.

The choice for the most appropriate $BMCL_{10}$ from among the various modeled values for chronic inflammation requires analysis of both the statistical and graphical outputs of the data. The shape of the dose-response curve from information given in Chapter 6 (Table 6-2) gives evidence of considerable "S" character, e.g., several low HECs without any reported effects up to about 0.2 mg/m^3. The shape of the dose-response curves generated by several of the models, including gamma-hit, Weibull, multistage, and quantal linear were all a uniformly upward sloping arc from the origin (graphs not shown) with minimal evidence of any "S" character, a shape not concordant with the data array in Table 6.2. Models that did generate curves with "S" character included log-logistic, logistic, probit, quantal-quadratic, and log-probit. Because of their concordance with this independent data array on dose-response, the latter outputs are further analyzes.

The results for both chronic inflammation and focal fibrosis for those models with outputs having appreciable "S" character suggest that females may be more sensitive than males for these endpoints as the incidences are higher and the $BMCL_{10}$ values are generally lower for females than for males. However, the model fits of the $BMCL_{10}$s to the chronic inflammation data segregated by sex were generally inadequate as judged from the p values (most being far less than 0.1) or from visual inspection of the fits to the data, several of which (e.g., log-logistic and log-probit) were lacking any appreciable "S" character. However, combining female and male data improved data fitting as judged by the increased p values to where nearly all were >0.1 and to where the visual fits were concordant with the independent information on dose-response. Too, most of the combined $BMCL_{10}$s were either intermediate between the female and male values or somewhat closer to the female values such that the combined $BMCL_{10}$ values were not much different from the females $BMCL_{10}$s.

From among the combined male and female model outputs in Table B-1, the logistic, probit, and quantal quadratic results were all excluded based on the high AIC value relative to the log-logistic and log-probit results. The log-logistic results were excluded based on the shape of the lower portion of the dose-response curve which was upward sloping near the origin (graph not shown) and not as concordant with the independent dose-response information in Table 6-2 as was the fit of the log-probit model (Figure B-1). This leaves the fit of the log-probit model as being most reflective of the information in Table 6-2. The $BMCL_{10}$ of the log-probit curve at 0.37 mg/m^3 remains and, by elimination, appears to be the most defensible choice from among the $BMCL_{10}$s arrayed in Table B-1. Figure B-1 shows the graphical representation of the log-probit model fit to the data and the origin of the $BMCL_{10}$. This graph also shows the relationship of the $BMCL_{10}$ of 0.37 mg/m^3 to the variability that exists around the control value and that the value of 0.37 mg/m^3 is not far removed from the outer range of this variability. The log-probit $BMCL_{10}$ for focal fibrosis (combined) of 1.3 mg/m^3 noted as being representative of this lesion from the BMC analysis in Table B-1.

Characterization of this benchmark value indicates that it may not be a suitable candidate for use as a point of departure for development of a dose-response assessment such as the RfC. An attribute of the benchmark method is that the response (such as the 10% as used here) is near the range of the actual experimental values, such that extrapolation is not far below the observed experimental range. However, due to the paucity of data points overall and lack of any values below an HEC of nearly 2 mg/m^3 in the Nikula et al. (1995) study, the extrapolation of this BMC to the 10% response level is considerable, the $BMLC_{10}$ of 0.37 mg/m^3 being > 5-fold below the nearest observed value of 1.95 mg/m^3. Also, the high experimental exposures used in this study are in the range of those resulting in pulmonary overload conditions in rats and therefore in the range of the model assumptions of Yu et al. (1991) about this phenomenon in humans for calculation of the HECs (Chapter 3). The $BMCL_{10}$ of 0.37 mg/m^3 is considerably greater than other NOAELs in the DPM data base of 0.144 mg/m^3 and 0.128 mg/m^3 (Table 6-2 in Chapter 6), possibly indicating that these NOAELs represent actual incidence levels that are considerably less than10%; from the same log-probit model the corresponding $BMCL_{05}$ was 0.21 mg/m^3 (near the range of these NOAELs) and the corresponding $BMCL_{01}$ was 0.07 mg/m^3 (below the range of these NOAELs). These limitations on this $BMCL_{10}$ make it a less than optimal candidate for consideration as a point of departure in the development of dose-response assessments.

B-4. SUMMARY

The recently developed EPA Benchmark dose software (U.S. EPA, 2000) and preliminary guidance was utilized to analyze diesel data by the benchmark approach. Data from only one of the array of principal studies identified elsewhere (Chapter 6) was found to contain data amenable to benchmark analysis. The data from this study, that of Nikula et al. (1995) on pulmonary inflammation and histopathology, was extracted and analyzed as dichotomous data using all available models and designating a 10% response level such that $BMCL_{10}$s were calculated; as the models were ran with HECs, the $BMCL_{10s}$ were also HECs.

The analysis resulted in an array of $BMCL_{10}$s from 3 different effects in two sexes (both separate and combined) with 9 different models. These $BMCL_{10}$s were each considered from a perspective of biological relevance, known dose-response character, and from the individual fit to the data by the models from statistical parameters and visual judgments. The $BMCL_{10}$ that emerged after the above considerations was 0.37 mg/m^3 for the combined male plus female incidence of chronic active pulmonary inflammation. A $BMCL_{10}$ of 1.3 mg/m^3 for pulmonary focal fibrosis was also noted in this analysis. Characterization of these benchmark values indicates that neither may be a suitable candidate for use as a point of departure in development of a dose-response assessment such as the RfC but that they are concordant with other quantitative dose-response aspects of the DPM database.

Table B-1. BMC analysis of pathology incidence data in male and female F344 rats from the study of Nikula et al. (1995) using the different models available from U. S. EPA benchmark dose project (U.S. EPA, 2000) for dichotomous data based on 10% extra risk (i.e., a 10% increase relative to a total that has been adjusted for background) and no threshold term. The concentrations used in the analysis are human continuous equivalent concentrations (HECs) obtained from the interspecies extrapolation model of Yu et al. (1991). The table listings include the $BMCL_{10}$ (the benchmark response level of 10% obtained from the lower 95% limit of the benchmark curve in mg/m^3), the BMC_{10} (the corresponding estimate at 10% response from the best fit benchmark curve, also in mg/m^3), P = goodness-of-fit values. NA indicates a G-O-F value was not available, usually due to the lack of degrees of freedom. AIC = Akaike Information Coefficient (see U.S. EPA, 2000 and below) which may be used for model comparison on the same data set.

Effect (from Table 5 and 6, p 86, Nikula et al., 1995)	Inc @ 0 mg/m^3	Inc @ 1.95 mg/m^3 HEC	Inc @ 5.1 mg/m^3 HEC	$BMCL_{10}$ (BMC_{10}) log-logistic	$BMCL_{10}$ (BMC_{10}) log-probit	$BMCL_{10}$ (BMC_{10}) multi-stage	$BMCL_{10}$ (BMC_{10}) - Weibull	$BMCL_{10}$ (BMC_{10}) - gamma	$BMCL_{10}$ (BMC_{10}) - quantal linear	$BMCL_{10}$ (BMC_{10}) - probit	$BMCL_{10}$ (BMC_{10}) - logistic	$BMCL_{10}$ (BMC_{10}) quantal quadratic
Chronic active inflammation >18 mos, grades 1-3, male + female combined	5/177	59/162	118/174	0.32(0.64) P= NA AIC= 483	0.37(.70) P=NA AIC = 483	0.43(.49) P= 0.982 AIC= 481	0.43(.49) P= 0.982 AIC= 481	0.43(.49) P=0.98 AIC= 480	0.43(.49) P= .982 AIC= 481	1.06(1.19) P= 0.000 AIC= 499	1.12(1.26) P=0.000 AIC= 502	1.34(1.45) P= 0.000 AIC = 505
Chronic active inflammation >18 mos, grades 1-3 in males	1/86	19/81	54/85	0.67(1.16) P= NA AIC= 217	0.74(1.22) P = NA AIC = 217	0.56(.95) undefined AIC= 217	.56(1.04) P= NA AIC= 216	.56(1.09) P= NA AIC= 217	0.50(.61) P= 0.15 AIC= 216	1.31(1.55) P= 0.05 AIC= 219	0.67(1.16) P= NA AIC= 217	1.42(1.57) P= 0.055 AIC = 218
Chronic active inflammation >18 mos, grades 1-3 in females	4/91	40/81	64/89	0.18(0.26) P= NA AIC= 257	.016(.30) P = NA AIC = 257	0.33(.40) P= 0.173 AIC= 257	0.33(.40) P= 0.173 AIC= 257	0.33(.40) P= 0.17 AIC= 257	0.33(.40) P= 0.173 AIC= 257	0.83(.96) P= 0.0001 AIC= 272	0.85(1.0) P= 0.000 AIC= 273	1.21(1.35) P= 0.000 AIC = 279
Focal fibrosis with epithelial hyperplasia, grades 1-4 in males and females combined	0/177	18/162	63/174	1.25(1.8) P= 1.000 AIC= 345	1.3(1.8) P = 1.000 AIC = 345	1.21(1.8) P= 1.000 AIC= 345	1.21(1.8) P= 1.000 AIC= 345	1.21(1.8) P= 1.0 AIC= 345	1.1(1.3) P= 0.363 AIC= 345	2.32(2.61) P= 0.013 AIC= 353	2.50(2.8) P= 0.006 AIC= 356	2.14(2.34) P= 0.091 AIC = 347
Focal fibrosis with epithelial hyperplasia, grades 1-4 in males	0/86	5/81	19/85	1.72(2.7) P= 1.00 AIC= 132	1.6(2.7) P = 1.000 AIC = 132	1.79(2.8) undefined AIC= 134	1.79(2.8) P= 1.00 AIC= 132	1.79(2.75 P= 1.0 AIC= 132	1.7(2.4) P= 0.70 AIC= 131	2.98(3.5) P= 0.199 AIC= 134	3.17(3.69) P= 0.153 AIC= 135	2.68(3.1) P=0.552 AIC = 131
Focal fibrosis with epithelial hyperplasia, grades 1-4 in females	0/91	13/81	44/89	0.80(1.4) P= 1.00 AIC= 199	0.87(1.47) P = 1.000 AIC = 199	0.77 P= 0.99 AIC= 199	0.77(1.4) P=1.0 AIC=199	0.71(1.4) P= 1.00 AIC= 199	0.71(.88) P= 0.445 AIC= 198	1.76 P= 0.037 AIC= 205	1.89(2.2) P= 0.02 AIC= 207	1.7(1.9) P= 0.21 AIC = 200
Septal fibrosis, >18 mos, grades 1-4 in males	1/86	79/81	83/85	.003(.008) P= 0.35 AIC= 53	(failed)	0.07(.08) P= 0.000 AIC= 65	0.07(.08) P= 0.000 AIC= 65	0.07(.08) P= 0.000 AIC= 65	0.07(.08) P= 0.000 AIC= 65	0.29(.37) P= 0.000 AIC= 114	0.32(.44) P= 0.000 AIC= 86	0.42(0.47) P= 0.000 AIC = 100
Septal fibrosis, >18 mos, grades 1- 4 in females	2/91	75/81	87/89	0.009 (.05) P= NA AIC= 87	(failed)	0.08(.10) P= 0.003 AIC= 91	0.08(.10) P= 0.000 AIC= 91	0.08(.10) P= 0.003 AIC= 91	0.08(.10) P= 0.003 AIC= 91	0.32(.40) P= 0.000 AIC= 131	0.34(.45) P= 0.000 AIC= 109	0.46(.51) P= 0.000 AIC = 119

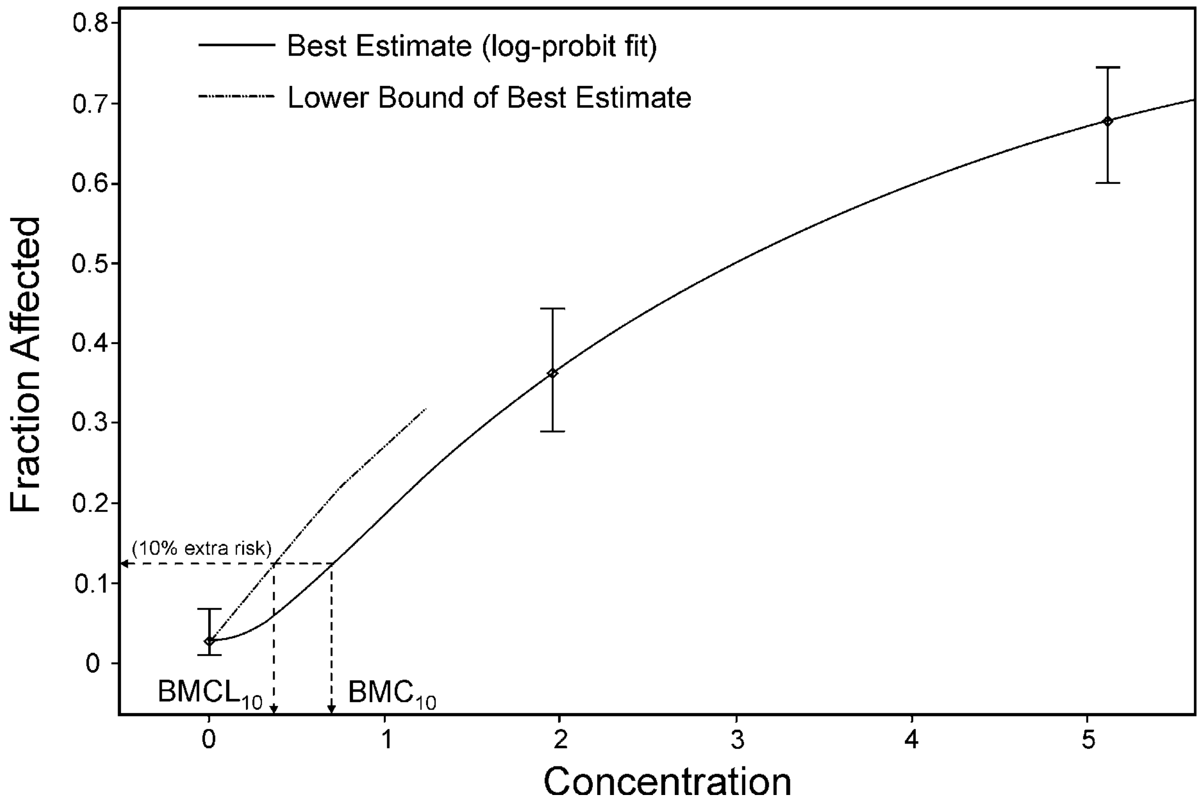

Figure B-1. Benchmark concentration analysis (log-probit) of chronic pulmonary inflammation in rats exposed to DPM from Nikula et al. (1995). $BMCL_{10}$, the lower confidence estimate of the concentration of DPM associated with a 10% incidence (extra risk); BMC_{10}, the corresponding estimate from the best (log-probit) fit. (◊) data with 95% error bounds.

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Appendix C

A Summary Review of Cancer Dose-response Analyses on Diesel Exhaust

C.1. INTRODUCTION

Several individuals and organizations have previously conducted dose-response assessments to estimate quantitatively the cancer risk from exposures to DE. Estimations were performed on the basis of either epidemiologic and/or experimental data. As concluded in Section 8.5, EPA finds that available epidemiologic data are too uncertain to confidently derive a unit risk estimate for DE-induced lung cancer, and that rat data are not suitable for estimating human risk. Nevertheless, a review of historical dose-response evaluations is provided here as background information. This information is not intended to constitute endorsement or a recommendation for use in quantitative risk assessment.

Early analyses to quantitatively assess the carcinogenicity of DE were hindered by a lack of positive epidemiologic studies and long-term animal studies. One means of overcoming these obstacles was the use of comparative potency methods based on combined epidemiologic and experimental data. By the late 1980s, the availability of dose-response data from animal bioassays and epidemiologic studies provided an opportunity for the derivation of both animal and human data-based estimates, although considerable uncertainties were generally acknowledged by the authors of these assessments.

C.2. COMPARATIVE POTENCY METHODS

In this method, the potency of diesel particulate matter (DPM) extract is compared with other combustion or pyrolysis products for which epidemiology-based unit risk estimates have been developed. Comparisons are made using short-term tests such as skin painting, mutations, and mammalian cell transformation. The ratio of the potency of DPM extract to each of these agents is then multiplied by their individual unit risk estimates to obtain the unit risk for DE. If epidemiology-based estimates from more than one pollutant are used, the derived potencies are generally averaged to obtain an overall mean. Major uncertainties of this method include the assumptions that (1) the cancer potency of DE can be determined on the basis of the relative effectiveness of the organic fraction alone; (2) the relative potency in short-term tests is an accurate predictor of lung cancer potency; and (3) DPM extracts are similar in chemical composition and proportion as combustion or pyrolysis products.

In the study by Albert et al. (1983), epidemiology-based unit cancer risk estimates for coke oven emissions, cigarette smoke condensate, and roofing tar were used. Samples of DPM were collected from three light-duty engines (a Nissan 220 C, an Oldsmobile 350, and a Volkswagen turbocharged Rabbit), all run on a highway fuel economy test cycle, and from a heavy-duty engine (Caterpillar 3304) run under steady-state, low-load conditions. The DPM extracts were tested in a variety of assays. Dose/concentration-dependent increases in response were obtained for the four assays listed below:

- Ames *Salmonella typhimurium* (TA98) reverse mutation,
- Gene mutation in L5178Y mouse lymphoma cells,
- Sencar mouse skin tumor initiation test, and
- Viral enhancement of chemical transformation in Syrian hamster embryo cells.

Only the first three assays were used to develop comparative potency estimates because of variability of responses in the enhancement of the viral transformation assay. The in vitro studies were carried out both in the presence and absence of metabolic activators. The potency, defined as the slope of the dose-response curve, was measured for each sample in each short-term assay.

The skin tumor initiation test was positive for all the engines tested except the Caterpillar engine. Only the Nissan engine, however, resulted in strong dose-response data. Because skin tumor initiation was considered to be the most biologically relevant test, it was used to derive potency estimates for the Nissan engine. An estimate for the Nissan engine was then derived by multiplying the epidemiology-based potency estimates for each of the three agents (coke oven emissions, roofing tar, and cigarette smoke condensate) by the ratios of their potencies in the skin

tumor initiation test to that of the Nissan diesel engine. According to this method, three 95% upper-bound estimates of lifetime cancer risk per microgram per cubic meter of extractable organic matter were derived for the Nissan diesel, based on potency comparisons with each of the three agents. These values are: coke oven emissions, 2.6×10^{-4}; roofing tar, 5.2×10^{-4}; and cigarette smoke condensate, 5.4×10^{-4}. The average of the three equals 4.4×10^{-4}.

The potency of the other diesel emission samples was not estimated directly because of the weak response in the skin tumor initiation test. Instead, their potency relative to the Nissan engine was estimated as the arithmetic mean of their potency relative to the Nissan in the Salmonella assay in strain TA98, the sister chromatid exchange assay in Chinese hamster ovary cells, and the mutation assay in mouse lymphoma cells. The estimated lifetime cancer risk per microgram per cubic meter of extractable organic matter for extracts from these engines are as follows: Volkswagen, 1.3×10^{-4}; Oldsmobile, 1.2×10^{-4}; and Caterpillar, 6.6×10^{-6}.

Harris (1983) developed comparative potency estimates for the same four engines used by Albert et al. (1983) but used only two epidemiology-based potency estimates: those for coke oven emissions and for roofing tar. He employed preliminary data from three of the same assays used by Albert et al. (1983): the Sencar mouse skin tumor initiation assay, enhancement of viral transformation in Syrian hamster embryo cells, and the L5178 mouse lymphoma test. The DE cancer potency estimates were then derived by multiplying the epidemiology-based cancer potency estimates for both coke oven emissions and roofing tar by the ratio of their potencies compared with DPM extract in each of the three bioassays. Harris (1983) derived an overall mean relative risk value of 3.5×10^{-5} per µg/m^3 for the three light-duty engines with a 95% upper confidence limit of 2.5×10^{-4}. Individual mean values for each engine were not reported.

McClellan (1986), Cuddihy et al. (1981, 1984), and Cuddihy and McClellan (1983) estimated a risk of about 7.0×10^{-5} per µg/m^3 DPM using a comparative potency method similar to those reported in the preceding paragraph. The database was similar to that used by Albert et al. (1983) and Harris (1983).

C.3. EPIDEMIOLOGY-BASED ESTIMATION OF CANCER RISK

The first lung cancer risk estimates based on epidemiologic data were derived by Harris (1983). He assessed the risk of exposure to DE using data from the London Transport Worker Study reported by Waller (1981). Five groups of employees from the London Transport Authority (LTA) were used: bus garage engineers, bus drivers, bus conductors, engineers in central works, and motormen and guards. The first group was considered to have received the highest exposure; the next two, intermediate; and the last two groups, none. When cancer death rates for the high-exposure group were compared with those of London males, there was no increase in the observed-to-expected (O/E) ratios. The author, in fact, considered the results to be negative. However, because the low rate of lung cancer in all the LTA exposure groups may have been the result of a "healthy worker" effect, Harris (1983) compared the exposed groups with internal controls. He merged the three exposed groups and compared them with the two groups considered to be unexposed. An adjustment was made for the estimated greater exposure levels of garage engineers compared with bus drivers and conductors. Using this method, the relative risk of the exposed groups was greater than 1 but was statistically significant only for garage engineers exposed from 1950 to 1960. In that case, the O/E ratio was 29% greater than the presumed unexposed controls.

Harris (1983) identified a variety of uncertainties relative to potency assessment based on this study. These included:

- small unobserved differences in smoking incidences among groups, which could have a significant effect on lung cancer rates;
- uncertainty about the magnitude of exposure in the exposed groups;
- uncertainty regarding the extent of change in exposure conditions over time;
- random effects arising from the stochastic nature of the cancer incidence; and
- uncertainty in the mathematical specification of the model.

Taking the uncertainties into account, he derived a maximum likelihood excess relative risk estimate of 1.23×10^{-4}, with a 95% upper confidence limit of 5×10^{-4} per µg/m^3 DPM per year.

McClellan et al. (1989) reported risk estimates based on the Garshick et al. (1987) case-control study in which lung cancer in railroad workers was evaluated. Using a logistic regression, the expected relative risk of lung cancer death was estimated to rise 0.016 per year of exposure to DE. Adjustments were made to convert to continuous exposure (168 vs. 40 hours) for 70 years. Because exposure levels could not be defined exactly, two sets of calculations were made, assuming inhaled DPM concentrations of either 500 or 125 $\mu g/m^3$ DPM. The number of excess cancer deaths per year in the United States was estimated to be 3,800 (95% C.I. 400-7400 when an exposure of 125 $\mu g/m^3$ was used, and 950 (95% C.I. 100-1,900) when 500 $\mu g/m^3$ DPM was used.

The California EPA (Cal-EPA, 1998) derived unit risk estimates for lung cancer based upon the Garshick et al. (1987) case-control study and the Garshick et al. (1988) cohort study of U.S. railroad workers. A variety of exposure patterns were considered, characterized by two components: the average exposure concentration for the workers as measured by Woskie et al. (1988) and the extent of change in exposure from 1959 to 1980. The lowest lifetime risk estimate derived was 1.3×10^{-4} per $\mu g/m^3$ and the highest was 2.4×10^{-3} per $\mu g/m^3$. The geometric mean was 6×10^{-4} per $\mu g/m^3$.

Steenland et al. (1998) estimated lung cancer risk of truck drivers on the basis of a case-control study of decedents in the Teamsters Union (Steenland et al., 1990). Retrospective exposure estimates were made starting with a set of 1990 exposure measurements for different job categories and then retrospectively estimating from 1982 to about 1950 using various factors, including diesel vehicle miles traveled and engine emission rates per mile. The 1990 job category estimates came from an extensive industrial hygiene survey of elemental carbon (EC) exposures in the trucking industry by Zaebst et al. (1991). Lifetime (through age 75) excess risk of lung cancer death for male truck drivers was calculated with the aid of a cumulative exposure model. Assuming a most likely emissions scenario of 4.5 g/mile in 1970, and a 45-year exposure to 5 $\mu g/m^3$ of EC beginning at age 20 and ending at age 65, the estimated excess lung cancer risk was determined to be 1.6% (95% CI 0.4%-3.1%). Using the same data base, Stayner et al (1998) presented an estimate of excess lifetime risk of 4.5E-4 for a worker exposed to 1 $\mu g/m^3$ of DE for 45 years.

C.4. ANIMAL BIOASSAY-BASED CANCER POTENCY ESTIMATES

With the availability of chronic cancer bioassays, a considerable number of potency estimates were derived using lung tumor induction in rats. A high degree of uncertainty exists in the use of the rat data to predict human risk. Major uncertainties include: (1) differences in particle deposition patterns between rats and humans, (2) differences in sensitivity between rats and humans to the carcinogenic action of DE, and (3) extrapolation of rat lung tumor responses at high concentrations to ambient concentrations without a clear understanding of the mode of action of DE. It is now widely recognized that the rat lung tumor response associated with any insoluble particles at high concentrations is mediated by a particle-overload mechanism (ILSI, 2000), suggesting that rat data for DE are not suitable for estimating human risk at low environmental concentrations.

The first risk estimate was reported by Albert and Chen (1986), based on the chronic rat bioassay conducted by Mauderly et al. (1987). Using a multistage model and assuming equivalent deposition efficiency in humans and rats, they derived a 95% upper confidence limit of 1.6×10^{-5} for lifetime risk of exposure to 1 $\mu g/m^3$. Pott and Heinrich (1987) also used a linear model and data reported by Brightwell et al. (1989), Heinrich et al. (1986), and Mauderly et al. (1987). They reported risk estimates ranging from 6×10^{-5} to 12×10^{-5} per $\mu g/m^3$. Smith and Stayner (1990), using time-to-tumor models based on the data of Mauderly et al. (1987), derived point (MLE) estimates ranging from 1.0×10^{-4} to 2.1×10^{-4} per $\mu g/m^3$ after converting from occupational to environmental exposure scenario.

Pepelko and Chen (1993) developed unit risk estimates based on the data of Brightwell et al. (1989), Ishinishi et al. (1986), and Mauderly et al. (1987) using a detailed dosimetry model to extrapolate dose to humans and a linearized multistage (LMS) model. Taking the geometric mean of individual estimates from the three bioassays, they derived unit risk estimates of 1.4×10^{-5} per $\mu g/m^3$ when dose was based on carbon particulate matter per unit lung surface area rather than whole DPM, and 1.2×10^{-4} per $\mu g/m^3$ when based on lung burden per unit body weight.

Hattis and Silver (1994) derived a maximum likelihood estimate for occupational exposure of 5.2×10^{-5} per $\mu g/m^3$ based on lung burden and bioassay data reported by Mauderly et al. (1987) and use of a five-stage Armitage-Doll low-dose extrapolation model. California EPA (CAL-EPA, 1998) derived a geometric mean estimate of 6×10^{-5} per $\mu g/m^3$ from five bioassays using an LMS model.

To demonstrate the possible influence of particle effects as well as particle-associated organics, an additional modeling approach was conducted by Chen and Oberdorster (1996). Employing a biologically based two-stage model and using malignant tumor data from Mauderly et al. (1987), the upper-bound risk estimate for exposure to 1 $\mu g/m^3$ was estimated to be 1.7×10^{-5}. This estimate is virtually identical to that using the LMS model, assuming nonthreshold effect of particles. If a threshold of particle effect is assumed, however, the estimated risk decreases about fivefold. The results also show that the mechanism of DE-induced lung tumor at high exposure concentrations may differ from that at low exposure concentrations, with the organics and particles playing primary roles of tumorigenesis, respectively, at low and high concentrations. Overall, the potency estimates on the basis of animal bioassays are in the range of 10^{-6} to 10^{-4} per 1 μg/m^3 of DPM.

Valberg and Crouch (1999) conducted a meta-analysis of rat bioassays by pooling together data of low-dose groups from different bioassays. There are eight bioassays used in the meta-analysis; half of them had duration of 24 months, and the remaining studies had duration of 30 months or more. Animals with continuous lifetime exposure of less than 600 μg/m^3 of DE were included in the analysis. Continuous lifetime exposure is calculated by protracting actual DE exposure to 30 months (24 hours per day, 7 days per week). The researchers concluded that exposure of rats to DE at concentrations not associated with lung overload is consistent with no tumorigenic effect.

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An Urgent Need for Higher Gas-mileage Standards

To: Mary E. Peters, Secretary
U.S. Department of Transportation

Global warming will have devastating effects this century if greenhouse gas emissions continue unabated. These impacts include loss of up to 70 percent of all plant and animal species, major human health risks, loss of our coastlines and coastal communities, and severe drought and flooding.

You hold one of the keys to preventing catastrophic climate change: increased fuel-economy standards. You are required by law to set U.S. fuel-economy standards at the "maximum feasible level." Doing so requires an honest assessment of the real costs and benefits of these standards, but your agency has failed to do so. For example, your assumption that gas will cost $2.36 per gallon in 2020 is completely unsupportable and contributed to the ridiculously low proposed standards.

Your decision to set the "maximum feasible" fuel-economy standard for U.S. automobiles in 2015 at 31.6 mpg, far below what vehicles must achieve today in Europe, Japan, China, Australia, and elsewhere is not only illegal, but also an affront to American ingenuity and resourcefulness. Your decision to condemn our nation, the most scientifically and technologically advanced country in the world, to lead the way in waste and pollution, rather than in technological innovation, is unacceptable.

But it is not too late to make a change. I call upon you to raise the proposed fuel-economy standards for model years 2011-2015 to at least 50 mpg, in order to challenge automakers to respond to the urgent need to conserve energy and reduce greenhouse pollution.

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Stephen Sample, Cave Creek, AZ, US
Sheryl Iversen, Murrieta, CA, US
Jason Stoller, Bala Cynwyd, PA, US
Ginny Short, Thousand Palms, CA, US
Joyce Pusel, Durham, NC, US
Raymond Gettins, Wymong, OH, US
Dana McCurdy, Weehawken, NJ, US
Nick Delaune, PRAIRIEVILLE, LA, US
Traci Rodriguez, Tustin, CA, US
Joel Rocha, medellin, ot, CO
Frank Stivers, Ripley, OH, US
Nicole Stawasz, Westminster, CA, US
John Pritchard, Woodstock, CT, US
Gary Maxwell, Sunnyvale, CA, US
Sheila Barrand, Mission Viejo, CA, US
Andrew Dorman, Aliso Viejo, CA, US
James Murphey, Fort Bragg, CA, US
Doug Perlich, Belmont, CA, US
Meleesa Reichert, Fairfield, IA, US
Vernon and Mary Joyce Dixon, Hiawassee, GA, US
Julie Dominian, Latham, NY, US
Mary Alice Bloch, Bedford, MA, US
Ronald Smith, Langhorne, PA, US
Joe Anshien, Falls Church, VA, US
Mark Bewsher, Tiburon, CA, US
Carla Rei, Kirkland, WA, US
Kemuel Valdes, Hallandale Beach, FL, US
Bipin Giri, Edmonds, WA, US
Roderick Brown, San Diego, CA, US
Jillian Gallagher, Pittsburgh, PA, US
Carole Holley, Anchorage, AK, US
Teri Sigler, Santa Cruz, CA,
Cynthia Bauer, Pittsburgh, PA, US
Candiann Roswell, West Haven, CT, US
Laurel Federbush, Ann Arbor, MI, US
Jean Downing, Lake Stevens, WA, US
Burt Edwards, Wilkesboro, NC, US
Leslie Keats, San Francisco, CA, US
Kitty HUgenschmidt, Colorado Springs, CO, US
Jules Fraytet, Charlotte, NC, US
Emy Monroe, Hamilton, OH, US
Sandra Krocza, El Cajon, CA, AS
Sally Hardy Mullen, Elkins Park, PA, US
Christine Hannum, Tucson, AZ, US
Carla Rei, Kirkland, WA, US
Victoria Varone, Staten Island, NY, US
Burt Edwards, Wilkesboro, NC, US
Donna Scaletta, Batavia, IL, US
alejandra escobar, Los Angeles, AL, CL
Robert Herdliska, Tucson, AZ, US
diana wilson, scottsville, VA, US
Karen Neumeier, Shingle Springs, CA, US
Roderick Brown, San Diego, CA, US
Brian Galloway, University Place, WA, US
Rich Moser, santa Barbara, CA, US

Dennis Lynch, Felton, CA, US
Liz Casey, Pembroke, ON, CA
Dawn Fromel, Chicago, IL, US
Teresa Mason, Encino, CA, US
Debbie Parvin, Fancy Gap, VA, US
joan Butcher, St. Louis, MO, US
Theresa Boisseau, Saratoga Springs, NY, US
David Buck, Staten Island, NY, US
Nancy Grimes, Huntington Beach, CA, US
Matthew Foss, Los Angeles, CA,
Kassie Siegel, Joshua Tree, CA, US
JAY A, VIRGINIA BEACH, VA, US
Jeanine Wilder, San Marcos, TX, US
Martha GIROLAMI, APEX, NC, US
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heather manni, Los Angeles, CA, US
Theresa Boisseau, Saratoga Springs, NY, US
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william Grant, Godfrey, IL,
Cheryl Fike, Galt, CA, US
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Chelsea Antonides, Wallingford, CT, US
Bob Beaudry, Kihei, HI, US
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Sue-Lynn Chu, culver city, CA, US
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Isabelle Ohayon, Loxahatchee, FL, US
David Kaplan, Hollywood, CA, US
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Michael Bailey, Milton, IN, US
Jamie Caito, pittsburgh, PA, US
Dorothy Carlo, Holyoke, MA, US
Catherine Tierney, Saint Louis, MO, US
Sue-Lynn Chu, culver city, CA, US
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Eric Arevalo, New York, NY, US
Connie Livingston-Dunn, Springville, TN, US
Helen Drwinga, Apopka, FL, US
Liana Moran, Glendale, AZ, US
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Diana McDaniel, Shirley, IN, US
Erika Ellis, RIdgecrest, CA, US
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Monique Agia, Solana Beach, CA, US
Jon Leslie, Ventura, CA, US
Ashley Winkler, Corpus Christi, TX, US
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Colleen McMullen, Kanab, UT, US
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Rex Dowling, Green Bay, WI, US
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Donna Jensen, Playa Vista, CA, US
Lynn Wilkinson, Taos, NM,
Glen Dey, Wichita, KS, US
Bryan Todd, Pinole, CA, US
Marian Buckner, Shepherdstown, WV, US
Shelby Haukos, Fergus Falls, MN, US
Simmons Buntin, Tucson, AZ, US
drew depalma, Hoboken, NJ, US
Andy Eubanks, Boone, NC, US
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Suzanne Kindland, Cannon Beach, OR, US
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Tony Povilitis, Makawao, HI, US
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Paul Garrett, Eugene, OR, US
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Nicole Pancino, saugus, CA, US
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David Corbett, Litchfield, ME, US
Wendy Vigneault, Derry, NH, US
Carol Brown, San Francisco, CA, US
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Steve Lance, Smyrna, GA, US
Jon Phillips, Ashford, CT, US
Amy Anderson, Phoenicia, NY,
Steven Gordon, Chapel Hill, NC, US
Laura Jones, Ann Arbor, MI, US
Patricia Swenson, Allen, TX, US
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Todd Ramsey, Shenandoah, TX, US
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Linda Rowland, San Antonio, TX, US
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Julie McKee, NYC, NY, US
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James Cunningham, Columbus, OH, US
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Katy Leverenz US
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Carole Mathews, Smyrna, GA, US
David Romportl, St Louis Park, MN, US
Chris Casper, Madison, WI, US
patricia conway, west chester, PA, US
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Robert Morgart, Santa Fe, NM, US
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Cathy Crum, Agoura Hills, CA, US
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Rick Panozzo, Twin Lake, MI, US
James H Jorgensen, Ames, IA, US
Steve Cosgrove, Auburn, AL, US
Christopher Grunke, Brooklyn, NY, US
Nicole Berkheimer, Knoxville, TN, US
Kevin Chaney, Madison Heights, VA, US
Karen Fleming, austin, TX, US
Anton Feokhari, Brooklyn, NY, US
Peg Kucek, Pottstown, PA, US
Rita Carlson, Eureka, CA, US
Amber Sumrall, Soquel, CA, US
Nancy McClelland, Chicago, IL, US
C.K. Mertz, Eugene, OR, US
robert garrett, maineville, OH,
Paul Moss, White Bear Lake, MN, US
Neko Case, Tucson, AZ, US
D. Dirk Davenport, Port Charlotte, FL, US
JOAN MCBRIDE, TOWNSHIP OF WASHINGTON, NJ, US
KIM CHAUDOIR, chicago, IL, US
janet doughtery, west Chester, PA, US
Gary Shogren, Las Vegas, NV, US
D Burdick, Scottsdale, AZ, US
Jean Cassilagio, San Mateo, CA, US
Mary Hood, Plain City, OH, US
Bernard Huff, Hamilton, MT, US
Kelly Brenner, Eugene, OR, US
Harriet Pfister, Bloomington, IN, US
Olivier Resca, Lenox Dale, MA, US
Jenny Vegan, Carlsbad, NM, US
Christina Barnes, Ralston, NE, US
Justin Sternberg, San Francisco, CA, US
Jennifer Brockway-Peirce, West Newbury, MA, US
marlene brooks, dallas, TX, US
Guy Zahller, Aptos, CA, US
Minji Jo, San Diego, CA, US
Carla Lamarr, Margate, FL, US
Jennifer Heneghan, Jacksonville, FL, US
marlene brooks, dallas, TX, US
Christopher Galton, Myrtle Beach, SC, US
Helen Bryenton, Knoxville, TN, US
Susie Zwiener, Sonoma, CA, US
Amanda Carter, Brooklyn, NY, US
Jan Killian, Balsam Lake, WI, US
Marci Koski, Escondido, CA, US
Melanie Climis, Shepherdstown, WV, US
Luis Sanchez, Bay Shore, NY, US
Patrick O'Neil, Carlsbad, NM, US
Steve Hood, Plain city, OH, US
Christy Levine, Saint George, UT, US
Donna Thomas, Morongo Valley, CA, US
Kent Lupton, gastonia, NC, US
Ellen Hamilton, Goleta, CA, US
Doug Battema, Westfield, MA, US
Josh Wentworth, Newport, RI, US
Diane Berger, Langley, WA, US
Pamela Strachan, Irvington, NY, US

Gary Blanchard, Austin, TX, US
Ann Chapman, Corpus Christi, TX, US
Lynn Wolf, Saugus, CA, US
yen pham, el monte, CA, US
Don Jacobson, POrtland, OR, US
Bret Polish, sherman oaks, CA, US
Cassandra Suarez, Albuquerque, NM, US
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shanna mcdonell, san diego, CA, US
Meyer Jordan, Pensacola, FL, US
susan kuhn, Portalnd, OR, US
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Joseph Bateman, Salt Lake City, UT, US
Kip Bush, Ridgecrest, CA, US
Amy Denio, SEATTLE, WA, US
Dylan Neubauer, Santa Cruz, CA, US
Ivan White, Price, UT, UT, US
marisa landsberg, manhattan beach, CA, US
pete behm, Petaluma, CA, US
James Schmitt, Monroe, NY, US
ROBERT SCHADE, ONTARIO, CA, US
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Susan Odlum, Monroe, WA, US
William Dane, Ontario, CA, US
Mary Metcalf, Panton, VT, US
Mrs Jack Mcmullen, Montgomery, AL, US
Mary Reed, Lancing, TN, US
Alan Fawley, Ft. wayne, IN, US
Emily Rideout, Cambridge, MA, US
Laura Whitton, Clinton, AR, US
Susan LoFurno, Webster, NY, US
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Marlee Ostrow, Los Angeles, CA, US
Zachary Nelms, Lake Oswego, OR, US
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Denise Dunlap, Woodbridge, VA, US
James Kirks, Chico, CA, US
Liz Fox, Taos, NM, US
Anna Kail, Des Plaines, IL, US
Emilie Mullins, Round Lake, IL, US
BARBARA STRICKLAND, LAKE SAINT LOUIS, MO, US
Jackie Wagoner, Oakdale, TN, US
Allyson Frye-Henderson, Del Mar, CA, US
Keri Dixon, Tucson, AZ, US
Krishna Vemuganti, Austin, TX, US
Tsar Fedorsky, Rockport, MA, US
Mark Van Horne, Bristol, CT, US
Alice Hanson, Hanover, NH, US
Tsar Fedorsky, Rockport, MA, US
Julie Beer, Palo Alto, CA, US
Kathleen Wolfe, Des Moines, WA, US
Katherine Gould-Martin, Annandale, NY, US
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Endra Malyn, Monroeville, PA, US
Alexandra Bowers, San Jose, CA,

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Megan Garrett, Sacramento, CA, US
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Eugene Black, Crown Point, IN, US
Courtney Small, Los Angeles, CA, US
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Dave Dittman, Mount Airy, MD, US
Marilyn Jeffery, Manlius, NY, US
Mark vanCleef, Rio Linda, CA, US
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Carolynn Griffith, Honolulu, HI, US
Dirk Meenen, Los Angeles, CA, US
Jennifer Wallace, Moab, UT, US
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Diane Vang, Chicago, IL, US
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Donna Pittman, Denton, TX, US
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Lynn Hicks, Tucson, AZ, US
Steven Huber, Lincoln, NE, US
lisa Milligan, Lombard, IL, US
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Alvin Hass, BROOKLYN, NY, US
Steve Brown, Hamilton, MA, US
Laura Reifinger, Allentown, PA, US
Phoebe Blanchford, Decatur, GA, US
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Jenifer Gibson, Hudson, FL, US
Glenn Lyons, Hopatcong, NJ, US
Tim Stahl, San Diego, CA, US
Susan Preston, La Crosse, FL, US
Luke Avery, Flagstaff, AZ, US
Clayton Pope, Newark, DE, US
Dina Koehly, Santa ana, CA, US
Bill Kimmich, Camp Hill, PA, US
Janice Gloe, Oakland, CA, US
John Hess, Roslindale, MA, US
philip moyer, mill valley, CA, US
Wylie E. Cox, Daleville, AL, US
Taryn Sokolow, Glendale, CA, US
William Bell, Sunnyvale, CA, US
Ore Carmi, Berkeley, CA, US
Heather Platt, Waltham, MA, US
Martin Dreyfuss, Oakland, CA, US
Eric & Cedra Spragett, Phoenix, AZ, US
Michael Tomczyszyn, San Francisco, CA, US
Laurel Alexander, Madison, WI, US
Patricia Farrelly, Islip, NY, US
Clifton Chadwick, Albuquerque, NM, US
Shellie Donbrosky, Ottawa Lake, MI, US
Kathleen Simmons, Easthampton, MA, US
Vicky Jo Neiner, Perth Amboy, NJ, US

Don Cordes, Coolin, ID, US
Len Milich, TUCSON, AZ, US
E. Karsten Smelser, Minneapolis, MN, US
roberta forest, jamaica, NY, US
Laura Reifinger, Allentown, PA, US
Carol Collins, Dover, DE, US
Ken Metz, North Richland Hills, TX, US
Kathy Skaggs, Sunnyvale, CA, US
denise moon, Vancouver, WA, US
Michael Bowling, Davis, CA, US
aaron smith, lenexa, KS, US
Glenn Whiteside, Monument, CO, US
Mark Holdom, studio city, CA, US
Lois Robin, Santa Cruz, CA, US
Lois Robin, Santa Cruz, CA, US
denise moon, Vancouver, WA, US
michele johnson, San Diego, CA, US
Jan Bates, Fallbrook, CA, US
Anita Das, Seattle, WA, US
Lisa Mikolich, Vineland, ON, CA
Rachel Ford, Portland, OR, US
Alexandra Mummery, Alameda, CA, US
Jan Bates, Fallbrook, CA, US
Matsi Yasei, McKinney, TX, US
Marie Perkins, Oak Park, IL, US
adam culp, sullivan, MO, US
Diana Vest Goodman, San Francisco, CA, US
geraldine baron, nyc, NY, US
debra henriksen, Livingston, MT,
T Metz, Bethesda, MD, US
Robert Strebeck, EULESS, TX, US
GARY JONES, SAN MARINO, CA, US
Jackie Grannis-Phoenix, Warren, ME, US
John Flitcraft, Cambria, CA, US
Bess Edwards, Timmins, ON, CA
Brooks Jones
Frank Herda, Parma Heights, OH, US
Peter Stone, Bethlehem, PA, US
Jan Davidson, Iron Mountain, MI, US
Al Bonowitz, Westminster, CA, US
Valdemar Phoenix, Houston, TX, US
Faith Conroy, Boulder, CO, US
Ross Kelson, Miami Beach, FL, US
Lisa Merkord, Fillmore, CA, US
Donald Farrow, Westerville, OH, US
Fred Bichl, Yakima, WA, US
Terry Tedesco, Phoenix, AZ, US
Beth Mitchum, Poulsbo, WA, US
James Junior, Kailua, HI, US
Therese Ryan, Palmdale, CA, US
Tara Gland, Christiansburg, VA, US
Alan Wilhite, Austin, TX, US
Stamatios Varias, Selinsgrove, PA, US
Cynthia Romer, oakland, CA, US
Barbara Wishingrad, Santa Barbara, CA, US
Halina Just, San Antonio, TX, US
Ron Harvey, Prescott, AZ, US

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Noreen Wheller, Smithtown, NY, US
Michael Stuart, Auburn, MA, US
Liza Greenfield, New York, NY, US
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Arianne Macy, Madison, CT,
Beth Dunlop, Alert Bay, BC, CA
Karen Baouche, Ellington, CT, US
Donald Bachant, Sautee Nacoochee, GA, US
Prochazka Penelope, Schererville, IN,
Christian Comstock, Richmond, VA, US
Marjorie Lovell, San Francisco, CA, US
Michele Meyer, Vallejo, CA, US
Danny Wouters, Hay Springs, NE, US
Donald Bachant, Sautee Nacoochee, GA, US
Robin Brong, Wilmington, DE, US
Jack Oruch, Gahanna, OH, BV
James Biser, Provo, UT, US
Anita Fieldman, Mill Valley, CA, US
Caroline Courchaine, Goose Creek, SC, US
Emery Kapples, Jacksonville, FL, US
Joanna Welch, Valley Center, CA, US
Donna Tillman, Carson, WA, US
Judith Kahle, Fairfield, CA, US
Janet Black, Tenino, WA, US
Anne Reid, New York, NY, US
Clifford Mayes, Lufkin, TX, US
Ariana Saraha, Boulder, CO, US
Robin Doidge, Tucson, AZ, US
Michaek Kelly, Portland, OR, US
Molly Walsh, Marshfield, MA, US
Amanda Lowe, Boise, ID, US
Thomas Jones, South Haven, MI, US
Marilynn Smith, Ssebastian,, FL, US
robert treadway, manhattan, IL, US
Jack Paxton, Urbana, IL, US
Kelly Behrends, Thiells, NY, US
James L Wolcott, Evansville, IN, US
Frederick Ruch, North Olmsted, OH, US
betty schuessler, tucson, AZ, US
Brighton Flaus, SANTA CRUZ, CA, US
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Mario Maraldo, Harrison Twp., MI, US
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Barbara Heard, Seattle, WA, US
RICHARD HERKALO, FREEHOLD, NJ, US
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Matthew Reid, Calistoga, CA, US
Jessica Chesney, Seattle, WA, US
erin lockwood, bronx, NY, US
Mark Fodor, Orlando, FL, US
John Reilly, Lincoln, CA, US
Frances Simpson, Tacoma, WA, US
Leslie McMahon, LA, CA, US
Brooks Onley, Pocomoke City, MD, US
Aspen Reese, las vegas, NV, US

Jim Hedley, Olymmpa, WA, US
Roberta Wills, Marshfield, MA, US
Karin Kozie, Washburn, WI, US
Michael Martin, Plainfield, IL, US
dylan edwards, San Francisco, CA, US
erin lockwood, bronx, NY, US
Michael Hildreth, San Jose, CA, US
Jim Hedley, Olymmpa, WA, US
Darren Liebman, Tampa, FL, US
Karen WEssel, Homer, AK, US
kindra bandy, olympia, WA, US
Lisa Whitacre, Jerome, AZ, US
Brian Ainsley, Laveen, AZ, US
Lisa Anichini, Seattle, WA, US
robert rychlowski, long beach, NY, US
Richard Dougherty, Alameda, CA, US
Carla Wenzlaff, Eugene, OR, US
Nico DiMonte, AZ, US
Jane Simpson, Lorton, VA, US
Gary Lavinder, Statesville, NC, US
Nico DiMonte, AZ, US
Robyn Kranzler, North Hollywood, CA, US
Dave Angst, Elgin, TX, US
Donald Bulitta, Phoenix, AZ, US
Maarit Leppala, Fort Worth, TX, US
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Tara Jankovic, Melbourne, FL, US
Nicole Perkins, Fremont, CA, US
Tami Redi, Hollywood, FL, US
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David Freedman, Clemson, SC, US
doug la follette, madison, WI, US
Wesley Carmichel, syracuse, NY, US
Martin Graham, Campbell, CA, US
Bruce Fowles, Washington, ME, US
Lorri Neal, Taylor, MI, US
Triska F. Hoover, Phoenix, AZ, US
Tara Cross, Shakopee, MN, US
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Becky Crane, North Ridgeville, OH, US
Albert Fecko, Center Line, MI, US
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Sue Spahr, Kawartha Lakes, ON, CA
Karen Barcklay, Torrance, CA, US

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Jennifer M Weishaar, Lawrence, KS, US
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Frank Smith, Whigham, GA, US
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Christine Bourgeois, Santa Barbara, CA, US
Terry Hoffman, Oregon City, OR, US
Dennis Mcmanus, Duluth, MN, US
d michael Nowacki, San Francisco, CA, US
.John Miskelly, baltimore, MD, US
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Lorraine Foster, Portland, OR, US
Philip Shively, Blue River, WI, US
Max Jackson, Ashland, KY, US
Alexandra Tumarkin, White Plains, NY, US
Rachel Nostrom, safety harbor, FL, US
Joanna Behrens, Jackson, WY, US
Terry Glase, Plains, MT, US
Kevin Fetterman, Los Altos, CA, US
Robert Snitgen, Wabasha, MN, US
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Connie Smith, Whigham, GA, US
Kelly Popp, Hamden, CT, US
Dan York, Pasadena, CA, US
Richard Burgess, Land O Lakes, FL, US
Linda Joy Lyerly, Cardiff by the Sea, CA, US
jeff hopkins, lindenhurst, IL, US
Susanne Burtis, Lynbrook, NY, US
Ursula Mecking, Newport News, VA, US
William McMullin, St. Paul, MN, US
Teddy Sedlmayr, vero, FL, US
David Lien, Colorado Springs, CO, US
stefanie mattfeld, P rovincetown, MA, US
Nancie Chalmers-Herbst, Tucson, AZ, US
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Thomas Cole, St Louis Park, MN, US
Beverly Blackburn, San Antonio, TX, US
Ed Schlegel, Capistrano Beach, CA, US
Walter Berrie, Trainer, PA, US
Natalie DeFee Mendik, Jeannette, PA, US
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Gloria Picchetti, Chicago, IL, US
Sharon Barbell, Ithaca, NY, US
Robert Snitgen, Wabasha, MN, US
Hugh moore, El Cajon, CA, US
Ren Navez, Venice, CA, US
Darrin Duling, Greenwich, CT, US

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Kate Holley, Bozeman, MT, US
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Jennifer Hocking-Wiley, Madison, NH, US
Michael Finnegan, KINGMAN, AZ, US
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Gloria Picchetti, Chicago, IL, US
Larry Reynolds, Winchester, TN, US
christine tippens, sheboygan falls, WI, US
Susan Morgan, Maple Falls, WA, US
Ben Greensfelder, Portland, OR, US
Richard Henderson, San Anselmo, CA, US
Susan Morgan, Maple Falls, WA, US
David Abel, Portland, OR, US
Annmarie Lucchesi, Reno, NV, US
Patricia O'Hearn, Katy, TX, US
val lura, lake geneva, WI, US
Jeanne Kinnard, Shoreline, WA, US
chad mallett, st martinville, LA, US
George K. Kiel, Rockford, MI, US
David Calleja, Islip Terrace, NY, US
Kani Nicolls, Black Mountain, NC, US
Kathryn Anderson, Tucson, AZ, US
Karla Garcia, miami, FL, US
Nancy Henninger, Houston, TX, US
Ian Conners, Brunswick, ME, US
Joseph Corio, San Francisco, CA, US
David Laufer, Granada Hills, CA, US
Susan Babbitt, PHILADELPHIA, PA, US
Mark Brostrom, georgetown, CO, US
Jessie McGee, Kirkwood, MO, US
Jack Brown Jr, Payette, ID, US
John Colgan-Davis, PHIALDELPHIA, PA, US
Lindsay Murphy, Novato, CA, US
Rebecca Connors, Boston, MA, US
Amber Huntoon, Tolleson, AZ, US
Jennie Mugrace, Bayonne, NJ, US
Erik Olafsson, Canyon, CA, US
Dawn Beveridge, Forest Hill, MD, US
Bruce Silvey, Tucson, AZ, US
Jackie Pomies, San Francisco, CA, US
Christie Robnett, EAST PEORIA, IL, US
David Trask, Snyder, NY, US
Michael A. Cerrato, Westville, NJ, US
Michael Bard, Salt Lake City, UT, US
Christina Merlo, Oakland, CA, US
Sherry Amen, portland, OR, US
Laurie Puca, New City, NY, US
Robert Myers, Roswell, NM, US
mindy cain, safety harbor, FL, US

Robert Rand, Brunswick, ME, US
Christina Pinkney, Pasadena, CA, US
David Zidlick, Moncks Corner, SC, US
Karina Black, Boulder, CO, US
Douglas Galasko, San Diego, CA, US
Albert Ritchey, Jr., Vestavia Hills, AL, US
Roger Katz, Old Westbury, NY, US
chX whitfield jr, tempe, AZ, US
Jim Burdeshaw, East Meadow, NY, US
Roger Katz, Old Westbury, NY, US
Chadwick Cox, Norman, OK, US
Linda Moloney, Glasgow, KY, US
Eric Stordahl, Marquette, MI, US
Michael John, Chester, VT, US
Jenny Robertson, Beulah, MI, US
Jake Thompson, Queens Village, NY, US
Connie McCue, Indianapolis, IN, US
Catherine Raymond, Odenton, MD, US
Sherry New Harvest Organics, Patagonia, AZ, US
Gregory Pickett, Waukegan, IL, US
Julia Burwell, San Diego, CA, US
Harold Self, Little Switzerland, NC, US
Carl Howard, Columbus, OH, US
Sherry New Harvest Organics, Patagonia, AZ, US
Michael Anderson, Schererville, IN, US
Keith Woodard, Portland, OR, US
Larry Wheeler, Watauga, TX, US
Colleen Powers, Mt. Morris, NY, US
Andrea Amend, Highland Park, IL, US
Holland Garcia, Carmel, CA, US
Roger Plaut, Rockville, MD, US
Bruce Thomas, Stow, MA, US
Diane Liptack, INDIANAPOLIS, IN, US
Patricia Pursell, Belleville, IL, US
Anne Mickatavage, Yelm, WA, US
Muriel Rosenholtz, Coconut Creek, FL, US
Eric Fleming, Los Angeles, CA, US
Barb James, Warrenville, IL, US
Lisa Williamson, Pasadena, CA, US
Ernesto Lopez, Plainfield, IL, US
Barbara McLendon, Blairsville, GA, US
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Marcia Bentley, Coronado, CA, US
Rob Justin, Bozeman, MT, US
Jo Beall, Nags Head, NC, US
Bill Call, Oceanside, CA, US
Dianna Dennis, Spring Hope, NC, US
Joan Piowaty, Chicago, IL, US
Peter Taylor, Los Gatos, CA, US
Constance Hillard, Mesa, AZ, US
Susan Watts-Rosenfeld, Riverside, CA, US
Jason Hirsch, Park Forest, IL, IL, US
Michael Allen, Moriarty, NM, US
Nancy Schilling, Western Springs, IL, US
darlene kerner, New Port Richey, FL, US
Lindsey & Jim Wanner, Milford, IL, US
Michael Souza, San Diego, CA, US

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Thomas Nass, Sacramento, CA, US
anne marie frerichs, Lincoln, NE, US
Barbara Erlichson, Somerset, NJ, US
Henry Rosenfeld, Riverside, CA, US
Sharon Koperek, Housatonic, MA, US
curt sommer, West Linn, OR, US
Mark Stanton, Pine Hill, NJ, US
Mary Detrick, St. Petersburg, FL, US
JOSEPH REEL, PACIFIC GROVE, CA, US
Fred Pomerantz, Sheffield, MA, US
Ron Schmidt, San Francisco, CA, US
john rowland, pensacola, FL, US
Lena Johnson, San Diego, CA, US
Paul Greatrix, Winthrop, MA, US
Ron Boddicker, Tavares, FL, US
Duane Kubischta, San Francisco, CA, US
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Stephen Fischer, Los Angeles, CA, US
Deborah Sebenste, Hammond, IN, US
darlene kerner, New Port Richey, FL, US
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David Kozlowski, Santa Fe, NM, US
Donna Bryant, Houston, TX, US
Paul Moulton, Tallahassee, FL, US
Donald Shaw, Syracuse, NY, US
Natalie Tedford, Glendale, AZ, US
Karen Clarke, North Charleston, SC, US
Anne DeMers, Crookston, MN, US
Gerri Reaves, Fort Myers, FL, US
Sherri Ellis, Ithaca, NY, US
joyce cotter, decatur, GA, US
sherry benson, Steamboat Springs, CO, US
Amber Stogo, Redondo Beach, CA, US
Lindsay Stewart, Wichita, KS, US
Helen Anderson, Portland, ME, US
Roxana Carrillo, Oceanside, CA, US
Gerianne Carillo, Milford,, NY, US
Don Erhard, Dassel, MN, US
Trisha Schawo, Michigan City, IN, US
Mini Richards, Chandler, AZ, US
Laura Lasater, Denver, CO, US
James Hamilton, Palos Verdes Estates, CA,
Laura Elton, Lancaster, CA, US
Kimberly Eastin, Deltona, FL, US
Laura Lasater, Denver, CO, US
Delainie Aguilar, Jersey Village, TX, US
Meghan Blydenburgh, Riverhead, NY, US
Peter White, TUCSON, AZ, US
Ann Bornstein, Delray Beach, FL, US
Karen Ackoff, South Bend, IN, US
Alberto Quijano, pasto, ot, CO
David Unger, Indianapolis, IN, US
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Susan Sinkiewicz, Valparaiso, IN, US

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Dennis Morley, Old Bridge, NJ, US
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Michelle Dudeck, Monessen, PA, US
John Toth, Salem, IL, US
Eric Muehlbauer, Rego Park, NY, US
Cata Wood, Vancouver, WA, US
Sandra McCarthy, Commerce City, CO, US
Bill Mcgoldrick, Atlanta, GA, US
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S. Terry Carter, Phoenix, AZ, US
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Rob Gonzalez, Davie, FL, US
marion jimenez, valley Glen,CA, CA, US
Ronald Lyons, Arroyo Grande, CA, US
Mary Ellen Scribner, Austin, TX, GH
Michael Wichman, Naples, FL, US
Alejandro Garcia, Richmond, CA, US
Thomas Pritchard, Milford, NY, US
J Woodhull, Solon Springs, WI, US
Crystal Jenkins, Boulder, CO, US
Anne Duvall Romano, Arlington, TX, US
Jitka Mencik, Springerville, AZ, US
Dan Silver, Los Angeles, CA, US
Mark Ogonowski, Tucson, AZ, US
Clare Thorpe, Pickering, ON, CA
Sandra Stock, Tucson, AZ, US
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James Bond, Wisconsin Rapids, WI, US
Kathryn Wild, San Diego, CA, US
Doug Petty, Rochester, MN, US
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Glenn White, Franklin, TN, US
Jeannine Frazier, KEnmore, WA, US
Donna Tartt, Cullen, VA, US
caroline Sumpter, Arlington, WA, US
Jason Nicholson, Calgary, AB, CA
Karen Gerst, Los Angeles, CA, US
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Myron Thornberry, Bloomington, MN, US
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Linda Reese, Fremont, CA, US
Rick Rosner, Westlake Village, CA, US
Pam Evans, Kemp, TX, US
Amy Hilburger, Oakdale, MN, US
Laura Garrett, Pasadena, CA, US
Stephanie Myers, Las Vegas, NV, US
Deborah Thelen, NEW YORK, NY, US
Diana Parsons, Alta Loma, CA, US
Harley Pierce, Paw Paw, MI, US
Donna Clark, Alhambra, CA, US
Pamela Allport, North Hollywood, CA, US
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Lisa Gosnell, Georgetown, DE, US
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Sarah Barrs, San Francisco, CA, US
Greg Kareofelas, DAVIS, CA, US
Erin Cali, Grand Rapids, MI, US
Stephen Rosenthal, San Francisco, CA, US
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Richard Harvey, Paso Robles, CA, US
Charles Lawson, Kent, WA, US
John A Ferguson, Berkeley, CA, US
Dan Williams, Las Vegas, NV, US
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Harold Pike, Seymour, TN, US
Anna Couvillon, Rockville, MD,
Fred Buwhler, Okemos, MI, US
James Jachimiak, Franklin, IN, US
Gusti Boiani, Eckert, CO,
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Sharon Gillespie, Austin, TX, US
Tracey Cha, Scottsdale, AZ, US
Kirsten Zollo, Ringwood, NJ, US
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Linda Riebel, Lafayette, CA, US
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Margaret Moss, New Orleans, LA, US
Sally Small, Salt Lake City, UT, US
Yonna Graham, Dublin, VA, US
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Frances Dunham, Gulf Breeze, FL, US
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Richard Hackett, Emeryville, CA, US
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Susan Cunningham, San Marcos, CA, US
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Barbara Clay, Gary, IN, US
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Tara Bradman, Attica, NY, US
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Betty Young, Converse, TX, US
Dorothy Brown, Newton, MA, US
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Rebecca Pint, Akron, OH, US
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Irving Napert, Dallas, TX, US
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Denise Mitchell, Woodland Hills, CA, US
Emily Kenny, Chicago Heights, IL, US
Ruth Busch, Lafayette, AL, US
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Irving Napert, Dallas, TX, US
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Justine Olmez, North Attleboro, MA, US
Michael Ruzza, Schenectady, NY, US
Mark Wheeler, Portland, OR, US
Jill Placzek, West Tisbury, MA, US
Ivonne Arias, Newhall, CA, US
Jim Phillips, Sonoma, CA, US
Jennifer Lance, Hyampom, CA, US
kelleen farrell, placerville, CA, US
Jacqueline Stimpert, Cleveland Heights, OH, US
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William e. Sarovec, Lake Ronkonkoma, NY, US
Tom Thayer, Auistin, TX, US
Jonny Knowles, Alton, ot, GB
Andrew Bellak, Amherst, MA, US
Shirley Keenum, Houston, TX, US
Larry, Barbara Lough, Temperance, MN, US
Beverly McNeilly, Alturas, CA, US
Dena Hernandez-Kosche, Glendale, CA, US
John Doyle, New York, NY, US
Larry, Barbara Lough, Temperance, MN, US
Sandy Hunting, Chesapeake Beach, MD, US
Miranda Saunders, Studio City, CA, US
Susan Montague, Fort Ann, NY, US
Krista Mahoney, Sacramento, CA, US
Susan Seager, Rancho Palos Verdes, CA, US
Angela Palmisono, Hialeah, FL, US
Margaret Sueoka, Kapaa, HI, US
Sybil Chappellet, Hana, HI, US
dr michael stocker, ny, NY, US
Fali Engineer, Houston, TX, US
David Tatlock, North Dartmouth, MA, US
Jesse Spears, Austin, TX, US
Gloria Sferra, Seattle, WA, US
Helen Malinauskas, Montello, WI, US
Annette McMullen, Vincennes, IN, US
John Matz, Hanover Park, IL, US
Jay Harter, Susquehanna, PA, US
Susan Christie, T or C, NM, US
Jack Harris, Nashville, TN, US
Nancy Jackson, Blountsville, AL, US
Jennifer Butler, Wilmington, NC, US
Gloria Sferra, Seattle, WA, US
Wayne Bamberger, St. Petersburg, FL, US
dr michael stocker, ny, NY, US
Krystal Pruin, Williams, IA, US
Robin Perl, Brooklyn, NY, US
Lisa Mislak, Tucson, AZ, US
William Horne, Salisbury, MD, US
Wolfgang Nehring, Los Angeles, CA, US

Kari Lopez, Knoxville, TN, US
Alice Polesky, San Francisco, CA, US
John Cleveland, North Stonington, CT, US
Thomas Coffeen, Phoenix, AZ, US
Paul Collins, Hillsborough, NC, US
Anjali Orlando, Rougemont, NC, US
mary anne combs, Marion, NC, US
Edith Churich, Martinrz, CA, US
Suzy Norris, Santa Cruz, CA, US
David Gascon, Lyndonville, VT, US
Patricia Greiss, Carlisle, PA, US
Donna Butler, Coon Rapids, MN, US
Donna Butler, Coon Rapids, MN, US
Leah Reynolds, Lovelady, TX, US
Heather Coleman, Goleta, CA, US
Michael and Iris Weng, Phoenix, AZ, US
Tina Brown, Juneau, AK, US
Donadl Waltman, State College, PA, US
Gail Findley, Las Vegas, NV, US
Mary Harte, Berkeley, CA, US
Jerry Clymo, Union City, CA, US
Cornelius McHugh, Dublin, ot, IE
M. Addison, Lakeland, FL, US
Maria Jackson, San Luis Obispo, CA, US
Paul Koluvek, Medford, OR, US
Beth Schrader, Onamia, MN, US
Denise Mitchell, Woodland Hills, CA, US
Molly and Craig Dana, West Seneca, NY, US
Peter Klosterman, Piedmont, CA, US
Heather Marsh, Greenbelt, MD, US
Ruth Bescript, Tucson, AZ, US
Jeffrey Hight, Winston-Salem, NC, US
Cheri Langlois, Mendocino, CA, US
Patty Brothag, mantua, OH, US
Kevin Branstetter, Lodi, CA, US
Audrey Peters, LANSING, MI, US
Stephanie Calabrese, Rego Park, NY, US
Molly and Craig Dana, West Seneca, NY, US
Robert Luce, Sierra Vista, AZ, US
Duncan McFarland US
Lauryn Galindo, Hanalei, HI, US
Kenneth Mattos, Rutledge, PA, US
Katherine Iosif, San Francisco, CA, US
Charlene Chauvaux, Cambria, CA, US
Ron Bogin, El Cerrito, CA, US
Christa Dailey, Paducah, KY, US
judith Martinez, St Augustine, FL, US
Rolland Fellows, Austin, TX, US
Janice Bernard, Scarborough, NY, US
Linda Anderson, Ridgecrest, CA, US
Janice Bernard, Scarborough, NY, US
William Eiholzer, Kirkland, IL, US
Connie Beck, El Cajon, CA, US
Scott Staats, Prineville, OR, US
Dani Duke, Iowa City, IA, US
Brittany Carr, Saltillo, MS, US
Valerian Alexander, Alpharetta, GA, US

Robert Jadin, Arlington, TX, US
Daniel Saltz, salem, OR, US
Peggy Pianalto, Tulsa, OK, US
Kevin Limb, Evanston, WY, US
Pat Johnson, Galloway, OH, US
Pat Rose, Largo, FL, US
Amy Williams, Long Beach, CA, US
Jennifer Hill, Westerville, OH, US
Cherie Gaston, Tucson, AZ, US
Terry Percival, Topeka, KS, US
Philip De Rosa, White Rock, BC, CA
William Conner, st augustine, FL, US
kelly Rose, Orange, CA,
Cynthia Morefield, Fuquay Varina, NC, US
Sara Deutsch, Asheville, NC, US
Sara Deutsch, Asheville, NC, US
Joel Hildebrandt, Berkeley, CA, US
Cat Solicito, oxford, CT, US
Anna Smith, Oxford, MS, US
Mary Alexander, Glen Allen, VA, US
Shena Kieval, Soquel, CA, US
Mary Petrilli, Pacifica, CA, US
Ellen Jordan, Los Angeles, CA, US
Diana Hofman, Murrieta, CA, US
Steven St. Clair, Manitou Springs, CO, US
Veronica Newton, sumner, GA, US
Gretchen Schneider, yachats, OR, US
Ellen Schiff, Sonoma, CA, US
Linda Hogle, Sunnyvale, CA, US
Kiki Pollard, Madison, GA, US
John Wendell, Santa Rosa, CA, US
Mallikarjuna Kishtagoni, saint paul, MN, US
Bill Mullen, Winchester, KY, US
Mel Henshaw, San Diego, CA, US
Nancy Meadows, Chico, CA, US
Kathy Duke, Austin, TX, US
Jack Stansfield, Stanwood, WA, US
Jeffrey Jones, Faribault, MN, US
Lauri peacock, HOBBS, NM, US
Juna Madrone, Redway, CA, US
Elizabeth Gladfelter, Bethlehem, PA, US
Janet Yasenchak-Votta, Eastpointe, MI, AF
Richard Boone, Chapel Hill, NC, UM
lisa comfort, Cave Creek, AZ,
Ingrid Scott, Castine, ME, US
Maureen Fahlberg, Boulder City,, NV, US
Atiya Ahsan, Minneapolis, MN, US
Shirley Smith, Sound Beach, NY, US
Jeannie Dworak, Gravenhurst, ON, CA
Lenore Rosenblatt, Nashville, TN, US
James Gloeckner, Asheville, NC, US
Julie Evens, Sacramento, CA, US
Daniel Valley, Cadillac, MI, US
Beth Gelsey, Glendale, AZ, US
krista koller, Olympia, WA, US
Doris Waxberg, Tempe, AZ, US
Susan Markowitz, LAHASKA, PA, US

Benjamin Reiss, Gainesville, FL, US
Susan Kepner, Hampton, NH, US
Rick Sanchez, Eagan, MN, US
Ann Dupuis, Randolph, MA, US
Marian Cooley, Muncie, IN, US
Jane McCullam, Newbury, OH, US
Wendy Ledendecker, Florissant, MO, US
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Claire Perricelli, Eureka, CA, US
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Carly Hanssler, Irvine, CA, US
Ed Moore, san mateo, CA, US
Glenn Hogg, Concord, CA, US
Mark Walker, Petaluma, CA, US
Dawn Lauryn, Gainesville, FL, US
Paul Ezust, Cambridge, MA, US
Joe Myers, Azusa, CA, US
Marsha Buck, Juneau, AK, US
ronald brown, Longmont, CO, US
Mary Rogers, Clearlake, CA, US
Kristin Hurley, Poway, CA, US
Nancy Nangeroni, Beverly, MA, US
Matthew Stephens, Hubbard,Oh, OH, US
Douglas Metzler, TURTLE CREEK, PA, US
Evan Kaiser, Evansville, IN, US
Cheryl Bogle, Clarksville, TN, US
Priya Bhatt, Savoy, IL, US
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judy schwartz, los angeles, CA, US
Philip Stratton, Saint Paul, MN, US
Ian Cree, San Francisco, CA, US
Patricia Hurley, Poway, CA, US
Kevin Walker, Haymarket, VA, US
William McQueen, Buena Vista, CO, US
Sally Shannon, Tiburon, CA, US
Jody Gibson, Des Moines, IA, US
Merideth Genin, New York, NY, US
Diane Loos, Greenfield, WI, US
Jim Hopkins, Eatonton, GA, US
Thomas Cox, Kirkland, WA, US
Patrick Coulson, Bandon, OR, US
Linda SALAMON, Harwich, MA, US
Jill Kotch, Redding, CT, US
Christopher Norcross, Harwich, MA, US
Steve Velasco, Costa Mesa, CA, US
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KAREN Pope, PALM SPRINGS, CA, US
Elaine Evans, Lexington, KY, US
Dale Cullen, Kearny, NJ, US
Jerry Bloomer, Hot Springs, SD, US
mariel stephenson, columbia, MO, US
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Ellen Dryer, loveland, OH,
Andrew Cohen, Memphis, TN, US
Lori Harmon, Humble, TX, US
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Abby Coble, Silverdale, WA, US

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A Bonvouloir, Sunnyvale, CA, US
Gary Canary, Placerville, CA, US
George Buckingham, Chiloquin, OR, US
Shawna Steeley, Shoemakersville, PA, US
Maureen Mcelligott, Idyllwild, CA, US
Albert Lannon, Tucson, AZ, US
Brent Koenig, San Diego, CA, US
S. Chapek, SF, CA, US
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wendy terra, scarsdale, NY, US
alan blixt, sierra vista, AZ, US
Laura Bernstein, Highland Park, IL, US
Robert Brownscombe, Rhododendron, OR, US
Dan Herman, West Chester, PA, US
Ted von Hippel, Miami, FL, US
S. Chapek, SF, CA, US
Kris Gilbert, Binghamton, NY, US
Alan Herman, Arlington, VA, US
Rick Clark, Spotsylvania, VA, US
Daniel Ward, Syracuse, NY, US
Sandie Friedland, Las Vegas, NV, US
Robin Mayerat, Hamburg, NY, US
Donna Lozano, Harlingen, TX, US
Cheri Dzubak, Yardville, NJ, US
Sandie Friedland, Las Vegas, NV, US
Carol Lane, Concord, CA, US
Kathleen Gittel, LIBERTY HILLS, TX, US
Joe Cundari, Phoenix, AZ, US
Joan Dulberg, Raleigh, NC, US
Debbie Sequichie-Kerchee, Cache, OK, US
Jocelyn Blake, Madison, WI, US
Sandie Friedland, Las Vegas, NV, US
Amy Bohnsack, Miami, FL, US
barbara heil, tarzana, CA, US
Benjamin Welch, Eugene, OR, US
Jennifer Lahey, south salem, NY, US
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Jill Dahlman, Honolulu, HI, US
J. Brad Jarvis, Kingman, AZ, US
Robert Taylor, Porterville, CA, US
Megan Emry, Maple Grove, MN, US
Charles Leiden, Altoona, PA, US
John Domingue, Englewood, CO, US
Donna Schiller, Michigan City, IN, US
Brooke Bryant, Venice, CA, US
roger Levin, San Francisco, CA, US
cara gubrud, milaca, MN, US
Rick Flory, Scottsdale, AZ, US
Patricia Klatt, Calistoga, CA, US
Duane Benton, Farmivlle, VA, US
Jennifer Sellers, Concord, CA, US
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Lisa Decker, Kennesaw, GA, US
Den Mark Wichar, Vancouver, WA, US
Tresa Frazier, Porter, TX, US
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Deborah Donofrio, West Haven, CT, US
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Pamela VourosCallahan, Granger, IN, US
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Rosemary Griffith, Honolulu, HI, US
Mary Link, Ashfield, MA, US
Wesley Wolf, Lake Barrington, IL, US
inga kaminski, chicago, IL,
Peter Marko, Ottawa, ON, CA
Collette Novak, Chandler, AZ, US
Kevin Armitage, Oxford, OH, US
Ann and Eric Godfrey, Ripon, WI, US
Mary Crooks, Coralville, IA, US
Marguerite Hossler, San Pedro, CA, US
Richard Lombard, Groveland, MA, US
Janet Reichmann, Los Angeles, CA, US
Patti Thomas, Durham, NC, US
Frances Alet, Calabasas, CA, US
Anne Hanson, Novato, CA, US
Janet Reichmann, Los Angeles, CA, US
Davi Stewart, Hunt, TX, US
Amanda Johnson, East Hampton, CT, US
Margo Brown, Buffalo, WY, US
Michael Asbell, Nashville, TN, US
S. Sohmer, Fort Worth, TX, US
Sam Keener, Berkeley, CA, US
Laura Collins, Knoxville, IL, US
Peter Arneson, Colfax, WI,
Kalev Pehme, Redondo Beach, CA, US
jerome pindell, Niskayuna, NY, US
Linda Hermann, Lebanon, PA, US
Sallie Delahoussaye, Austin, TX, US
Bruce Blacknight, Marshall, NC, US
Frank Arnold, Saan Jose, CA, US
Deborah Voves, Anchorage, AK, US
catherine graf, stamford, CT, US
june Veloce, Patterson, NY, US
Bonnie Mc Cune, Miami, FL, US
Ryan Danzinger, Arlington Heights, IL, US
Jane Reynolds, Madison, WI, US
Janis Monier, Norton, KS, US
luis vega, brooklyn, NY, US
Cheryle Steele, Whittier, CA, US
Jan Scudra, Centerville, OH, US
jeremiah baker, surrey, BC, CA
Carlos Schomaker, Fort Myers, FL, US
Eric P Godfrey, Ripon, WI, US
Claudia von Grunebaum, Winston-Salem, NC, US
Kalyn Stanley, Eden Prairie, MN, US
Dori Weppler, Issaquah, WA, US
J. Dupee, Katonah, NY, US
Randall Notgrass, Austin, TX, US
Thomas V. Connor, Wallkill, NY, US
jeremiah baker, surrey, BC, CA
Jill Kotch, Redding, CT, US
Eric Wickiser, Minneapolis, MN, US

Dori Weppler, Issaquah, WA, US
James Thoubboron, Ringwood, NJ, US
John Steiner, Taylorsville, UT, US
Lauren Schiffman, El Cerrito, CA, US
Dodie Shepard, Burbank, CA, US
Theersa Everett, Tarrytown, NY, US
Cheryle Steele, Whittier, CA, US
Ann Smith, West Orange, NJ, US
Patty Bonney, Portland, OR, US
Pamela Kjono, Grand Forks, ND, US
Jonathan Hall, Port Charlotte, FL, US
Jeremy Brown, Kalamazoo, MI, US
Gary Cronin, Santa Fe, NM, US
Emma Leyburn, Eugene, OR, US
Jerry King, Spokane, WA, US
Janet Reid, Belen, NM, US
Roger Woitte, Herndon, VA, US
Michael Fazio, Astoria, NY, US
Janet Tyler, Pasco, WA, US
Joanna Jaworowska, Boulder, CO, US
Bonnie McLean, Pensacola, FL, US
Jeanne Steig, Boston, MA, US
Connie Lippert, Seneca, SC, US
Ron Rattner, San Francisco, CA, US
Mary Beth Hostrup, Hollywood, FL, US
Nancy Royce, Wilmington, NC, US
Andrew Jones, Gladstone, MI, US
Janet Jamerson, Emeryville, CA, US
Martha Ruben, Ottawa, ON, CA
Jung Shin, Fairfield, CA, CA, US
Adrienne Eisenberg, Lackawaxen, PA, US
Mike Relac, Bar Harbor, ME, US
m uccello, hallandale, FL, US
Desiree Fernandez, San Antonio, TX, US
Kelly Dubois, Modena, NY, US
Kaye Fissinger, Longmont, CO, US
LILIANA LOPEZ, SAN DIEGO, CA, US
Mark McClelland
Linda Lillow, Albuquerque, NM, US
Susan Brittain, Bellevue, NE, US
Mike Relac, Bar Harbor, ME, US
Yvonne Marlin, Cortez, CO, US
Max Tzinman, NY, NY, US
Melanie Hauf, Tega Cay, SC, US
Hilary Auker, Denver, PA, US
Brandon Danaher, Blue Springs, MO, US
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H. Gerald Smith, Toccoa, GA, US
Murray and Shari Grounds, Kailua, HI, US
Ds Powell, Clairemont, CA, US
ANNE LEWIS, KENT, WA, US
Gloria Morrison, Pecos, TX, US
Deborah Chielli, Dallas, PA, US
Melissa Wright, Thunder Bay, ON, CA
D Farmer, Brooklyn, NY, US
Fred Anderson, TUCSON, AZ, US
Morgan Clark, South Orange, NJ, US

carol rigrod, encino, CA, US
Fran Stallings, Bartlesville, OK, US
Jennifer Davidson, Fillmore, IL, US
J. Gregory Twain, Portland, OR, US
Caroline Fowler, Oroville, CA, US
Deborah Chielli, Dallas, PA, US
bethany comeau, Phoenix, AZ, US
Hilary Auker, Denver, PA, US
gretchen breese, jamaica Plain, MA, US
mohammed benbouchaib, Ottawa, ON, CA
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Adam Pastula, Longmont, CO, US
Sarah Tjeder, Sacramento, CA, US
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Daniel Mckinley, Albany, NY, US
Warren Harkey, Las Cruces, NM, US
William Weber, University Hts., OH, US
Mariann Farrell, seattle, WA, US
Sandra Desmedt, Boonton, NJ, US
Monnie Efross, El Sobrante, CA, US
jamie green, newhall, CA, US
Scott Weitz, Oakland, CA, US
David Nix, TUCSON, AZ, US
Ken Wright, Kalispell, MT, US
William Callahan, San Rafael, CA, US
Chip Waldron, Austin, TX, US
Chris Aycock, San Francisco, CA, US
Jill Kotch, Redding, CT, US
Donna Knipp, New York, NY, US
Vic Burton, Kansas City, MO, US
Sandy Draus, Phoenix, AZ, US
David Nix, TUCSON, AZ, US
Sharon Haley, Lebanon, OR, US
Regina Zanettin, Chicago, IL, US
Beverly Janowitz-Price, Apache Junction, AZ,
Joanne Gerstle, Westchester, CA, US
Tristen Robbins, Arvada, CO, US
Jolene Bishop, EL DORADO, CA, US
SHELLY STEVENSON, Solana Beach, CA, US
Lisa Martin, Monroe, ME, US
Rich Olson, New River, AZ, US
MILENA POPOVICH, LOS ANGELES, CA, US
Jesse Williams, Urbana, CA, US
John Webb, Charles Town, WV, US
Edward Button, Rochester, NY, US
Lou Sherry, Placerville, CA, US
tonia beckler, Cloudcroft, NM, US
Lindsay Moon, Los Angeles, CA, US
Emily Johnson, E. Stroudsburg, PA, US
Loren Amelang, Philo, CA, US
Carol Niemi, Houston, TX, US
Stephen Nicklay, Moorhead, MN, US
Michele Samuelson, San Leandro, CA, US
Elizabeth Dowd, Bloomsburg, PA, US
Harriet McCleary, Minneapolis, MN, US
Melissa Thyoneus, San Diego, CA, US
Lee Hunt, Longveiw, TX, US

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John Peterson, McMinnville, OR, US
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Angela Elniski, Hamburg, NY, US
Chaz Groves, Cambria, CA, US
Angel Logsdon, Plymouth, WI, US
Livia Hanich, Altadena, CA, US
Val DeGrace, Saranac Lake, NY, US
Steven Stewart, Santa Cruz, CA, US
Julia Echternach, Highlands Ranch, CO, US
Ulla Schmid, Berlin, ot, DE
chris hall, oracle, AZ, US
Matthias Hildebrandt, Los Angeles, CA, US
Ernest Endes, Carlsbad, NM, US
Claire Flewitt, San Lorenzo, CA, US
Rachel Baker, Katonah, NY, US
Joy Nishioka, Charlotte, NC, US
Mary Fabian, Charlotte, NC, US
Robin Davis, Atlanta, GA, US
Craig Nazor, Austin, TX, US
Christopher Turon, West Wyoming, PA, US
bruce cohen, worcester, MA, US
Kim Dyer, Mechanicsville, VA, US
James McAndrew, San Francisco, CA, US
Xander Kennedy, Studio City, CA, US
Merlin Emrys, Santa Fe, NM, US
Antoinette Calavas, Mendocino, CA, US
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James Bauman, Seattle, WA, US
Margerite Gamboa, Hinsdale, IL, US
John Templin, Bluffton, OH, US
Howard Stein, Chicago, IL, US
Brian Florian, Beverly Hills, CA, US
J.B. Coleman, Easley, SC, US
John Harris, Honolulu, HI, US
Aelred Glidden, Three Rivers, MI, US
Louise Slattery, St Lazare, QC, CA
James Bauman, Seattle, WA, US
Marsha Rpby, Greenville, CA, US
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Amy Gibson, Norwich, OH, US
Antoinette Calavas, Mendocino, CA, US
andrew doll, Denver, CO, US
Thomas Bejgrowicz, Lancaster, PA, US
Kathi Kibbel, Dallas, TX, US
Karen Cespedes, Hialeah, FL, US
Sharon Garrels, Burbank, CA, US
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David McCLosky, Oakland, CA, US
Eric & Cedra Spragett, Phoenix, AZ, US
Charles Warlop, Tucson, AZ, US
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Julie Marquis, Austin, TX, US
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Harry Hollack, prescott, AZ, US
Leslie Slater, Homer, AK, US
Brian Christian, Rio Rancho, NM, US
Sheri Archey, Salem, OR, US
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Jim Oxyer, Louisville, KY, US
Howard Strauss, Culver City, CA, US
Edward Thornton, Swarthmore, PA, US
Larry Lambeth, Springfield, MO, US
Vangie Poe, Durham, NC, US
Terelle Terry, Sacramento, CA, US
Malgorzata Kiandra-Puciaty, Rolling Meadows, IL, US
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Jorge Garza, Laredo, TX, US
Cristina Moody, Lafayette, IN, US
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Garold Barr, Covington, KY, US
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John Markowitz, New York, NY, US
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Tom Perkins, Smiley, TX, US
Anna Kazanjian, San Francisco, CA, US
Susan Stross, Seattle, WA, US
Chris Buelow, hardwick, MA, US
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Michael White, Long Beach, CA, US
Linda Campbell, Prescott Valley, AZ, US
Jim Leske, Glendale, CA, US
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Claire Dunaway, DeSoto, TX, US
Clive Julianus, Fairfax, CA, US
Barbara Whitney, Sylmar, CA, US
Andres Pacheco, Keller, TX, US
Cass Lockhart, Parma, ID, US
Meredith Donahue, Philadelphia, PA, US
Barbara Muldoon, Sleepy Hollow, NY, US
Alan Kardoff, Palm Bay, FL, US
Michael Rollins, Riverside, CA, US
Joseph Bail, clearwater, FL, US
Kari McWhirter, Monrovia, CA, US
Cheryl Rosenfeld, COLUMBIA, MO, US
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Jennifer Apkarian, Martinez, CA, US
Michael Powers, Tucson, AZ, US
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Gary Lampman, Hendersonville, TN, US
Aleta Orlandoni, Orlando, FL, US
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Robert Wagner, Lawrenceville, GA, US
Angela Shaw, Oakland Park, FL, US
Holly McMahon, Newington, CT, US
David Gordon, Crockett, CA, US
Stephen Lang, northport, NY, US
Darcy Jones, Knoxville, TN, US
Kenneth Duncan, ft collins, CO, US
Tamela Roberson, Everett, WA, US
Elaine Fischer, Houston, TX, US
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Karen Soh, Jasper, AB, CA
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Robert Beach, Maumee, OH, US
Richard and Rebeca Kane, Port Washington, NY, US
Elaine Becker, Houston, TX, US
Johanna Elias, Brooklyn, NY, US
Irina Foster, Everett, WA, US
Roxana Sherman-Heath, Vernonia, OR, US
Raine Brogden, Calera, AL, US
Annette Almazan, Forest Hills, NY, US
Rebecca Hale, Gouverneur, NY, US
Lacy Gibson, Elkhart, IN, US
Martha Williams, Roanoke, VA, US
William Bruce, San Diego, CA, US
Carl Kanun, tucson, AZ, US
JOE LUCIANI, VICTORVILLE, CA, US
Katrina Rivers, LA, CA, US
Kelvin Walker, San Jose, CA, US

Brie Schmidt, Cincinnati, OH, US
andrew Stapinski, Decatur, GA, US
Susan Harquail, San Juan Capistrano, CA, US
Tom Lankford, Crown Point, IN, US
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Kathleen Moraski, Woodbury, MN, US
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Natalene Cummings, Crandon, WI, US
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Dan Melius, Penn Valley, CA, US
Terry Dassow, Menomonee Falls, WI, US
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Jerrille Tarectecan, Dumont, NJ, US
Carol Hilton, Royal Oak, MI, US
Sue Becker, Cedarville, CA, US
Melissa Kenzari, Glen Gardner, NJ, US
Florence Saeger,, Kirkwood, MO, US
Christine Coughlin, Plaistow, NH, US
Reginald Durant, Irvine, CA, US
Matthew Bayer, Columbus, IN, US
Erin Gabrielson, Woodland Hills, CA, US
Caroline Hogue, Boulder, CO, US
Robert Bartlett, Newton, NH, US
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Harrison Grathwohl, Green Valley, AZ, US
Nancy Brodersen, Glendale, CA, US
Heather Simmons, Los Angeles, CA, US
Karen Worthington, Enumclaw, WA, US
Carolyn Treadway, Normal, IL, US
Robert Kalovsky, Onalaska, WI, US
Steve Kreider, San Francisco, CA, US
Susan Markowitz, LAHASKA, PA, US
John Wise, Mesa, AZ, US
Kimberly Mooney, Baltimore, MD, US
Eric West, Daytona Beach, FL, US
Deborah Holljes, Narberth, PA, US
Stephanie Fairchild, Cambridge, OH, US
Miles Janke, Ash Flat, AR, US
Elizabeth Rosalen, Staten Island, NY, US
Alan Mineo, Key West, FL, US
Joanna Nicolini, Phoenix, AZ, US
Bradford Goodwin, Maple valley, WA, US
Victor Kern, Yukon, OK, US
Barbara MacAlpine, San Antonio, TX, US
Brian Guadagno, Bayonne, NJ, US
Beth Cook, Bloomington, MN, US
Michael Klausing, Nitro, WV, US
Connie Doak, Tulsa, OK, US
Barbara Higgins, Hamilton, AL, US
Susan Goldin, Canaan, NY, US
Connie Devine, San Jose, CA, US
Luis Lemus, Bellaire, TX, US
Susan Boles, Murrells Inlet, SC, US

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Linda Chappel, Tucson, AZ, US
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Ellen Fauerbach, Denver, NY, US
Katherine Domeny, Davis, CA, US
Art Hanson, Lansing, MI, US
Brett Pike, Boise, ID, US
kathleen port, Pacific Palisades, CA, CA, US
Pamela Amon, Crossville, TN, US
Chris Ashthon, La Mesa, CA, US
holly perez, chula Vista, CA, US
Jack Modena, Meriden, CT, US
Steven Aripotch, New York, NY,
Scott Tucker, Raleigh, NC, US
Maria Scherer, Culver City, CA, US
John Marchese, Henderson, NV, US
Robert Lindsey, Hernando, FL, US
Jack Modena, Meriden, CT, US
Lydia Garvey, Clinton, OK, US
Carolyn Straub, San Jose, CA, US
Scott Tucker, Raleigh, NC, US
Kenny Lerner, Geneseo, NY, US
Helen Goldenberg, Tamarac, FL, US
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Alana Silvani, Los Angeles, CA, US
David Melvin, Chester, NJ, US
Chris Triplett, Rochester, PA, US
Richard Leibold, Golden Valley, AZ, US
Stephen Faes, Kalaheo, HI, US
Christine Keeley, Bloomfield, NJ, US
Suzanne Griscom, Shoreline, WA, US
Doris Roth, Victorville, CA, US
Kinney Evitt, Odessa, TX, US
Julie Bannister, Tempe, AZ, US
Shane McDermott, Flagstaff, AZ, US
Helen Forsythe, Cornwall, PA, GB
Gregg Oelker, Altadena, CA, US
Kaaren Zvonik, Tamuning, GU, US
Jackie Willis, Locust Grove, VA, US
Peter Luitjens, Lakeside, CA, US
Peter Newton, Phoenix, AZ, US
Randy Thomas, Richardson, TX, US
Rick Avant, San Antonio, TX, US
Eric Probola, East Pittsburgh, PA, US
Wendy Krupnick, Santa Rosa, CA, US
Lisa Smith, 29 Palms, CA, US
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George Horton, Oakland, CA, US
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Kenneth Hardy, South Pasadena, CA, US
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Sherry Gerszberg, Kendall Park, NJ, US
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Philip Moore, Belvidere, IL, US
Roseann Foley, Crown Point, IN, US
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Howard Lasater, Lynnwood, WA, US
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Joan Zawaski, Oakland, CA, US
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Teresa Smith, Columbus, OH, US
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Larry Dennis, Union City, CA, US
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Jonathan Evans, SANTA MONICA, CA, US
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Chris Moyer, Urbana, IL, US
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Thomas Allison, Ocala, FL, US
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Evelyn Brakopp, Kailua, HI, US
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Julie Ostoich, Sacramento, CA, US
Suzanne Cook, Phoenix, AZ, US
Jennifer Lance, Hyampom, CA, US
Bonnie MacRaith, Arcata, CA, US
Roz goldstein, greenbrae, CA, US
Helen Baker, Modesto, CA, US
Kathleen Eaton, Middletown, DE, US
Laura Cooper, Coral Springs, FL, US
Barbara Tucker, West Palm Beach, FL, US
Paul Mack, Crested Butte, CO, US
Barbara Hoffmann, Urbana, IL, US
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Rachel Baker, Chicago, IL, US
Candice Davis, el cajon, CA, US
Robert Lappo, Tujunga, CA, US
Michael Checa, Carpinteria, CA, US
Trista Golike, San Diego, CA, US
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Jeff Weinberger, Plantation, FL, US
Sacha Sullivan, Miami, FL, US
Aegina Barnes, Forest Hills, NY, US
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Pamela Unger, Columbus, OH, US
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Sarah Johnson, Nyack, NY, US
Gail Conway, Bothell, WA, US
Brent Salisbury, Edinboro, PA, US
Gail Conway, Bothell, WA, US
Carol Kuelper, Oakland, CA, US
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Keith Mullins, Johnson City, TN, US
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Lorraine Profeta, Margate, FL, US
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Michael Krikorian, Santa Rosa, CA, US
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Geneva Hollyer, prescott, AZ,
Kimberly Rowlett, Cleveland, TN, US
Greg Jalbert, Berkeley, CA, US
Denise Corcoran, Fremont, CA, US
Magali Lequient, salt lake, UT, US
Sean Slattery, Chicago, IL, US
John Gehr, Holland, MI, US
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Jerry Pullam, Florissant, MO, US
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Mark Schneider, Garden Grove, CA, US
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Diane Brannan, Albuquerque, NM, US
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Adrian Hunter, Albuquerque, NM, US
Bill Little, Denver, CO, US
Brittany Beatty, new york, NY, US
Daniel Cobb, Sacramento, CA, US
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Michael Roberts, Knoxville, TN, US
Phil Huss, franklin, TN, US
Thomas Herzog, South Salem, NY, US
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Melodie Huffman, Danville, IL, US
Dianne Jarreau, Lancaster, PA, US
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Fred Fabry, Woodland Park, CO, US
Chuck Wieland, San Ramon, CA, US
S. Farrand, Carmichael, CA, US
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Brent Larsen, La Jolla, CA, US
Megan Boynton, Bakersfield, CA, US
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Donna Mitchell, NYC, NY, US
Paul Feschuk, Chicago, IL, US
Marjorie Ann Ottenberg, Saratoga, CA, US
Margery Coffey, Rosalie, NE, US
Ester Locorotondo, Ceglie Messapica, IT
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Paul Strauss, Chicago, IL, US
Tim Baures, Onalaska, WI, US
Matthew Bennett, Port Washington, NY, US
Lyle Henry, Los Angeles, CA, US
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Corlyn Seifer, Littleton, CO, US
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Jill Canoyer, Eastlake, OH, US
Craig Wright, Cedar Rapids, IA, US
Wendy Hernandez, Rockport, WA, US
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Craig Geiger, olympia, WA, US
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Ransom Stone, El Paso, TX, US
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Susan Kreml, Sequim, WA, US
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Robert Boltje, Santa Cruz, CA, US
Claudia Bloom, Mesa, AZ, US
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JoAnne Cohen, San Diego, CA, US
Fawna Brown, Napa, CA, US
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Sandy Stuhaan, Pueblo, CO, US

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Sandra Reese, Springfield, MO, US
Brian Jones, Tucson, AZ, US
Lynn Peters, Slidell, LA, US
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Marcia Keller, San Diego, CA, US
Kris Harker, Lancaster, PA, US
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Heidi Burns, Black Hawk, SD,
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Saul Markowitz, Burbank, CA, US
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John Gregory, Dripping Springs, TX, US
Linda Stevens, Hemet, CA, US
Mary Scott, Brooklyn, NY, US
David Richard, Seattle, WA, US
Wayland Augur, Chico, CA, US
Kelly Ryan, Bronx, NY, US
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Sandy Kucinski, Toledo, OH, US
Susan Bullock, Nanaimo, BC, CA
Sherry Marsh, Oceanside, CA, US
Debra Desjardins, Altamonte Springs, FL, US
Lawrence Thompson, Livermore, CA, US
John Keiser, New York, NY, US
Vasu Murti, Oakland, CA, US
Janice Smith, Kingsville, TX, US
Ron Goldman, Los Altos, CA, US
TM Akashi, Fountain Valley, CA, US
jorie polainer, mesa, AZ, US
ronald keezer, Eau Claire, WI, US
Sonnie Grossman, Bend, OR, US
Pamela Albert, Forest Hills, NY, US
Deborah Smith, Westbury, NY, US
Phil Everingham, Coral Gables, FL, US
Claudia McEntee, Chestnut Hill, MA, US
Machelle Smith, Mesquite, TX, US
Roslyn Simon, Portland, OR, US
Enixy Collado, Stony Brook, NY, US
suzan woodruff, santa monica, CA, US
Candi Teachout, Kentwood, MI, US
Cynthia Wennemark, Tullahoma, TN, US
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Zoe Austermann, Denver, CO, US
Gordon Wing, Richmond, CA, US
John Cloonan, Ventura, CA, US

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Karen Palmer, New York, NY, US
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Jim Dupuis, West Lebanon, NH, US
Brett Pfeifer, Kansas City, MO, US
Betty Nudelman, El Cerrito, CA, US
Dave Rock, Los Angeles, CA, US
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Richard Phillips, Neenah, WI, US
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Floyd Hiar, savage, MN, US
Rhea Forester, Seguin, TX, US
Lisa McCown, Alta Loma, CA, US
pamela murphy, ojai, CA, US
Cecilia Brown, Oakland, CA, US
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Martyn Roberts, Wakefield, ot, GB
Mark Elvin, Ventura, CA, US
Celeste Hong, Los Angeles, CA, US
Kim Johnson, Maricopa, AZ, US
Steve Goldstein, Oregon City, OR, US
Nancy Caton, Oakland, CA, US
Kim Johnson, Maricopa, AZ, US
Arjang Hourtash, Santa Clara, CA, US
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Janet Apuzzo, clintondale, NY, US
Edward Hess, Phoenix, AZ, US
Rose Lernberg, El Cerrito, CA, US
Gerard Russo, Norwalk, CT, US
Wm. A./Janet M. Corkran, Walnut Creek, CA, US
Ross Kelson, Miami Beach, FL, US
Phoenix Vie, Berkeley, CA, US
Ross Kelson, Miami Beach, FL, US
Morgan Margraf, Medford, NY, US
Steven Weigner, Seattle, WA, US
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Frances Raskin, Anchorage, AK, US
Charlotte Price, Brooklyn, NY, US
Steven Weigner, Seattle, WA, US
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Bridgette Garcia, San Diego, CA, US
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David Wilson, Myrtle Point, OR, US
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Tamara Treuhardt, Georgetown, TX, US
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Melinda Fink, North Hills, CA, US
Tom Doar, Jamul, CA, US
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Edward Hodgman, Vernon Hills, IL, US
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Sam Youngs, Chelmsford, ot, GB
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Rich Smith, Los Angeles, CA, US
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Louise Simon, Springfield, MO, US
Deborah Acs, Black Mountain, NC, US
Gabriella Smith, Lawrence, KS, US
Tom Ragle, Guilford, VT, US
Louise Simon, Springfield, MO, US
Ronald D. McVeigh, Olathe, KS, US
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Kim Palmer, Charlotte, NC,
Jeremy Watson, washington, NC, US
Jane Gwinn-Sigler, Smithville, OH, US
Albin Warth, Cockeysville, MD, US
Rachel Ziesk, New Haven, CT, US
Marian Reiff, Haddonfield, NJ, US
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Faith Voigt, Friedeburg, ot, DE
Susan Kalan, Orange, VA, US
Ben Burrell, Toano, VA, US
Doug Payne, Bloomingdale, NY, US
Patricia McClanahan, Montgomery, AL, US
Raffael Trimmel, Klostermarienberg, ot, AT
Stefanie Trimmel, Klostermarienberg, ot,
Stan Samuels, Decatur, GA, US
Susanne Trimmel, Klostermarienberg, ot,
Steve McCormick, Boulder, CO, US
louise friedenson, des plaines, IL, US
Jan Davidson, Iron Mountain, MI, US
Christopher Blanchard, Decatur, GA, US
Martha Emeson, Nashville, TN, US
meagan frame, beltsville, MD, US
Judith Staublin, Norcross, GA, US
Jordanne Godwin, Pfafftown, NC, US
Sara Espowood, Brookline, MA, US
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Jane Altman, New York, NY, US
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craig mankowski, naperville, IL, US
Suzanne Valencia, West Melbourne, FL, US
Nancy Newbury, Burlington, WI, US
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Karen Miller, Seal Beach, CA, US
Rayna Caldwell, saratoga Springs, NY, US
Pamela Alcid, Troy, NY, US
Luiz Lopes, Bloomington, IN, US
Klazina Crawford, santa barbara, CA, US
Sara Zahendra, West Lebanon, NH, US
John Pinezich, Longmont, CO, US
ross levin, Brooklyn, NY,
Stacia Burton, Buford, GA, US
William Protheroe, Port Charlotte, FL, US
Harold Robinson, Talladega, AL, US
Michael Malone, Ronkonkoma, NY, US
Liz Powell, Flitwick, ot, GB
Lindsey Waddell, Hendersonville, TN, US
sarah selph, ASTON, PA, US
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James Spagnolo, Syosset, NY, US
Shelly Simmons, Newton Centre, MA, US
Marilyn Gaydos, Georgetown, KY, US
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Carol Hoch, FAYETTEVILLE, TN, US
Barrie Collins, Bethany, CT, US
James Beeby, Finlayson, MN, US
John Carlton, Concord, MA, US
vitold kobisz, mt. pleasant, MI, US
Vivian Valtri, Granville, VT, US
Diane Ellis, Grandview, MO, US
Lannie Webb, Lancaster, CA, US
Jim Hunt, Brighton, MA, US
Lisa Burkstaller, Albuquerque, NM, US
Martha Brown, Wilmington, NC, US
Jean Linos, Rome, GA, US
dwight fellman, st. louis park, MN, US
Eugene Pumphrey, Hamburg, NJ, US
Stephen Plummer, Thomasville, NC, US
Ashlee Charters, Frankfort, MI, US
Sherrie Ehrlich, Penllyn, PA, US
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Raymond Baker, Norfolk, VA, US
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Diane W. Young, San Marcos, TX, US
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Tracey Goral, Danbury, CT, US
Laure Hillman, Mt. Dora, FL, US
Avra Leigh, Harrisonburg, VA, US
Cynthia Zembryki, Shinglehouse, PA, US
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Ron Silver, Atlantic Beach, FL, US
Fran Andersen, Eaton Rapids, MI, US
bill gilchrist, cave creek, AZ, US
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Crystal Jagger, Thunder Bay, ON, CA
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Mark Knight, Arlington, VA, US
Leslie Glendye, Somerset, MA, US
Melinda Rankins, Clive, IA, US
Paul Szymanowski, Curtice, OH, US
Raymond Baker, Norfolk, VA, US
Leslie Coon, Charlestown, RI, US
Mitchell Tingiris, Brewerton, NY, US
Larry Dale, Rapid City, SD, US
jOANT Turner, Winter Haven, FL, US
Casey Cross, Rancho Mirage, CA, US
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Stephanie Weisser, Westerville, OH, US
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Earl Towery, Newark, DE, US
John Littleton, Medford, OR, US
Allen Sylvester, Plymouth, MA, US
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Anne Kominowski, Martinsville, IN, US
James Baney, Exton, PA, US
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Meredith Boyd, Greenville, SC, US
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Eric Hoyer, Lees Summit, MO, US
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Eva Thielk, Glendale, CA, US
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Sara Ewen, Eagle, ID, US
Thanice Petrak, S. Newfane, VT, US
Lee Bailey, Brooktondale, NY, US
Ray Iasiello, Brookline, MA, US
Marla Broom, Milton, FL, US
Dana Doyle, Shrub Oak, NY, US
Joan Harlowe, East Burke, VT, US
Sandra Nunes, Gloucester, MA, US
Jim Harrison, Evanston, IL, US
Roger Horn, Clarion, PA, US
Judith Ford, Hollywood, FL, US
Helen McGinnis, Harman, WV, US
Jon Zurit, Fairfield, VT, US
Jim Hill, New York, NY, US
Jon Zurit, Fairfield, VT, US
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Lois Vanderkooi, Broomfield, CO, US
Kelly DeNicolo, ASTORIA, NY, US
Kathleen Clemmons, Fairfield, IA, US
Thayer Heath, Altamont, NY, US
Shari Iacone, Oyster Bay Cove, NY, US
Joe Loree, Berkeley, CA, US
Nick Cohen, Rochester, NY, US
Randall Brady, Driftwood, TX, US
George Bromley Jr., Tucson, AZ, US
Wanda Winters, Clayton, NY, US
krissa lee-regier, Omaha, NE, US
Paul Stansel, Clarksville, TN, US
Nancy Corley, Parker, TX, US
Edith Davis, Brooklyn, NY, US
Karin Ralph, Greenlawn, NY, US
David Cosby, Orienntal, NC, US
Sheila Erwin, West Linn, OR, US
Roger Auringer, Aguadilla, PR, PR
G Greene, Jacksonville, FL, US
Leslie Bemis, Westboro, MA, US
Jamie Tomek, Bowling Green, MO, US
Mel Dickerson, Tecumseh, MI, US
Susan Hawker, Baie d'Urfé, QC, CA
Edwin J. Martz, Greenville, SC, US
Ken Stern, Fair Lawn, NJ, US
Martha Carson, Andover, NH, US
Erin Yang, Louisville, KY, US
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Kristi Wellenberger, Epping, NH, US
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Jessica Engel, Tinley Park, IL, US
Donna Schwartz, Newburgh, NY, US

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Timothy Bain, Washington, DC, US
E. Duvert, Bergheim, TX, US
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Scott Myers, Powder Springs, GA, US
Carol Thompson, South Park, PA, US
Dianne Sheaffer, South Plainfield, NJ, US
William Schermerhorn, Black Mountain, NC, US
Donna Darnell, Ridgefield, CT, US
Erna Beerheide, Ormond Beach, FL, US
Maggie Hawk, Vernon,, AZ, US
April Wilk, Orlando, FL, US
April Wilk, Orlando, FL, US
David Wilcox, Glen Ellyn, IL, US
Dawn Golden, Cincinnati, OH, US
Igot Katrach, Brooklyn, NY, NY, US
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Kelly Arellanes, Bryant, AR, US
Kathy Ryan, Indianapolis, IN, US
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Lauren Devine, Boca Raton, FL, US
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Michelle Roper, Auckland, ot, NZ
Lisa Cleary, Schwenksville, PA, US
Ella Heister, Irving, TX, US
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Mary Shea, Falls Church, VA, US
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Richard Foster, Winter Springs, FL, US
Marc Weber, New City, NY,
Darren Strain, Brookhaven, PA, US
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Vicki Goulding, Quakers Hill, ot, AU
Sandra Starr, Georgetown, MA, US
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Vivian Ng, Brooklyn, NY, US
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Mary Fischer, Gainesville, FL, US
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Karen Bryant, Wilmington, NC, US
Judith Swain, Swansea, ot, GB
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Joyce Burk, Barstow, CA, US
f belsky, pawtucket, RI, US
Julie Beard, Manitou Springs, CO, US
Mark Hodie, Munster, IN, US
Ana Cruz, Valley Stream, NY, US
Barbarak\ Kates, Alexandria, VA, US

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Vernon Batty, La Luz, NM, US
Jean Forward, Wendell, MA, US
Alicia Ray, Jonesville, NC, US
Suzanne Barns, Batesburg, SC, US
Elizabeth Brensinger, New Tripoli, PA, US
Sharyn Park, Canby, OR, US
linda Weaver, Henderson, NC, US
linda Weaver, Henderson, NC, US
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Dennis Ledden, Rancho Murieta, CA, US
Linda Hamilton, Old Lyme, CT, US
Diana Gillis, Queensbury, NY, US
AnnMarie Wilson, Garland, TX, US
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Pilar Fernandez, Lima 03, ot, PE
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Janet Whittington, Nazareth, PA, US
sheldon sagan, riverwoods, IL, US
Melissa Ruel, Manheim, PA, US
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Mary Jill Bays`, Pinon Hills, CA, US
Stephanie Commyn, Walled Lake, MI, US
Fred Cato, Melbourne, FL, US
Adolfo Miralles, Claremont, CA, US
Cindee Zobac, Cedar Rapids, IA, US
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Carole A Adams, Jacksonville, FL, US
Dave Fallow, Madison, WI, US
Courtney Ragel, tucson, AZ, US
Susan Collins, Boynton Beach, FL, US
Edward Talmo, Highland Lakes, NJ, US
Rebecca Hengsteler, Tucson, AZ, US
Roy Dauzat, Bella Vista, AR, US
Bonnie Shrader, Washington, PA, US
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judy orchard, Winston Salem, NC, US
Jerome Decker, Gold Canyon, AZ, US
Robert Parkinson, Fort lauderdale, FL, US
Jack & Pat Crowther, Bishop, CA, US
Robert Webster, Oxford, MA, US
Joel and Mary Bonham, Pine Grove, PA, US
james j high, pepperell, MA, US
Joel and Mary Bonham, Pine Grove, PA, US
Steve Henry, Basking Ridge, NJ, US
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Alfred S Fuller, Santa Fe, NM, US
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Julie Maisel, Atlanta, GA, US
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Harold Smith, Indianapolis, IN, US
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Nicole Louie, Chicago, IL, US
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Linda Matychak, Huntington, NY, US
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Rene Dennis, Leesburg, VA, US
Charmaine Crismon, Freedom, CA, US
Mark Hodie, Munster, IN, US
Gloria Korhonen, Port Huron, MI, US
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Diane Jalbert, atlanta, GA, US
Catherine Lowrey, Fresno, CA, US
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Kim Brack, Evansville, IN, US
Nancy Green, madison, WI, US
Sheila Kloss, Idyllwild, CA, US
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J Mueller, Aspen, CO, US
Robbie Zuuring, seattle, WA, US
Patricia Jacobs, Perrysburg, OH, US
Denise Kobylarz, Pequannock, NJ, US
Jay Karliner, Vernon, CT, US
Tom Tamplin, Wallington, ot, GB
robert stockstill, indio, CA, US
Diane Skeel, Austin, TX, US
Sandra Walker, RSM, CA, US
Joan Adams, Park Forest, IL, US
matthew rubino, raleigh, NC, US
Karen Wachs, Covington, KY, US
Benjamin Zank, Boston, MA, US
J Spotswood Bowyer, Charlottesville, VA, US
Christine Kennedy, Brooklyn, NY, US
Eleanor Wootten, Gila, NM, US
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Rodney Derbigny, Sugar Land, TX, US
Bettye Whipp, Bridge City, TX, US
Indra Patel, Cary, NC, US
Diane Ohanian, SAN DIEGO, CA, US
Everett Shattuck, Mill Creek, IN, US
Donna Selquist, Port Saint Lucie, FL, US
Indra Patel, Cary, NC, US
Cindy Sprecher, Hereford, AZ, US
Sheila Ward, San Juan, PR, US
Christi Brockway, Fort Collins, CO, US
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David Massie, Austin, TX, US
Sharone Ketterman, Eatonville, WA, US
Kimberly Tilley, Mountain Home, ID, US
Michael Sweeney, PHILADELPHIA, PA, US
David Strunk, Phoenixville, PA, US
Michael Sweeney, PHILADELPHIA, PA, US
Bjoern Mannsfeld, Denver, CO, US
Daniel Romeo, Huntington, MA, US
Alexander Cameron, Sarasota, FL, US
Lark Paulson, Madison, WI, US
Brad Hanscom, Florence, OR, US
Robert Smith, CA, US
Phyllis Mollen, New York, NY, US
Steven Stiller, Norridgewock, ME, US
Brian Sumner, Sugar Land, TX, US
barbara horn, new york, NY, US
Chet Resko, wichita, KS, US
Chad Fordham, Big Rapids, MI, US
Amy Garcia, St. Paul, MN, US
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Jason Agnew, Sebastopol, CA, US
Marcy Reid-Smith, Greensboro, NC, US
Cassandra Browning, Salem, OR, US
Jessica Bouboulis, Chicago, IL, US
Bettemae Johnson, Albuquerque, NM, US
Charlotte Sonoda, BERKELEY, CA, BR

Dr. James Hanson, Winter Park, GA, US
Robert Rogan, Detroit, MI, US
S Ginsburg, Pittsburgh, PA, US
Mary Van de Ven, Des Moines, WA, US
Kate Krimsky, salisbury mills, NY, US
Darin Lee, Street, ot, GB
Mike eddy, seattle, WA, US
Bob Parvin, Fancy Gap, VA, US
lisa lipschutz, bala cynwyd, PA, US
Meg Simonds, bolinas, CA, US
kelly barker, Mauston, WI, US
Carla Pickett, Frederick, MD, US
Beverly Welber, Marathon, FL, US
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Laurita Summerton, Morrison, CO,
Donnamari Scippa, Mil;l Valley, CA, US
bob harper, indianapolis, IN, US
sally carmany, melbourne, FL, US
Nancy Hurte, Junction, TX, US
Lenore Swaim, Colorado Springs, CO, US
Timothy Farrell, Ventura, CA, US
Lacey Brown, West Lawn, PA, US
JoAn Saltzen, Yreka, CA, US
Michael Dowd, Santa Ana, CA, US
Ed Pleskovitch, Rock Falls, IL, US
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mary Durando, St. Paul, MN, US
Karen Luther, Santa Fe, NM, US
James Angelo, Orlando, FL, US
Leanne mathis, Jacksonville, Fl, FL, US
Lisa Geer, Albany, WI, US
Jeannine Mendrola, Broomall, PA, US
Colleen Freeman, Richmond, VA, US
Cathie Barrows, Orinda, CA, US
Janice Wright, Des Moines, IA, US
Linda Schrag, Estes Park, CO, US
Peter Thompson, Syracuse, NY, US
Raja Mitry, Burlingame, CA, US
Ann Roylance, Santa Fe, NM, US
Susan Seitz, Tyler, TX, US
Thomas Brinkman, Rochester, MN, US
Daniel Barber, Asheville, NC, US
Dennis Feichtinger, Trenton, MI, US
Timothy Redman, Neversink, NY, US
Lisa Vana, Vernon, TX, US
Jack Desabla, Chattanooga, TN, US
Caroline Dowell, Austin, TX, US
healy patt, santa monica, CA, US
Rachel Strivelli, Waynesville, NC, US
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Roberta Richardson, Melbourne, FL, US
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Audrey Fee, Shelton, CT, US
Cleo Collins, Flemingsburg, KY, US
Caitilin Rabbitt, Liberty, NY, US
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KEVIN BOLEMBACH, CLIFTON, NJ, US
Aloysius Wald, Columbus, OH, US
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Brian Kapler, Cherry Valley, IL, US
Denise Diaz, Berkeley, CA, US
Alice Strickland, Los Angeles, CA, US
Bonnie Dawson, Hay River, NT, CA
Marsha Foutz, Clarkdale, AZ, US
Corinne Van Houten, San Rafael, CA, US
Kevin Bourke, Chicago, IL, US
Tom Linell, Hanover, NH, US
Jan Mitchell, Hendersonville, TN, US
Terri Gallion, Onyx, CA, US
Norman Patten, sierra vista, AZ, US
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Leanne Dodd-Mathis, Jacksonville, FL, US
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Karen Martin, Vernon, NJ, US
Melissa Myers, Logan, OH, US
Carolyn Foran, Cumberland, VA, US
Howard Urbach, Petersburg, VA, US
Anita Bryant, Young Harris, GA, US
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Janet White, Flagstaff, AZ,
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Juli Langelund, Bartlett, IL, US
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Alice Green, Wheat Ridge, CO, US
Lynn Harman, Plainfield, IL, US
Wayne Wilkinson, St Louis, MO, US
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Bonnie Morgan, Lahaina, HI, US
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Audrey Fee, Shelton, CT, US
Gerald Leitzell, Elizabethtown, KY, US
Laura Zuckerman, Oakland, CA, US
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Christine Campbell, Los Angeles, CA, US
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Kathy Hanlon, Urbandale, IA, US
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Devon Carson, Pasadena, CA, US
Jennifer Wolfsong, Beaverton, OR, US
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Kevin McVan, Clearwater, FL, US
Cynthia Carlson, New York, NY, US
Deanne Benjamin, Danville, CA, US
Gwynne Heard, Susanville, CA, US
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Catherine Dishion, Santa Barbara, CA, US
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Megan Horton, Toledo, OH, US
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Kim Ostrenko, Hollywood, FL, US
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Susan Tanner, Mesa, AZ, US
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Alice Weis, St. Louis, MO, US
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Stuart Skadden, Hurley, NM, US
Kurt Olsen, Prescott, AZ, US
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Justin Overdevest, Newport, OR, US
John Hayes, Horseshoe Bend, AR, US
Judith Swink, San Diego, CA, US
Ronald Rogalski, Junction City, KS, US
Carol Hendler, Silver Spring, MD, US
Leona Klerer, stamford, CT, US

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John Fredrickson, Littleton, CO, US
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Kenneth Salins, Jefferson, MA, US
John Fredrickson, Littleton, CO, US
Douglas Hill, Roswell, GA, US
James Stephenson, Cedarcreek, MO, US
Caitlin Campbell, Groton, MA, US
Vinny Mullins, Palm Beach Gardens, FL, US
Nell Green Nylen, New Haven, CT, US
Ruth Snedic, West Alis, WI, US
Bob Macaux, EastGreenwich, RI, US
Sister Mary Fran Gebhard, EAU CLAIRE,, WI, US
David Volckhausen, Mahopac, NY, US
Jeanne Phillips, Milwaukee, WI, US
Stephen Weitz, Oakland, CA, US
Abigail Jewkes, Forest Hils, NY, US
Sarah Apfel, New York, NY, US
Janice Mastin-Kamps, Medina, OH, US
Manfred Wenner, Prescott, AZ, US
Vanessa Boland, Malibu, CA, US
Robin Raida, Culver City, CA, US
David Chervek, St. Louis, MO, US
Harley Winfrey, Boone, IA, US
Jonathan Eger, New York, NY, US
bill kretz, kearney, NE,
jesse koechling, brooklyn, NY,
R. J. Williams, Hollywood, FL, US
Victoria Beerman, Brooklyn, NY, US
Don Lichtenberg, Bloomington, IN, US
teresa hatry, knoxville, TN, US
William Stone, Carrboro, NC, US
shirley whalen, blairsden, CA, US
Eleanor McCabe, Oak Ridge, TN, US
Saundra Whitten, Cave Junction, OR, US
Brendon Thomas, chester, VT, US
Bobbi Seymour-Linder, Bellevue, OH, US
Susan Jacoby, Canton, OH, US
Julie Sperling, los angeles, CA, US
Debbie Dominguez, Malden, MA, US
Paul Woolery, Hood River, OR, US
weyman lundquist, hanover, NH, US
Wanda Stephens, Fayetteville, AR, US
joni moretti, whitehouse, NJ,
Jignasha Rana, Washington DC, MA, US
Leonard Meyer, Batavia, IL, US
Diane Hert, Canton, OH, US
Jennifer Shepard, Glen Allen, VA, US
Paul Schneller, Bloomington, IN, US
Rev. Nano Nathan, Snowflake, AZ, US
Thomas Windberg, Spicewood, TX, US
Susan Yatsky, Pottstown, PA, US
Matt Rainson, San Jose, CA, US
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Robert Clark, levittown, PA, US
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helen neely, brooklyn, NY, US
D. M. McLaughlin, San Diego, CA, US
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Michelle Rekstad, Bowie, MD, US
Frederick Reif, Pittsburgh, PA, US
Carol Boone, Asheville, NC, US
Audrey Fee, Shelton, CT, US
David kuntz, Telluride, CO, US
Nicole Mettler, Afton, MN, US
James Xavier, Cary, NC, US
Lisa Feurzeig, Grand Rapids, MI, US
kristi lynn grunow, milwaukee, WI, US
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Obiora Embry, Lexington, KY, US
Joan Scurran, Tucson, AZ, US
Cary Ryerson, Holly, MI, US
Wendy Babbe, Elk, CA, US
Fred & Sara Krauthamer, Monterey Park, CA, US
Sandra York, Stanford, KY, US
Korinne Taylor, Florence, OR, US
Georgia Mattingly, Longmont, CO, US
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steve archambault, ft collins, CO, US
Dean Webb, Seattle, WA, US
Marya Zanders, Centerville, IA, US
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Janice Foss, El Cerrito, CA, US
Pat Frankenfield, Palo Alto, CA, US
Doug Keran, Brainerd, MN, US
Jayna Monroe, Dallas, TX, US
kimg groom, orting, WA, US
Cindee Barrett, Monroe, ME, US
jake burch, atlanta, GA, US
Aviva Rossi, San Anselmo, CA, US
Donald Lederle, Boulder, CO, US
Mieko Aoki, Eugene, OR,
Peggy Howard, Lexington, KY, US
Jeffrey Keller, Palo Alto, CA, US
Ruth Silverman, StoneRidge, NY, US
Doug Beran, Pleasant Dale, NE, US
Blaise Brockman, Santa Clarita, CA, US
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Roxanne Funes, Austin, TX, US
Nina Marrocco, Deltona, FL, US
Sue Petteway, Santa Monica, CA, US
Brandi Dringus, penndel, PA, US
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David Farmer, Las Cruces, NM, US
Elizabeth Rogero, Coral Gables, FL, US
Elaine Howes, Land O' Lakes, FL, US
Sally Woodard, Lewisburg, WV, US
Scott Byrne, Dover, NJ, US
Holly Poindexter, Brooklyn, NY, US
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Michael Norden, Defiance, OH, US
Andrew Bezella, SAN FRANCISCO, CA, US
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Cynthia Plockelman, West Palm Beach, FL, US
Kathie Lambert, Colorado Springs, CO, US
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J Noble, Madison, WI, US
Kathleen Lee, Woodbury, MN, US
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Monte Greene, Hollywood, FL, US
JR Summers, Richmond, VA, US
logan welde, New York, NY, US
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kay Yeuell, maitland, FL, US
William White, Prescott Valley, AZ, US
Anne Winters, Clarksville, TN, US
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Gideon Banner, New York, NY, US
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simone leiss, lloret de mar, ot, ES
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Lois Swanson, South St. Paul, MN, US
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Loyd Cortez, San Antonio, TX, US
Hannah Feig, W. Melbourne, FL, US
Nancy Phillips, Philomath, OR, US
Matt Adams, Chicago, IL, US
Cheryl Strimple, Fort Worth, TX, US
Armen Carapetian, San Francisco, CA, US
Patricia Brooks, Houston, TX, US
Lynn Minneman, Portland, OR, US
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Toni Jaros, Mesa, AZ, US
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George Buerer, Oakdale, CA, US
Mike Anderson, Lynwood, IL, US
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Gertrude Miller, AUSTIN, TX, US
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Lisa Tart, Homosassa, FL, US
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Robert Seidel, Minneapolis, MN, US
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Michael Kobert, San Diego, CA, US
Carol Carson, Brooklyn, NY, US
Michelle Murphy, Effort, PA, US
George Michaux, Vero Beach, FL, US
Barb Ryman, Minneapolis, MN, US
LaRoy and Mary S eaver, Lincoln, NE, US
Linda Mckenzie, Jupiter, FL, US
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Shalom Fisher, Greenbelt, MD, US
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Sharlene White, Santa Fe, NM, US
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Mike Hansen, Deerfield, IL, US
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Linda Mckenzie, Jupiter, FL, US
Charlene Boydston, Pahrump, NV, US
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Estelle Gibson, Martinez, GA, US
Beth Richman, Crestone, CO, US
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Allegra Mitchell, Upper Montclair, NJ, US
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Lisa Pool, Edgewood, TX, US
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Connie Raper, Durham, NC, US
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Warren Roark, Toledo, OH, US
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James Wilcox, Falls Church, VA, US
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Erin Rauch, St. Louis, MO, US
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Helen Smylie, Margate, FL, US
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J. Harmon, Pottsboro, TX, US
mike sackman Family, savage, MN, US
Peter Lee, San Francisco, CA, US
Becki Wright, Newmarket, NH, US
Karl Hunting, South River, NJ, US
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Gisel Rodriguez, Rio Piedras, PR, PR
david h jones, seattle, WA, US
Mr. Dana Duncan, Hazard, KY, US
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Joyce Janicki, St. Clair Shores, MI, US
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Curt Schmidt, Bound Brook, NJ, US
Diana Cumming, Minneapolis, MN, US
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Gary Fry, Stowe, PA, US
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Katherine Laise, Spokane, WA, US
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m bare, machine. this is all empty, WA, UM
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Gail Koza, San Francisco, CA, US
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Effie K, Tenafly, NJ, US
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Peter Nicholas, Syracuse, NY, US
Michael Foster, KEARNEYSVILLE, WV, US
Heather Laing-Obstbaum, Los Angeles, CA, US
Laurel Dorr, Atlanta, GA, US
Micah West, Naples, FL, US
Michael van Atta, Van Nuys, CA, US
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Patricia Wycoff, St. Charles, MO, US
Michelle Shearer, Concrete, WA, US
William Weston, San Antonio, TX, US
charles bralley, catawba, NC, US
Maria Curran, NC, US
Dana Thornley, New York, NY, US

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Andrew Stephens, Pasadena, CA, US
Theresa Wengel, Concord, NC, US
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Doris Rodriguez, Ontario, CA, US
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Jim Pizzirusso, Cary, IL, US
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Nancy Bissett, Davenport, FL, US
Rick Hammel, Craig, CO, US
Dave Robinson, CURLEW, WA, US
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Ralph Novy, Hillsboro, WI, US
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Marilyn Smith, Lawrence, KS, US
Barbara Blackman, Mesa, AZ, US
Tiffany Gonsalves, Bronx, NY, US
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Susan Roy, Flint, MI, US
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Roman LoBianco, Danville, CA, US
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Peter Wash, Columbia, MD, US
Caroline Barrow, Yukon, OK, US
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leslie marlowe, San Jose, CA, US
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Barbara Walrafen, Prescott, AZ, US
Susan Gardner, Independence, MO, US
Ginny Schneider, Osprey, FL, US
Debra Croghan, Longmont, CO, US
Estefania Aparicio, Puebla, NY, MX
Cristi Lewis, Julian, CA, US
Pat Carter, Santa Cruz, CA, US
Bill Gettys, Clovis, CA, US
Barbara van Davis, Aurora, IL, US
Don Thomsen, Spokane, WA, US
James Ewing, WATER MILL,, NY, US
Stephanie Marsh, Austin, TX, US
Eric Brooker, Delaware, OH, US
Rosemary Hufker, St Louis, MO, US
Jean Woodman, Evanston, IL, US
Anne Montagna, Los Gatos, CA, US
debbie newbold, n canton, OH, US
steve oakes, Kansas City, KS, US
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Robyn Johnson, Westminster, CO, US
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Lois Shadix, Cincinnati, OH, US
Carolyn Vaughn, Ebensburg, PA, US

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Robert Sullivan, Argonne, IL, US
Beth Mantiply, Warrenton, VA, US
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Wendell Stevens, Spring Hill, FL, US
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Judith Snider, Tucson, AZ, US
Paul Luehrmann, Santa Fe, NM, US
Deborah Pendrey, Oak View, CA, US
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Albert Chou Albert Chou, Clayton, CA, US
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Heidi Hoffmann, Walkersville, MD, US
Brent Finley, Tucson, AZ, US
Walter Schwarz, Brattleboro, VT, US
Aaron Ucko, Washington, DC, US
Sharon Russick, Boca Raton, FL, US
Paula Johnson, Racine, WI, US
Helga Freund & Jack Morgenstern, Cornville, AZ, US
Jan Ravenwolf, Sandia Park, NM, US
Linton L. smith, Canyon lake, TX, US
Lorne Beatty, Brighton, MI, US
Steven Tracy, Gastonia, NC, US
Rachel Sim, Comox, BC, CA
Victor Flake, San Diego, CA, US
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John Higgs, Conifer, CO, US
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Cathy Brunick, Charlotte, NC, US
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Diane Marschke, Fort Collins, CO, US
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Carolyn Hawk, NEW FRANKEN, WI, US
Claude McDonald, san jose, CA, US
Laura Baker, Stephens City, VA, US
cilien hanna, garnerville, NY, US
tom hock, Sun Prairie, WI, US
Mary Cober, Glendale, AZ, US
owen woods, alamosa, CO, US
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Susan Whipple, Madison, OH, US
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Helen Hanna, Sacramento, CA, US
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Julie Neidich, Ladera Ranch, CA, US
Mary Sander, Wildwood, MO, US
steven lucas, austin, TX, US
joel kingery, Miamisburg, OH, US
Jessica de Ruiter, Los Angeles, CA, US
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Susan Schilling, Glen Cove, NY, US
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KRISTIN walsh, Chester, NY, US
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Adam Whiteman, Savannah, GA, US
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Stan Stokowski, sag Harbor, NY, US
Andrew Walker, Huntington Station, NY, US
Dave Kraig, Pojoaque, NM, US
Tony Hernandez, Wyoming, MI, US
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Tina McBride, Lexington, MA, US
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Terry Carlo, Pittsfield,, MA, US
Karl Hodges, Castro Valley, CA, US
Linda Peck, St. Cloud, MN, US
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Erin Foley, Hazlet, NJ, US
Mike Skidmore, Chicago, IL, US
Kevin Brewster, Eagle River, WI, US
Edward Stepinski, Hicksville, NY, US
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John Kirchner, Fort Wayne, IN, US
Alycia Bordlemay, Peoria, AZ, US
Andrew Samel, Andover, MA, US
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Jane Courtney, Stony Point, NY, US
Karen Hancock, Olympia, WA, US
Edward Hueneke, freeland, WA, US
Tom Moi, Stoughton, WI, US
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Joseph Armstrong, Hollywood, MD, US
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Karen Walsh, Branscomb, CA, US
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Chris Carothers, Aptos, CA, US
Mike Schutt, Everett, WA, US

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Marie Rose, Houston, TX, US
Angela Wilson, Bremerton, WA, US
Whitney Ranson, Memphis, TN, US
Mick Marz, West Hollywood, CA, US
Reggie Stiteler, Mount Shasta, CA,
Paul Betancourt, El Paso, TX, US
John Larson, Bellingham, MN, US
Susan Levinson, New York, NY, US
Kathleen Porter, Mt. Pleasant, SC, US
Hugh Eckert, Arlington, VA, US
Shannon Breslin, Tucson, AZ, US
Robin Holt, paducah, KY, US
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Amanda Clairmonte, Catharpin, VA, US
Cheryl Jackson, Guelph, ON, CA
Matt Guptail, Mosineeq, WI, US
D Cooper, N. Chelmsford, MA, US
Chrissantha Cramer, Billings, MT, US
Heath Hancock, Davenport, IA, US
Amy Thorne, North St Paul, MN, US
AMY beasley, columbia, TN, US
Michelle Giannetti, Chicago, IL, US
Colleen Evans, Sacramento, CA, US
Luigi Cipriani, Mentana (RM), ot, IT
Barry Desrosiers, Carson, CA, US
James Blevins, Salt Lake City, UT, US
Joni Peters, Gibson City, IL, US
Sharon Chandler-Barth, Painesville, OH, US
Erik Johnson, Lafayette, CO, US

LeRoy Haynes, Wooster, OH, US
John Thatcher, North Logan, UT, US
Gina Blanton, waxhaw, NC, US
Jason Kaas, Lindenhurst, NY, US
Sarai-David Martinez-Turrubiartes, Chicago, IL, US
Debra Bishop, Sacramento, CA, US
patricia wynn, Miami, FL, US
rusty simpson, Baltimore, MD, US
Marjorie Rathbone, Bryn Mawr, PA, US
Janis Shaw, Beaumont, CA, US
Jared Polens, North Adams, MA, US
Julianne Harp, Sierra Vista, AZ, US
William Hayden, Evansville, IN, US
Alan Fryar, Lexington, KY, US
Barry Zuckerman, Middletown, NY, US
Deanna Landini, Chicago, IL, US
Lynn Locke, Dayton, OH, US
Mark Salvo, Chandler, AZ, US
Monica Jaenicke, cottonwood, AZ, US
Sara Babbitz, Louisville, KY, US
Karen Loeffelman, Moscow, ID, US
Jody Baron, San Diego, CA, US
Jody Baron, San Diego, CA, US
Walter Mikulski, Vicksburg, MS, US
Jeannie Langston, Portland, OR, US
Lia Pileggi, Boulder, CO, US
Diana Oswald, San Leandro, CA, US
Charles Todd, Houston, TX, US
Amy Botello, New York, NY, US
Mercer Johnson, Wilmington, NC, US
Terrie Shouse, Dayton, OH, US
Alisa Thorne, Cary, NC, US
katheryn swanson, reno, NV, US
Brandy BENSON, WEST DES MOINES, IA, US
peter rubin, guilford, VT, US
Mercy Drake, Mesa, AZ, US
Tricia Toliver, Brooklyn, NY, US
Joe Rogers, Austin, TX, US
MARGARET MURRAY, Englewood, CO, US
Tricia Toliver, Brooklyn, NY, US
Chris Stricker, Middleton, WI, US
RuthAnne Dayton, Vacaville, CA, US
Sandra Griffin, Silver City, NM, US
Katie Courtland, Durham, NC, US
Kristi Gandee, Sioux Falls, SD, US
John Yerger, Tucson, AZ, US
Anais Tuepker, Portland, OR, US
Holly Chisholm, Oxford, MI, US
Sherry Gustafson, Alexandria, VA, US
Brigette Cuneo, Calistoga, CA, US
Cynthia Roberson, Dallas, TX, US
LINDA CAIN, CUSTER, WA, US
Randall Phillips, Santa Ana, CA, US
Stacey Pasquale, Castro Valley, CA, US
Eagan Wilson, Coppell, TX, US
Rhonda Rothrock, Pomona, IL, US
Rav Freidel, Montauk, NY,

Sid Johnson, La Canada, CA, US
Lori Colt, Santa Fe, NM, US
David Jognia, mentone, CA, US
joseph ciaramitaro, tucson, AZ, US
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Ann Marie Sunderland, St. Paul, MN, US
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Nancy Savage, Norman, OK, US
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Elizabeth Clark, Seattle, WA, US
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Solo Greene, Lapwai, ID, US
Craig Long, Mesa, AZ, US
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Lisa Frey, #3, WI, US
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Joe Bradley, Converse, TX, US
Toni Garmon, Dawsonville, GA, US
George Doran, Springfield, MO, US
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Sandra Steadman, Copperas Cove, TX, US
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Joe Edwards, Shipman, VA, US
Michele O'Marah, Los Angeles, CA, US
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Ruth Bowell, Troy, OH, US
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Lisa Thomas, Esparto, CA, US
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Ellis Tharp, Little Rock, AR, US
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Elizabeth Carey, San Pedro, CA, US
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Mary Ryan, Pottstown, PA, US
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Donna Skemp, Paso Robles, CA, US
John Rose, Goleta, CA, US
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Byron Davis, Salt Lake City, UT, US
Dan Tobin, Durango, CO, US
Tina Mohrfeld, Marlton, NJ, US
Terry Jordan, Ithaca, NY, US
Stefan Kudek, Redford, MI, US
John Miller, Miranda, CA, US
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Deborah Mead, MILFORD, CT, US
Virginia Carter, Clarkesville, GA, US
candy batten, los angeles, CA, US
Kristine Kowalski, Annapolis, MD,
Janice Mortenson, SAN FRANCISCO, CA, US
Jack Harris, Nashville, TN, US
Stacey Ingenito, Oceanside, CA, US
Elaine Koenig, Los Angeles, CA, US
Stephanie Donaldson, Wallingford, CT, US
Alison Rab, San Francisco, CA, US
t logan, austin, TX, US
Jennifer Wolf, Victor, ID, US
Carolyn Bigger, El Cajon, CA, US
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Teresa Coble, Springfield, OR, US
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MyHa Nguyen, San Francisco, CA, US
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Dr. James Hanson, Winter Park, GA, US
Amanda Palumbo, Davis, CA, US
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Angela Taylor, Moscow, ID, US
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Harold Morgan, Tulsa, OK, US
Allen Yun, Rockville, MD, US
Leith McCombs, Renton, WA, US
Loraine Wright, Lansing, MI, US
Nancy Harvin, Corrales, NM,
Donna Robinson, Stamford, CT, US
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Dan Harrigan, Kennesaw, GA, US
Valerie Leonard, columbia, MD, US
Loraine Wright, Lansing, MI, US
Rachel Chaput, Brooklyn, NY, US
Kathy Crosby, Raleigh, NC, US
Josie Coogan, Gardiner, ME, US
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Martha Lynch, Staten Island, NY, US
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Jacquelyn Corday, Missoula, MT, US
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Shelley Potts, Raleigh, NC, US
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Linda Madyda, Irvington, NY, US
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Sarah Nemeth, Sadorus, IL, US
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Emily Sussman, Doylestown, PA, US
Jeanie Sanchez, los lunas, NM, US
M Gregory, Boca Raton, FL, US
Angie Arnold, denver, CO, US
Quilla Miralia, Jacksonville, FL, US
Karen Glauber, vestal, NY, US
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Diane Sullivan, Oak Harbor, WA, US
Michelle Macy, Houston, TX, US
Adam Barnes, Blacksburg, VA, US
Paul Friesen, Alert Bay, BC, CA
Linda Twining, Kirksville, MO, US
Chris White, Chicago Park, CA, US
Lisa Love, Dearborn, MI, US
Chris White, Chicago Park, CA, US
Susan Lacy, Kent, OH, US
Marie Weis, Fox Island, WA, US
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Ania Serafin, Fort Collins, CO, US
Robyn Moore, Lawrence, KS, US
April van der Hoogt, San Francisco, CA, US
Shannon Fouts, Tacoma, WA, US
mike newlin, san angelo, TX, US
Stevie Foote, Oceanside, CA, US
Eleanor Rabinowitz, New York, NY, US
Greg Schneider, westfield, NJ, US
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Kerry O'Brien, Capitola, CA,
Jean Beyer, Bloomington, MN, US
Susan Dussing Bukowski, Agoura Hills, CA, US
Rachel Foxman, Portland, OR, US
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Art Wilkinson, St. Paul, MN, US
Nancy Savage, Norman, OK, US
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Bree Duffy, Helena, MT, US
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Lewis Kuhlman, Minneapolis, MN, US
Charlotte Weiser, Corte Madera, CA, US
Tracy Artley, Belleville, MI, US
Stephanie Slater, tucson, AS, US
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Natasha Shpiller, Chicago, IL, US
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Michael Dorer, Fremont, CA, US
Jessie Bacon, Kirkwood, MO, US
Jean Bolson, Council Grove, KS, US
D W, seattle, WA, US
Vallarie Enriquez, El Paso, TX, US
Meredith DiMeola, Old Birdge, NJ, US
Walter Birdwell, Osceola, MO, US
Mike Tomlinson, Sacramento, CA, US
Jim Mathis, San Diego, CA, US
Steve Plasse, Crothersville, IN, US
Jennifer Lake, Murray, UT, US
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Kristine Donovan, Middlesex, NJ, US
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Jeffrey Metzger, Springfield, OH, US
Katherine Coffing, Carson City, NV, US
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Laurie Saggan, Tinley Park, IL, US
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Celeste Borali, Rio de Janeiro, NM, BR
Charles Fox, Santa Fe, NM, US
Roger Clyne, Tempe, AZ, US
Laina Lamb, Bucyrus, OH, US
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Christina Fong, Daly City, CA, US
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Cate Brave, Whiteford, MD, US
Stephen Austin, Islip Terrace, NY, US
Scott Gibson, Saint Albans, WV, US
Kristin Haverlock, Edmonds, WA, US
Katherine Fell, Brewerton, NY, US
Matthew Pintar, Orono, ME, US
Alan Jenks, Elgin, IL, US
Valerie Dorn, Folcroft, PA, US
Cara Huether
James McKenna, San Francisco, CA, US
Lesley Cox, CARRABELLE, FL, US
Julia Bonfiglio, San Mateo, CA, US
Laura Holmes, Kidderminster, ot, GB
Dena Abney, Waco, TX, US
Paula Phillips, San Marcos, CA, US
Barrett Edgar, Wedderburn, OR, US
Charles Meece, Capistrano Beach, CA, US
Judy Lujan, Albuquerque, NM, US
MICHAEL DOMOZICK, west dennis, MA, US
janice santos, caribou, ME, US
Albert Cochrane, Glen Mills, PA, US
Paula Britton, Willits, CA, US
Marjorie Latham, East Hampton, NY, US
Rick Westcott, Salem, OR, US
Mardella Brown, Blue Grass, IA, US
K. Devi, SEATTLE, WA, US
Chere Negaard, Fallbrook, CA, US
Patricia Dishman, Nashville, TN, US
Nancy Miller, Westfield, IN, US

Constance Gilmore, Cottonwood, AZ,
Matthew Brewer, Commerce, TX, US
Tim Reichard, Toledo, OH, US
Dennis Shuman, Gainesville, FL, US
Jeff Thayer, San Diego, CA, US
Kathie Weiss, Atlanta, GA, US
Lorraine Lorenzini, Philadelphia, PA, US
Hannah Rose, Louisville, KY, US
Paul Sakren, New Preston, CT, US
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Amber Tidwell, Los Angeles, CA, US
Lorraine Lorenzini, Philadelphia, PA, US
Jorge Andromidas, Boulder, CO, US
Shera Blume, north san juan, CA, US
KT Snyder, Gorham, ME, US
Emilia Soltis, Clifton, NJ, US
Ben DeBruin, CHICAGO, IL, US
Chris Smith, uxbridge, MA, US
Dorothea Trible, Fairbanks, AK, US
Elizabeth Saenger, Mamaroneck, NY, US
Susan Tewell, Arma, KS, US
carrie snyder, los altos hills, CA, US
Jennifer Unger, York, PA, US
Geoff Hirsch, Shoreview, MN, US
David Cropper, Snellville, GA, US
Cynthia Kuhn, Medford, MA, US
Kimberley A Hormell, Frisco, TX, US
Philip Ratcliff, Cloverdale, CA, US
Angela Murry, placerville, CA, US
Jim Thomas, Chapel Hill, NC, US
Jim Thomas, Chapel Hill, NC, US
Marcia Cooperman, Portland, OR, US
jt tuck, tucson, AZ, US
Kent Johnson, Ballwin, MO, US
Nancy Fleming, Portland, OR, US
Jennifer Staiger, Gainesville, FL, US
Kevin Jones, Park Ridge, IL, US
Nicole Rahman, Flemington, NJ, US
Robert McKay, Red Bank, NJ, US
Amy Dick, Sarepta, LA, US
Julie Lind, Manawa, WI, US
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Tim Garvin, Waco, TX, US
Deb Sparrow, Tempe, AZ, US
Lori Brown, Milwaukee, WI, US
Sandra Peterson, Danville, CA, US
Michael Cozens, London, ON, CA
scott jung, South Pasadena, CA, US
Nancy Norris, Los Angeles, CA, US
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Joan Dwyer, Elizabeth, NJ, US
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Robert Dickinson, South Windsor, CT, US

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Dianne DeLisle, Capitola, CA, US
Kathryn Shaffer, Lake Oswego, OR, US
Dave Lenington, Yakima, WA, US
Dale Petersen, Sunnyvale, CA, US
Gretchen Lindquist, Houston, TX, US
Stephen Gliva, Chicago, IL, US
Barry Prusin, Atlanta, GA, US
Sherry Steele, Redwood Valley, CA, US
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Nick Rodin, Soquel, CA, US
Julie Hoffman, Los Angeles, CA, US
CHERIE REEVES-RUTLEDGE, MEDFORD, OR, US
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Cathy Popp, Hamden, CT, US
Wm Schultz, whitefish, MT, US
John D'Ambra, Butler, NJ, US
Mark Lungo, Middleburg Heights, OH, US
Beatrice Virga, Tracy, CA, US
Teri Dormady, St. Louis Park, MN, US
Meredith Davidson, Glen Ellyn, IL, US
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Ann Stetser, Miami, FL, US
Jennifer Westra, Spokane, WA, US
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Lynne Price, Evergreen, CO, US
Robert Van Hyfte, lakewood, CO,
Katheen Mcclafferty, New York, NY, US
Tammy Ozment-Skelton, Blountville, TN, US
Gail Wattier, Parrish, FL, US
Tiffany Dover, Carmichael, CA, US
J Freeman, Lincoln, NE, US
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Allison Hanes, LA, CA, US
Duncan McFarland US
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Sandy De Oliveira, Astoria, NY, US
David Thompson, Anadarko, OK, US
megan greenberg, tampa, FL, US
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Alisha BeGell, Savona, NY, US
Richard Rothstein, Miami, FL, US
Vicky Bada, Pemberton, NJ, US
Jeannie Park, Seattle, WA, US
kristina menig, evanston, IL, US
lisa sharp, brandon, WI, US
Steve Wold, Chimayo, NM, US
Tanya Koester-Radmann, Chisago City, MN, US
Alan Bennett, Shelton, WA, US
Sharren Juliano, Glen Mills, PA, US
Molly Diamond, Sunnyvale, CA, US
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Kurt Jirka, Ithaca, NY,
Diane Shooman, Milford, NH, US
Katherine Bradley, providence, RI, US
Julie Skelton, Belleville, MI, US
Ann Martinson, North Bend,, WA, US
Paige Swartley, Petaluma, CA, US
Karen Kedrowski, Madison, WI, US
Crystal Lynn Tracy, Broomall, PA, US
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Douglas Schleifer, Flemington, NJ, US
Roger Santerre, New Paltz, NY, US
Karen Arnold, O'Fallon, MO, US
Lorna Bosnos, New York, NY, US
Jon Levin, Macungie, PA, US
Tim House, Upton, MA, US
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Daniel Cadzow, Kenmore, NY, US
Steven Hemstreet, Glenn Dale, MD, US
Sarah McLean, Sedona, AZ, US
Charlotte Mckee, Silver Spring, MD, US
Denise Lytle, Fords, NJ, US
Leslie Pensack, Ames, IA, US
Brendan Hughes, Ridgecrest, CA, US
Lynn Gaesser, Cedar Grove, NJ, US
Phyllis Price, Indianapolis, IN, US
Mike Garcia, West Palm Beach, FL, US
Matthew Schaut, Minneapolis, MN, US
dennis thomas, PLEASANT HILL, CA, US
nicole pando, tampa, FL, US
Bethanie Anderson, Bryn Mawr, PA, US
Ash Fligor, Ft Worth, TX, US
Elizabeth Cheong, Auckland, ot, NZ
Elizabeth Wirt, Port Orange, FL, US
Shirley Wallack, Santa Rosa, CA, US
Doug and Lee Buckmaster, Cambria, CA, US
Janis Ley, Sault Ste. Marie, MI, US
stacy brown, miami, FL, US
Crystal Conklin, Glendale, AZ, US
Christine Thomas, St. Louis, MO, US
Stephanie Gamache, North Augusta, SC, US
Alan Johnstone, Fort Frances, ON, CA
Theresa Bucaro, Santee, CA, US
Zoe Rowlandson, Santa Cruz, CA, US
BD Stillion, Jonesboro, AR, US
Sarah Estes, Fairview Heights, IL, US
Bob Purosky, Haslett, MI, US
Judie Dalton, Pleasant Hill, CA, US
john diehl, boulder, CO, US
Cari Welsh, Largo, FL, US
Bruce Barnbaum, Granite Falls, WA, US
Lisa Banik, Waterbury, CT, US
tom butler, columbus, OH, US
Jan Cone, Boulder, CO, US
annee schuetz, hannibal, MO, US
Shelly Langton, Vancouver, WA, US
Florence Sandok, Rochester, MN, US
Adam Engst, Ithaca, NY, US
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Debbie McBride, Richmond, TX, US
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Christina Weidner, Stafford, VA, US
Richard Retherford, Lititz, PA, US
David Rudin, Peyton, CO, US
Donald Dougall, Knoxville, TN, US
Karen Phair, Portland, ME, US
Debbie Apperson, Monterey, TN, US
Linda Higgins, Corona, CA, US
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Beth Milne, Benicia, CA, US
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Joanne Sartor, Tracy, CA, US
Diana Dellamarie, Burbank, CA, US
Amber Calabro, Woodcliff Lake, NJ, US
Ted Cheeseman, Saratoga, CA, US
David Corcoran, Des Plaines, IL, US
Susan Duffy, Hoboken, NJ, US
Justin Malick, East Stroudsburg, PA, US
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Shirley Sonnichsen, Richland, WA, US
Denise Glass, Perris, CA, US
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Debbie Cole, Webb City, MO, US
Jonathan Adams, Somerville, MA, US
Jonathan Adams, Somerville, MA, US
Cathy Panus, Saint Louis, MO, US
Lee Demick, Portland, OR, US
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trixie deveau, Toronto, ON, CA
Dawn Wallace, Colton, WA,
Dawn Wallace, Colton, WA,
Kelly Cruce, Truckee, CA, US
Denise Lytle, Fords, NJ, US
Christopher Johnson, Pearl River, NY, US
colleen burke, chicago, IL, US
David Mc Millin, Gray, TN, US
Ruth Vitale, Los Angeles, CA, US
Christine Cosgrove, Salem, OR, US
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Blair Mclaughin, PHOENIX, AZ, US
Eulalia Riba, Barcelona, ot, ES
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Erin O'Brien, Ocala, FL, US
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priscilla franco, charlestown, MA, US
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Kerry Reamer, Cleves, OH, US
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Matt Rauch, Ukiah, CA, US
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Benita Crow, Chesapeake, VA, US
Steven Tempelman, Lone Tree, CO, US
LORI NEWSON, Athens, GA, US
Sharon Parshall, Fall City, WA, US
Doug Morse, New York, NY, NY, US
Nancy Wittenberg, chandler, AZ, US
Brad Behrens, Northfield, MN, US
Leila Merl, Brookline, MA, US
Jason Nadeau, Milford, NH, US
Michelle Rasmussen, Denver, CO, US
Rita Webber, Bakersfield, CA, US
G Bilwin, Bend, OR, US
Kristin Dryden, Westminster, CO, US
Rachel Lugn
Elizabeth Mozer, Fort Collins, CO, US
Michael Fitzgerald, Brooklyn, NY, US
Robert Atkinson, Tempe, AZ, US
Phillip Kehn, Wilmington, DE, US
Suzanne & Steven Dauber, Loxahatchee, FL, US
Elizabeth McCleary-Kiffe, Maricopa, AZ, US
Teri Richter, Hales Corners, WI, US
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Dia Redman, North St Paul, MN, US
Luci Evanston, San Bruno, CA, US
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Miranda Pessot, Ottawa, ON, CA
Frances Paterik, Des Moines, IA, US
celia murray, vancouver, WA, US
Kelly Wolcott, Clifton, VA, US
Daniela Skander-Marshall, Sisters, OR, US
Daniela Skander-Marshall, Sisters, OR, US
Jackie Sylvander-Sodano, Shrub Oak, NY, US
Billie Hughes, Nutrioso, AZ, US
Jill Pearson, Cairo, GA, US
Terri Schmidt, Capitola, CA, US
Janis Miesen, Portland, OR, US
Mark M Giese, Racine, WI, US
William Gonzalez Garcia, Spring Valley, NY, US
shareen Siegrist, Albuqeurque, NM, US
Larry Sopko, Winnipeg, MB, CA
Kristyn Noteware, Lakewood, CO, US
Llauren Peralta, Los Angeles, CA, US
Tori Myers, Farmington, NM, US
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Ai Mahoney, Philadelphia, PA, US
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Donnie and Joyce Faulk, Austin, TX, US

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Sue Hutch, Calgary, AB, CA
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raymond herr, denver, CO, US
Rachel Ricotta, avon lake, OH, US
Angela Rasmussen, Charlottesville, VA, US
Jessica Pacynski, Sylvania, OH, US
Elizabeth Attard, Sanford, FL, US
Leonard Mole, Cary, NC, US
Pamela Hunter, OR, US
Casey Heninger, Simi Valley, CA, US
Keith Barron, Athens, OH, US
Tamra Mcconoughey, Davenport, IA, US
Mehl Renner, Lenoir, NC, US
joan scott, arcadia, CA, US
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Nora Petersen, Los Angeles, CA, US
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Laura Bunton, Pleasanton, TX, US
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Mark & Judy Harvey, Great Bend, PA, US
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John E Miller, Tucson, AZ, US
Andrew Ireland, Bethesda, MD, US
Lauren Appling, Castro Valley, CA, US
David Griffith, Rancho Cucamonga, CA, US
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Susan Glover, Austin, TX, US
Jeffrey Segal, Louisville, KY, US
Walter Koch, Goleta, CA, US
timothy brown, johnston, RI, US
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Barbara Childers, Kekaha, HI, US
C. Russum, Portland, OR, US
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Theresa Hall, Durham, NC, US
Renee Johnson, desert hot springs, CA, US
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Eleanor Cox, Columbus, NC, US
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Gabriel Hornig, Washington, DC, US
Jennifer Wilde, Alameda, CA, US
Amelia Ryan, Larkspur, CA, US
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Thomas Atherton, Las Vegas, NV, US
Thomas Atherton, Las Vegas, NV, US
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Yvonne Bartsch, Hoffman Estates, IL, US
Ted Stearns, Albuquerque, NM, US
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Timothy Johnston, San Francisco, CA, US
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Wendi Harrison, BROOKLYN, NY,
Winifred Williams, Columbus, OH, US
Linda Olenick, San Diego, CA, US
David Weigel, Bisbee, AZ, US
David Leavitt, Boulder, CO, US
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John Andreoni, Oberlin, OH, US
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Martyn Phillips, gilroy, CA, US
Karen Gilroy, Waxahachie, TX, US
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Rochelle Davis, Bisbee, AZ, US
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Charlotte Schiaffo, Tampa, FL, US
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Kathleen Hennessy, Yellow Springs, OH, US
Shannon Aron, Santana Row, CA, US
Gwendolyn Stice, SUMMIT, AR, US
Cynthia Leigh-Nussenblatt, Gavleston, TX, US
Leah Wilde, Morgantown, WV, US
Dylan O'Reilly, Farmington, NM, US

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Susan Calhoun, Athens, OH, US
Debra Grove, Broomfield, CO, US
Kirsten Johnson, Eaton Rapids, MI, US
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Michael Pound, Kansas City, MO, US
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Anna Stoudemire, Atlanta, GA, US
Claudine Gossett, Oakland, CA, US
Dale Lacognata, Fishers, IN, US
Joel Rane, Los Angeles, CA, US
Susan Eller, Collinsville, IL, US
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Ka'imi Heffner, Santa Ana, CA, US
Jennifer White, Huntington Beach, CA, US
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Michelle Elzby, Burlington, ON, CA
Laura Dicus, Poulsbo, WA, US
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Acc. No. 0601 *Scientific Reticence and sea level rise* can be viewed on the docket:
http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

Acc. No. 0602 *An improved method for detecting anthropogenic CO2 in the oceans* can be viewed on the docket:
http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=NHTSA-2008-0060

BEFORE THE UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
DOCKET NO. NHTSA 2008-0060

COMMENTS OF THE ALLIANCE OF AUTOMOBILE MANUFACTURERS

Notice of Availability of a Draft Environmental Impact Statement (DEIS) for New Corporate Average Fuel Economy Standards; Notice of Public Hearing

(73 Fed. Reg. 16,615 (Mar. 28, 2008) & 73 Fed. Reg. 22,913 (Apr. 28, 2008))

I. INTRODUCTION

The Alliance of Automobile Manufacturers ("Auto Alliance" or "Alliance")[1] respectfully submits these comments under the National Environmental Policy Act ("NEPA"). These comments are specifically directed to the Draft Environmental Impact Statement ("DEIS") released on July 2, 2008. *See* 73 Fed. Reg. 37,922 (July 2, 2008).[2]

As the Alliance has noted on prior occasions, it supported and continues to support Congress's passage of the landmark Energy Independence and Security

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[1] The Alliance consists of BMW Group, Chrysler LLC, Ford Motor Company, General Motors, Mazda, Mercedes-Benz USA, Mitsubishi Motors, Porsche, Toyota, and Volkswagen.

[2] The Alliance reserves the right to file additional comments on a final Environmental Impact Statement (or Environmental Assessment, should one be issued). As was the case with the Alliance's comments on NHTSA's NEPA scoping analysis, the Alliance's substantive rulemaking comments should be deemed incorporated into these comments on the DEIS, and these comments on the DEIS should be deemed incorporated into the Alliance's substantive rulemaking comments. The fact that these comments on the DEIS focus on some, but not all of the issues raised in the Alliance's June 2, 2008 NEPA scoping comments should ***not*** be construed as an abandonment of any issues raised in those scoping comments.

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Act of 2007 ("EISA") amendments to the Energy Policy and Conservation Act of 1975 ("EPCA"). EISA establishes an aggressive target of at least a combined 35 mpg fuel economy level to be achieved by cars and trucks by model year ("MY") 2020, and requires NHTSA to establish standards for the years leading up to and following 2020 at "maximum feasible" levels by applying the balance of variables listed in 49 U.S.C. § 32902(f). Congress recognized that the 35 mpg target pushes the boundaries of feasibility, and hence Congress did not mandate a precise legislative target beyond that level.

At the public hearing NHTSA held on the DEIS on August 4, 2008, an automobile dealer from Maine argued that he has repeatedly told his customers that "Detroit" did not produce any models attaining fuel economy greater than 30 mpg. This is inaccurate. More generally, that same commenter argued incorrectly that Alliance members strongly resisted fuel economy regulation and only aggressive use by NHTSA of its CAFE standard-setting powers would lead to more fuel-efficient vehicles coming to market. Emblematic of the Alliance's support for EISA, however, the three American manufacturers that are members of the Alliance produce numerous vehicles that get 30 mpg or more in highway driving under EPA tests. Other members of the Alliance produce many such vehicles as well. For instance, Alliance members produce the Pontiac G5 (31-33 mpg on highway), the Ford Focus (33-35 mpg on highway), the Chrysler Sebring (30 mpg on highway), Toyota Camry Solara (31 mpg on highway), Smart fortwo (41 mpg on highway), and the Mercedes E320 Bluetec (32 mpg on highway). *See* Appendix A, listing current models of vehicles attaining 30 mpg or higher on highway.

Moreover, as the Alliance noted in its NEPA scoping comments, to the extent NEPA applies at all to the process of setting fuel economy standards under EPCA and EISA, it is a supplementary tool designed to provide additional information to NHTSA decisionmakers. It cannot be allowed to overtake or misshape the careful balancing of factors mandated by Congress in EPCA and refined in the Reform CAFE approach under EISA. Under bedrock NEPA precedent, the statute is purely procedural in nature and cannot be used to require an agency to act in any particular way. Numerous individuals or organizations testifying at the August 4 public hearing appeared to suggest otherwise. As it proceeds, NHTSA should be careful to maintain a clear distinction between its substantive obligations under EISA and its procedural obligations under NEPA.

II. EXECUTIVE SUMMARY

The Alliance agrees with much of the analysis presented in the DEIS. For instance, NHTSA's analysis of the fuel economy impacts associated with mandating higher levels of fuel economy under the alternatives studied leads to the conclusion that even if NHTSA were to adopt the so-called "technology exhaustion" alternative,[3] NHTSA would be able to reduce global mean surface temperatures in 2100 by only an additional 0.006°C as compared to the temperature reductions associated with the "optimized" alternative NHTSA favors in its notice of proposed rulemaking ("NPRM"). *See* DEIS 2-16 (Table 2.5-4 (comparing "Reduction from No Action" for the "Optimized" and "Technology Exhaustion" scenarios). This is obviously a very small change, and is less than both the natural variability in temperature on an annual basis and the error in measuring temperatures from year to year.[4] "[P]rojected differences among the CAFE alternatives are small — *i.e.*, CO2 concentrations as of 2100 are within 1.7 to 3.2 parts per million across alternatives . . . — regardless of reference scenario and climate sensitivity." 73 Fed. Reg. at 37,926. NHTSA's analysis of the effects

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[3] And NHTSA cannot adopt the technology exhaustion alternative because such an alternative wholly ignores the 49 U.S.C. § 32902(f) criterion of "economic practicability," and thus would be unlawful to impose. *See* 73 Fed. Reg. at 37,925 (defining "technology exhaustion alternative" as one "in which NHTSA applied all feasible technologies ***without regard to cost***" by determining the stringency at which a reformed CAFE standard would require every manufacturer to apply every technology estimated to be potentially available for its MY 2011-2015 fleet.") (emphasis added). *See also id.* (recognizing that "some of [the alternatives] may not satisfy the four EPCA factors that NHTSA must apply in setting 'maximum feasible; CAFE standards").

[4] *See* Volume 13-B Tr. Trans. (testimony of Dr. James E. Hansen) , *in Green Mountain Chrysler-Plymouth-Dodge v. Crombie*, Civil File No. 05-302 & 304 (May 3, 2007) (D. Vt.), at 96:1-5 ("The uncertainties are certainly larger than .2 [degrees Celsius]."); 110:11-22 (average variation in temperature in the last 50 years has been 0.2 degree Celsius per decade, which is 0.02 degree Celsius per year). NASA's Dr. Hansen is a leading proponent of policy action to avert climate change and was a witness for the state governmental defendants in the *Green Mountain* EPCA preemption in the District of Vermont.

on rainfall and sea level rise are similar. *See* DEIS 2-17 to 2-18. *See also* 73 Fed. Reg. at 37,926 (predicting sea level rise by the year 2100 by 0.1 centimeters). All of these impacts are sufficiently small that they fully vindicate NHTSA's decision in prior CAFE rulemakings to perform environmental assessments ("EAs") in lieu of performing full-blown EIS-level analyses.

These comments thus focus on areas of continuing disagreement with NHTSA, based on the scoping comments filed by the Alliance on June 2, 2008:

First, NHTSA argues that the functional equivalence doctrine does not apply to allow NHTSA not to perform an EIS under EPCA and EISA. But NHTSA's analysis in this respect is conclusory and fails to adequately respond to the Alliance's analysis supplied to the agency in its June 2, 2008 comments.

Second, even if the functional equivalence doctrine does not apply, NHTSA has not taken due account of the *en banc* petition it filed, with the permission of the Solicitor General, in the Ninth Circuit in *Center for Biological Diversity v. NHTSA*, No. 06-71891 (and consolidated cases). Should NHTSA vindicate the position it has taken in that *en banc* petition, then the agency could viably choose not to perform an EIS on remand. Yet, NHTSA is currently proposing to perform an EIS. NHTSA should not take this position before the pending *en banc* petition is resolved. Instead, NHTSA should at least decide in the alternative that performing an EA and issuing a finding of no significant impact ("FONSI") would be sufficient NEPA compliance to support the NPRM here.

Third, NHTSA should consider the Ninth Circuit's recent *en banc* decision in *Lands Council, Inc. v. McNair*, --- F.3d ---, 2008 WL 264001 (9th Cir. July 2, 2008). In that case, the Ninth Circuit overturned several aspects of its aggressive approach to the NEPA statute, bringing its jurisprudence more in line with of that of other circuits.

Fourth, NHTSA finds that more stringent CAFE standards will reduce criteria pollutant and air toxics emissions. Such a conclusion is demonstrably incorrect and ignores the fleet-turnover effect and the study of that effect submitted by the Alliance to EPA in 2007 to explain how California CO2 emissions standards that represent increases in stringency over the MY 2010

CAFE baseline would ***increase*** emissions of most criteria pollutant and air toxics. NHTSA has a duty to consider that submission and revise its analysis accordingly.

Fifth, NHTSA continues to misidentify the so-called "no action" alternative. NHTSA's persistence in making comparisons against a "no action" alternative that uses MY 2010 CAFE standards as a baseline counterfactually assumes that EISA was never passed and is based on circular reasoning.

Sixth, NHTSA concludes that NEPA requires it to analyze transboundary effects associated with the NPRM's proposed CAFE standards — especially climate-change effects outside the United States. This runs contrary to longstanding litigation positions approved by the Department of Justice. NHTSA does not even attempt to grapple with those prior positions in the DEIS. Since NHTSA's analysis concludes that the worldwide effects of higher CAFE standards would be very small, then they logically would be reduced even further once those effects are scaled back to effects within the United States alone. The Alliance has also submitted a study by National Environmental Research Associates ("NERA") bearing on this issue. That study attempts to calculate the magnitude of properly limiting an analysis of the social costs of carbon emissions to impacts within the United States alone. The analysis in that study, if adopted by NHTSA, would buttress the conclusion that the CAFE rulemaking here can be supported by an EA/FONSI in preference to an EIS. Instead, the DEIS makes no mention of this analysis.

Seventh, as several environmental groups and individual commenters noted at the August 4, 2008 public meeting, NHTSA's NEPA analysis relies heavily on its Volpe model analysis. This makes it critical that the public be able to understand how the Volpe model functions. The letter the Alliance sent to NHTSA on May 18, 2008 presenting questions posed by Sierra Research, Inc. concerning the Volpe model has still not been answered. *See* Appendix B. This violates basic principles of administrative law. As a general matter, NHTSA's use of confidential product plan information also cannot be used to obscure the functioning of the Volpe model.

BEFORE THE UNITED STATES OF AMERICA
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Notice of Availability of a Draft Environmental Impact Statement (DEIS) for New Corporate Average Fuel Economy Standards; Notice of Public Hearing

(73 Fed. Reg. 37,922 (July 2, 2008))

August 18, 2008

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III. ISSUES RELATED TO THE DECISION OF WHETHER AND HOW TO PERFORM AN EIS

A. FUNCTIONAL EQUIVALENCE DOCTRINE

NHTSA includes several paragraphs in its DEIS arguing that the functional equivalence doctrine does not apply to CAFE standard-setting under EPCA or EISA. *See* DEIS at 1-16 to 1-17. This attempted rebuttal does not adequately address the Alliance's NEPA scoping comments for several reasons. *First*, NHTSA does not consider the cases cited by the Alliance and the point made there that the functional equivalence doctrine has been applied by courts to statutes other than the Clean Air Act and Clean Water Act and in favor of agencies other than the EPA. NHTSA's rebuttal effectively continues to assert that the functional equivalence doctrine applies only in such highly limited situations, without addressing the other authorities brought to its attention.

Second, NHTSA's rebuttal does not attempt to compare the procedures mandated in statutory contexts where the courts have found the functional equivalence doctrine to apply with the statutory procedures created in EPCA and EISA. Without such a comparison, it is empty for NHTSA to simply declare that the functional equivalence doctrine is only narrowly drawn. Moreover, NHTSA's attempted rebuttal avoids addressing cases like *Portland Cement Ass'n v. Ruckelshaus*, 486 F.3d 375, 384 (D.C. Cir. 1973), *cert. denied*, 417 U.S. 921 (1974) which interprets a vague provision of the Clean Air Act (requiring EPA only to impose "the best system of emission reduction") as requiring the functional equivalent of NEPA analysis.

Third, NHTSA's argument is illogical, because it would render the functional equivalence doctrine useless. Under NHTSA's reasoning, a statute would have to specify a set of procedures that is essentially identical to NEPA (plus the great detail in NEPA's regulations) before it would serve to require the functional equivalent of NEPA analysis. But if that were the case, then the doctrine would serve no purpose at all and would fail to relieve agencies of any kind of compliance burden. Instead, as *Portland Cement* explains, functional equivalence exists whenever a "workable balance is struck between some of the advantages and disadvantages of full application of NEPA." *Id. Compare Center for Biological Diversity v. NHTSA*, 508 F.3d 508, 527-28 (9th Cir. 2007) (EPCA creates a "reasonable" balancing of multiple variables for courts to review deferentially).

Fourth, NHTSA provides no response at all to subsection III.A.2. of the Alliance's NEPA scoping comments. That subsection makes the point that the passage of EISA and the various directives it gives to NHTSA to consider environmental matters, as well as EISA's legislative history, indicates that environmental issues were in the foreground of Congress's mind in adopting that statute, and on that basis the functional equivalence doctrine can be applied.

Finally, even if NHTSA decides not to rely solely on the functional equivalence doctrine, it should recognize that its invocation in the alternative would help to protect its rulemaking against challenges asserting that the NEPA analysis being performed is defective or insufficient. NHTSA's analysis can be read to suggest that the agency agrees the defense is colorable, but is merely choosing not invoke it as a discretionary matter. NHTSA should reconsider at least adopting the defense in the alternative, which would permit a court to pass on the issue. There is no downside to the agency acting in that fashion.

B. NHTSA'S PENDING *EN BANC* PETITION

On February 6, 2008, with the permission of the Solicitor General, NHTSA petitioned for *en banc* review of the Ninth Circuit's decision concerning NHTSA's MY 2008-2011 light truck CAFE rules in *Center for Biological Diversity*. NHTSA argued that it could not be ordered to complete an EIS, but instead, consistent with limitations on remedies under the Administrative Procedure Act (which provides the only basis for enforcing NEPA in court), NHTSA had to be allowed the choice to exercise its discretion on remand as to whether to prepare an EIS or an EA. That *en banc* petition remains pending.

It is wholly inconsistent for NHTSA to voluntarily perform an EIS in this CAFE rulemaking while its *en banc* petition is pending in the Ninth Circuit, absent some explanation of independent reasons for doing so. NHTSA's present course of action risks mooting the *en banc* petition.[5] In order to maintain consistency with the position taken in the Ninth Circuit, NHTSA should issue, in the alternative, an EA/FONSI form of NEPA compliance document. The evidence NHTSA has developed in the DEIS amply supports a conclusion that environmental impacts are minimal. Doing so would ensure that the pending *en banc* petition in *Center for Biological Diversity* remains unaffected.

C. THE NINTH CIRCUIT'S *EN BANC MCNAIR* DECISION

In its *en banc* decision in *Lands Council, Inc. v. McNair*, --- F.3d ---, 2008 WL 264001 (9th Cir. July 2, 2008), the Ninth Circuit took a major step to bring its NEPA jurisprudence into greater harmony with the NEPA case law of other Circuits. In *McNair*, the Ninth Circuit overruled a number of its prior panel opinions in the NEPA area. The decision should be carefully considered by NHTSA in connection with finalizing its NEPA analysis for this rulemaking.[6] One aspect of the decision that NHTSA should particularly note, which is consistent with its approach in the DEIS (but inconsistent with the approach of many in the August 4 public hearing) is the following: "[T]o require the Forest Service to affirmatively present every uncertainty in its EIS would be an onerous requirement, given that experts in every scientific field routinely disagree; such a requirement might inadvertently prevent the Forest Service from acting due to the burden it would impose." *Id.* at *17.

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[5] The Alliance points out this issue for NHTSA's consideration without conceding that the voluntary preparation by NHTSA of an EIS in this rulemaking would moot the pending *en banc* petition. Clearly, the agency would have good arguments that even the voluntary preparation of an EIS on remand would not moot the case.

[6] In directing NHTSA's attention to the *McNair* decision, which as mentioned brings the Ninth Circuit more in line with other Circuits, we also note that even if a future final rule emerging from these proceedings were to be challenged, it is not a foregone conclusion that such a challenge would occur in the Ninth Circuit.

IV. IGNORING IMPACTS ON CRITERIA POLLUTANTS AND AIR TOXICS

As Attachment #14 to its substantive comments on NHTSA's CAFE NPRM for MY 2011-2015 (NHTSA Document ID: NHTSA-2008-0089-0170.1), the Alliance submitted the June 15, 2007 study performed by NERA, Sierra Research, and Air Improvement Resource ("AIR") entitled *Effectiveness of the California Light Duty Vehicle Regulations as Compared to Federal Regulations*, which was originally submitted to EPA in connection with its consideration of whether to grant California a waiver of preemption under the Clean Air Act for that State to set its own greenhouse gas emission standards for new vehicles. This study demonstrates how increases in fuel economy standards can, through the fleet-turnover effect,[7] delay new vehicle purchases, thereby prolonging the period that vehicles emitting greater levels of traditional criteria and toxic pollutants will be driven on the roads.

The NERA/Sierra/AIR study compared the real-world emissions control levels achieved by the California program to the federal program for light-duty vehicles. The analysis compared emissions of the five key pollutants (VOC, NOx, PM2.5, CO, and SOx), plus effects on an aggregation of five air toxics (acetaldehyde, benzene, 1,3 butadiene, formaldehyde, and acrolein) under the two programs from 2009 through 2023. The study concluded that increases in the relative stringency of fuel economy standards as adopted by California

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[7] The so-called "fleet turnover" effect is a commonplace in the economic literature and has been recognized by Congress and the courts in the area of fuel economy regulation. *See* 121 Cong. Rec. 18674 (June 12, 1975) (statement of Rep. Sharp) ("if we overdo it today [there is the possibility] that we will cause what is known as a stretch-out . . . . [M]ost of us could defer the purchase of new automobiles for 1, 2, or 3 years [and thus, as a consequence] we may end up with less [fuel-]efficient automobiles continuing to travel on the highways."); *Public Citizen v. NHTSA*, 848 F.2d 256, 260 (D.C. Cir. 1988) ("NHTSA regarded the magnitude of possible energy savings as 'uncertain' in light of the prospect that restrictions on the availability of larger cars might cause consumers to retain their older, even less fuel-efficient models."); *International Harvester Co. v. Ruckelshaus*, 478 F.2d 615, 634 (D.C. Cir. 1973) (higher prices from regulation "would … increase[e] actual total emissions of cars in use"). *See also* Alan Greenspan & Darrel Cohen, *Motor Vehicle Stocks, Scrappage, and Sales*, 81 Rev. of Econ. and Stat. 369 (1999).

would significantly drive up most criteria pollutant and air toxics emissions levels.

By contrast, NHTSA's analysis in its DEIS concludes that the more stringent CAFE standards become, the fewer criteria pollutants and air toxics are emitted from the vehicle fleet. *See* DEIS at 2-15 (Table 2.5-2) (moving from right to left on that table, which corresponds to increased CAFE stringency, criteria and toxic emissions generally are shown to decrease). This can only be in consequence of NHTSA failing to properly take account of the fleet-turnover effect. Failure to rectify this error would be arbitrary and capricious. *See Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 43 (1983) ("agency rule would be arbitrary and capricious if the agency has . . . offered an explanation for its decision that runs contrary to the evidence . . . .").

Indeed, NHTSA's discussion in the DEIS makes clear that the agency is refusing to consider fleet-turnover effects. *See* DEIS at 1-18 ("As these issues [including fleet turnover] raised by the AAM . . . do not relate to the effects on the physical environment, they are not addressed in this document."). This entirely misunderstands the NERA/Sierra/AIR study and the nature of the fleet-turnover effect. This effect will cause NHTSA's proposed CAFE standards to increase various criteria pollutant and air toxic emissions. These are ***direct physical*** effects on the environment. It is difficult to understand what NHTSA means when it attempts to call the effect on pollutant levels caused by the fleet-turnover effect a non-physical effect on the environment. If NHTSA means that it can ignore some physical effect on the environment whenever such an affect occurs based on economic cause and effect, then NHTSA surely errs. If that were the case, NHTSA's use of the Volpe model in connection with NEPA analysis would also be flawed, because the Volpe model is intended as a cost-benefit tool for comparing different fuel economy mandates, and the Volpe model is integral to NHTSA's NEPA analysis.

In fact, agencies are often compelled to consider environmental outcomes resulting from behavioral changes due to economic factors. *See generally Mid States Coalition for Progress v. STB*, 345 F.3d 520, 548-49 (8th Cir. 2003) (STB erred by failing to consider claimed increases in CO2 emissions by power plants associated with the STB's approval of a new rail line based on a lengthy chain of economic reasoning to the effect that the new rail line would lower the price and increase the availability of low-sulfur coal, and thereby increase emissions from power plants expected to consume the coal being carried). In the case of EISA, the consideration of economic factors is a particularly critical element of the statutory design. It would be nonsensical for NHTSA to ignore technically sound studies demonstrating a direct connection between the economic effects of CAFE standards and resulting environmental impacts.

V. MISIDENTIFICATION OF THE "NO ACTION" ALTERNATIVE

Under the case of *Department of Transportation v. Public Citizen*, 541 U.S. 752 (2004), commonly referred to as the "Mexican Trucks" decision — a case in which NHTSA's parent Cabinet Department prevailed unanimously in the Supreme Court — the Court held that NEPA analysis must be framed based on directives from Congress, and must be performed only to the extent that a particular agency has discretion:

> We hold that where an agency has no ability to prevent a certain effect due to its limited statutory authority over the relevant actions, the agency cannot be considered a legally relevant "cause" of the effect. Hence, under NEPA and the implementing CEQ regulations, the agency need not consider these effects in its EA when determining whether its action is a "major Federal action." Because the President, not FMCSA, could authorize (or not authorize) cross-border operations from Mexican motor carriers, and because FMCSA has no discretion to prevent the entry of Mexican trucks, its EA did not need to consider the environmental effects arising from the entry."

Id. at 770.

NHTSA never explains why the Mexican Trucks decision should not alter the no-action alternative the agency proposes, which imagines counterfactually that NHTSA can leave CAFE standards unchanged, contrary to Congress's directives in EISA. Instead, to justify continuing with its own view of how to define the no-action alternative, NHTSA states in a circular fashion that "NHTSA must analyze a scenario where NHTSA does not take this action [i.e., takes no action to increase fuel economy standards]." DEIS, at 1-11. That assertion is non-responsive to the Alliance's NEPA scoping comments. NHTSA clearly cannot specify a "no action" alternative that incorrectly assumes that the agency has no duty to carry out EISA's directives. Instead, NHTSA must specify a "no action" alternative that is formulated with the congressionally ordered baseline of achieving at least 35 mpg by MY 2020 in mind. Given the time period over which NHTSA is proposing to establish standards (i.e., for half of the model years between MY 2011 and MY 2020), the simplest way for NHTSA to specify a proper baseline is to use the fuel economy level in MY 2015 that makes half of the progress necessary to achieve the 35 mpg target in MY 2020, and then judge all of its alternatives against that halfway mark. There may also be other defensible ways of defining a "no action" alternative, but pretending that EISA does not exist is not one of them.

Moreover, this debate over how to define the no-action alternative is not an arid one lacking in practical significance. Properly specifying the baseline for analysis of regulatory alternatives that fall within NHTSA's discretion under EISA is vital. If NHTSA sets the baseline too high, then it will underestimate the benefits of a given set of fuel economy standards. If NHTSA sets the baseline too low, as it has done here by specifying a baseline that falls short of the congressional mandate in EISA, then it will ***overestimate*** benefits. For instance, using MY 2010 CAFE standards as the no-action alternative, NHTSA might conclude that the agency's preferred set of CAFE standards will reduce the global concentrations of CO2 that might otherwise obtain by 1 ppm. By contrast, it might find that if the no-action alternative instead were defined to take as a given mandated increases in fuel economy by Congress in EISA, then the same agency-preferred set of CAFE standards might reduce global concentrations of CO2 by only 0.1 ppm. These numbers are purely illustrative. The point is that by mis-specifying the no-action alternative, NHTSA improperly exaggerates the environmental benefits that its discretionary choices appear to achieve. Furthermore, if NHTSA corrects this error, it would provide further directional support for concluding the NEPA process with an EA/FONSI (primarily, or in the alternative), as opposed to concluding that process with a final EIS.

VI. UNLAWFUL CONSIDERATION OF TRANSBOUNDARY EFFECTS

In the DEIS, NHTSA disagrees with the Alliance's reading of NHTSA's pronouncement that "the appropriate value to be placed on changes [in] climate damages caused by carbon emissions should be ones that reflect the change in damages to the United States alone." 73 Fed. Reg. at 24,414. For NEPA purposes, NHTSA insists that "[p]otential environmental impacts are global in this instance and the analysis must look beyond the borders of the United States . . . . NHTSA has an obligation under NEPA to 'recognize the worldwide and long-range character of environmental problems.'" DEIS at 1-11 (quoting 42 U.S.C. § 4332(F)).

However, Section 4332(F), like much in the NEPA statute, is precatory. It does not create an obligation that attaches to the EIS requirement in Section 4332(C), which is judicially enforceable. Moreover, NHTSA selectively quotes Section 4332(f). In its entirety, Section 4332(F) reads as follows:

> The Congress authorizes and directs that, to the fullest extent possible: (1) the policies, regulations and public laws of the United States shall be interpreted and administered in accordance with the policies set forth in this chapter and (2) all agencies of the Federal Government shall . . . .
>
> > (F) recognize the worldwide and long-range character of environmental problems and, where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment . . . .

42 U.S.C. § 4332(F). To simply read this provision is to see why it cannot be read to be judicially enforceable, and to our knowledge has not been read by any court to be directly enforceable. Courts cannot police whether agencies have sufficiently "recognize[d] the worldwide and long-range character of environmental problems." Similarly, courts lack the power to decide whether agencies have lent enough support to programs maximizing international cooperation and protecting the world environment. *Compare Norton v. Southern*

Utah Wilderness Alliance, 542 U.S. 55, 66-67 (2004) (unanimous) (to be enforceable, statutory mandates must be "discrete," and on that basis refusing to enforce an overly broad "nonimpairment mandate" for wilderness study areas in a statute because "[i]f courts were empowered to enter general orders compelling compliance with broad statutory mandates, they would necessarily be empowered, as well, to determine whether compliance was achieved — which would mean that it would ultimately become the task of the supervising court, rather than the agency, to work out compliance with the broad statutory mandate, injecting the judge into day-to-day agency management.").

Finally, the proviso limiting Section 4332(F) to situations not inconsistent with the foreign policy of the United States is very significant. The United States in the past has argued in numerous different forums that the extraterritorial application of NEPA would interfere with the President's foreign policy prerogatives. "It has been the long-standing position of the Justice Department that NEPA was not intended nor can it be invoked to interfere with the President's authority as Commander-in-Chief, or with his exclusive responsibility for the conduct of foreign affairs, regardless of whether the government action in question affects the United States environment, the global commons, or the environment of foreign nations, because these responsibilities are confided to the President by the Constitution." Letter from Bruce C. Navarro, Deputy Assistant Attorney General, Department of Justice, to Minority Leader Robert Dole, 3 (Oct. 9, 1990), *quoted in* Joan M. Bondareff, *The Congress Acts to Protect Antarctica*, 1 Terr. Sea J. 223 n.64 (1991).

To support its contrary conclusion that NEPA can and does have extraterritorial application, NHTSA also cites a 1997 guidance document issued by the Council on Environmental Quality ("CEQ"). *See id.* at 1-11 n.29 (referencing CEQ, *Council on Environmental Quality Guidance on NEPA Analyses for Transboundary Impacts* (July 1, 1997), at 3, *available at* http://ceq.hss.doe.gov/nepa/regs/transguide.html. The Mexican Trucks decision by the Supreme Court recognizes that CEQ ***regulations*** are entitled to deference, *see Public Citizen*, 541 U.S. at 770, but a guidance document of this nature is void because it represents a clear shift in policy that occurred in 1997 without compliance with the Administrative Procedure Act's requirement to subject any substantive change in agency policy to notice-and-comment review by the public. *See, e.g., CropLife Am. v. EPA*, 329 F.3d 876 (D.C. Cir. 2003); *General Elec. Co. v. EPA*, 290 F.3d 377 (D.C. Cir. 2002); *Barrick Goldstrike Mines, Inc. v. Browner*, 215 F.3d 45 (D.C. Cir. 2000); *Appalachian Power Co. v. EPA*, 208 F.3d 1015 (D.C. Cir. 2000). Hence, NHTSA cannot rely on this lone guidance document. It has no legal effect.

Moreover, the guidance document reflects a divergence from Justice Department-approved interpretations of NEPA both prior to 1997 and after 1997. The Navarro letter to Senator Dole referred to above accurately summarizes policy predating the 1997 CEQ guidance document. And the current Administration had repeatedly made clear its position that NEPA is not sufficiently unambiguous to overcome the presumption against extraterritoriality, which remains vital. *See Microsoft v. AT&T Corp.*, 127 S. Ct. 1746, 1758 (2007).[8] To name just two examples, the Bush Administration took that position in *NRDC v. Department of the Navy*, No. CV-01-07781 CAS(RSZ) (C.D. Cal.) and *Manitoba v. Norton*, No. 02-cv-02057 (RMC) (D.D.C.). NHTSA nowhere even acknowledges these briefs, which represent the true position of the United States spanning across multiple agencies. *See* 28 U.S.C. § 516 (Attorney General represents the United States and agencies thereof in litigation). These positions therefore clearly trump the unlawfully issued and procedurally defective CEQ guidance document. At the very least, NHTSA must consider the positions taken in these briefs and others similar cases (by, *inter alia*, consulting with the Department of Justice) before deciding that NEPA applies extraterritorially in a final EIS or other final document issued for purposes of complying with the NEPA statute.

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[8] *Microsoft v. AT&T* also notes that the canon of presuming against extraterritoriality is entirely consistent with a presumption that "'legislators take account of the legitimate sovereign interests of other nations when they write American laws.'" *Microsoft*, 127 S. Ct. at 1758 (quoting *F. Hoffmann-La Roche Ltd. v. Empagran S. A.*, 542 U.S. 155, 164 (2004)). This helps to explain why Section 4332(F) of NEPA, with its emphasis on agencies giving some consideration to the world environment is fully consistent with concluding that the NEPA statute's enforceable duties nonetheless apply only to require the consideration of domestic effects.

VII. UNANSWERED VOLPE MODEL QUESTIONS

On May 18, 2008, the Alliance sent a letter to NHTSA posing a series of questions about the Volpe model that Sierra Research had formulated because Sierra found it necessary "to resolve [those questions] in order to be able to understand and fully unpack the technical analysis behind NHTSA's notice of proposed rulemaking, as published at 73 Fed. Reg. 24,352 (May 2, 2008), and the accompanying preliminary regulatory impact analysis." Appendix B at 1. NHTSA has still not responded to the questions posed.

As NHTSA knows, courts have interpreted the Administrative Procedure Act and other, analogous sources of law to require agencies to provide opportunities not just to comment, but to comment meaningfully upon the agency's analysis. *See, e.g., Honeywell Int'l, Inc. v. EPA*, 372 F.3d 441, 449 (D.C. Cir. 2004). Moreover, an agency cannot rely on data or analysis known only to itself. *See National Classification Committee v. United States*, 779 F.2d 687, 695 (D.C. Cir. 1985). In addition, agency reliance on its experience cannot overcome evidence that shows a particular methodology to be flawed. *See American Pub. Gas. Ass'n v. FERC*, 567 F.2d 1016, 1043 (D.C. Cir. 1977), *cert. denied*, 435 U.S. 907 (1978). Finally, in exploring the validity of the various assumptions that NHTSA made, Sierra needs to be able to test NHTSA's conclusions and its reliance on matters requiring judgment. Therefore, under OMB's aegis, NHTSA has been obligated to ensure that its scientific and technical conclusions are "substantially reproducible." Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies, 67 Fed. Reg. 8,452 (Feb. 22, 2002). Sierra Research was not able to replicate NHTSA's analysis in some significant ways because the questions it posed were not answered.

Numerous environmental organizations commented at the August 4 public hearing that the Volpe model was central to NHTSA's NEPA analysis. Hence, for NHTSA's protection both against potential legal challenges by those groups and to provide a rational response to the questions raised by the Alliance, NHTSA must provide answers to the issues posed in the May 18 Alliance letter. NHTSA's use of confidential product plans by manufacturers cannot form the answer to the concerns posed in that letter. *See Riverkeeper, Inc. v. EPA*, 475 F.3d 83, 112 (2d Cir. 2007) (approving agency use of confidential information only so long as it did not prevent the public "from commenting on the methodology and general cost data underlying EPA's approach").

VIII. CONCLUSION

For the foregoing reasons, NHTSA should either determine not to proceed with a NEPA EIS or, alternatively, announce its desire to do so only on a voluntary basis, producing in the alternative an EA/FONSI. In addition, NHTSA must address the other comments on the DEIS advanced by the Alliance herein and in its scoping comments filed June 2, 2008.

Respectfully submitted,

The Alliance of Automobile Manufacturers

DATE: August 18, 2008

APPENDIX A

Fuel Economy Values for 2008 Vehicles

	Trans Type/Speeds	Engine Size/Cylinders	MPG City/Highway
TWO SEATERS			
SMART			
fortwo convertible	A-S5	1.0/3	33/41
fortwo coupe	A-S5	1.0/3	33/41
MINICOMPACT CARS			
MINI			
Cooper	A-S6	1.6/4	26/34
Cooper	M-6	1.6/4	28/37
Cooper Convertible	AV	1.6/4	22/30
	M-5	1.6/4	23/32
Cooper S	A-S6	1.6/4	23/32
	M-6	1.6/4	26/34
SUBCOMPACT CARS			
AUDI			
A4 Cabriolet	AV	2.0/4	21/30
TT Coupe	A-S6	2.0/4	23/31
CHEVROLET			
Aveo 5	A-4	1.6/4	23/32
	M-5	1.6/4	24/34
Cobalt	A-4	2.2/4	22/31
	M-5	2.2/4	24/33
	A-4	2.4/4	22/31
	M-5	2.4/4	22/32
HONDA			
Civic	A-5	1.8/4	25/36
	M-5	1.8/4	26/34
	A-5	1.8/4	24/36
MINI			
Clubman	A-S6	1.6/4	26/34
	M-6	1.6/4	28/37
Clubman S	A-S6	1.6/4	23/32
	M-6	1.6/4	26/34
NISSAN			
Altima Coupe	AV	2.5/4	23/31
	M-6	2.5/4	23/32
PONTIAC			
G5/Pursuit	A-4	2.2/4	22/31
	M-5	2.2/4	24/33
	A-4	2.2/4	22/31
	M-5	2.2/4	22/32
SCION			
xD	A-4	1.8/4	26/32
	M-5	1.8/4	27/33
TOYOTA			
Yaris	A-4	1.5/4	29/35
Yaris	M-5	1.5/4	29/36
VOLKSWAGEN			
Eos	A-S6	2.0/4	21/30

Fuel Economy Values for 2008 Vehicles

COMPACT CARS			
AUDI			
A4	AV	2.0/4	21/30
	M-6	2.0/4	20/31
CHEVROLET			
Aveo	A-4	1.6/4	23/32
	M-5	1.6/4	24/34
FORD			
Focus	A-4	2.0/4	24/33
	M-5	2.0/4	24/35
HONDA			
Accord Coupe	A-5	2.4/4	21/30
	M-5	2.4/4	22/31
Civic Hybrid	AV	1.3/4	40/45
HYUNDAI			
Accent	A-4	1.6/4	24/33
	M-5	1.6/4	27/32
KIA			
Rio	A-4	1.6/4	25/35
	M-5	1.6/4	27/32
MAZDA			
3	A-S4	2.0/4	23/31
	M-5	2.0/4	24/32
PONTIAC			
G6	A-4	2.4/4	22/30
SATURN			
Astra 2DR Hatchback	A-4	1.8/4	24/30
	M-5	1.8/4	24/32
Astra 4DR Hatchback	A-4	1.8/4	24/30
	M-5	1.8/4	24/32
SUZUKI			
SX4 Sedan	M-5	2.0/4	22/30
TOYOTA			
Camry Solara	A-S5	2.4/4	22/31
	M-5	2.4/4	21/31
Corolla	A-4	1.8/4	26/35
	M-5	1.8/4	28/37

Fuel Economy Values for 2008 Vehicles

MIDSIZE CARS			
CHEVROLET			
Classic	A-4	2.2/4	21/31
Malibu	A-4	2.4/4	22/30
Malibu Hybrid	A-4	2.4/4	24/32
CHRYSLER			
Sebring	A-4	2.4/4	21/30
DODGE			
Avenger	A-4	2.4/4	21/30
HYUNDAI			
Elantra	A-4	2.0/4	25/33
	M-5	2.0/4	24/33
KIA			
Optima	A-5	2.4/4	21/31
	M-5	2.4/4	21/31
Spectra	A-4	2.0/4	24/32
	M-5	2.0/4	23/30
MERCEDES-BENZ			
E320 Bluetec	A-7	3.0/6	23/32
NISSAN			
Altima	AV	2.5/4	23/31
	M-6	2.5/4	23/32
Altima Hybrid	AV	2.5/4	35/33
Sentra	AV	2.0/4	25/33
	M-6	2.0/4	24/31
	AV	2.5/4	24/30
Versa	AV	1.8/4	27/33
	A-4	1.8/4	24/32
	M-6	1.8/4	26/31
SATURN			
Aura	A-4	2.4/4	22/30
Aura Hybrid	A-4	2.4/4	24/32
TOYOTA			
Camry	A-5	2.4/4	21/31
	M-5	2.4/4	21/31
Camry Hybrid	AV	2.4/4	33/34
Prius	AV	1.5/4	48/45

Fuel Economy Values for 2008 Vehicles

LARGE CARS			
HONDA			
Accord	A-5	2.4/4	21/31
	M-5	2.4/4	22/31
HYUNDAI			
Sonata	A-4	2.4/4	21/30
	A-5	2.4/4	21/31
SMALL STATION WAGONS			
HONDA			
Fit	A-S5	1.5/4	27/33
Fit	A-5	1.5/4	27/34
Fit	M-5	1.5/4	28/34
PONTIAC			
Vibe	M-5	1.8/4	26/33
SUZUKI			
SX4	A-4	2.0/4	22/30
SX4	M-5	2.0/4	22/30
TOYOTA			
Matrix	A-4	1.8/4	25/31
Matrix	M-5	1.8/4	26/33
SPORT UTILITY VEHICLE 2WD			
CHEVROLET			
HHR FWD	A-4	2.2/4	22/30
	M-5	2.2/4	21/30
HHR PANEL FWD	A-4	2.2/4	22/30
	M-5	2.2/4	20/30
FORD			
Escape Hybrid FWD	AV	2.3/4	34/30
MAZDA			
Tribute Hybrid 2WD	AV	2.3/4	34/30
MERCURY			
Mariner Hybrid FWD	AV	2.3/4	34/30
SATURN			
Vue Hybrid	A-4	2.4/4	25/32
DIESEL VEHICLES			
MERCEDES-BENZ	A-7	3.0/6	23/32
E320Bluetec	A-7	3.0/6	23/32

APPENDIX B

May 16, 2008

Mr. Peter Feather Office of Rulemaking National Highway Traffic Safety Administration 1200 New Jersey Avenue, S.E. Washington, D.C. 20590	Stephen Wood Office of the Chief Counsel National Highway Traffic Safety Administration 1200 New Jersey Avenue, S.E. Washington, D.C. 20590

Re: Questions Regarding Docket No. NHTSA-2008-0089, Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011-2015

Dear Messrs. Feather and Wood:

On May 9, 2008, Tom Austin, of Sierra Research sent an e-mail to Mr. Feather posing a series of questions that Sierra finds necessary to resolve in order to be able to understand and fully unpack the technical analysis behind NHTSA's notice of proposed rulemaking, as published at 73 Fed. Reg. 24,352 (May 2, 2008), and the accompanying preliminary regulatory impact analysis. As of today, Sierra has not received the answers to those questions, and I write to urge NHTSA to answer them as quickly as possible. As you are aware, the magnitude of the CAFE rulemaking contemplated in the May 2 NPRM is sweeping and of the greatest importance to the automobile industry, while the comment period is relatively short (ending July 1, 2008). For this abbreviated comment opportunity to be meaningful, as is required by law, NHTSA must fully assist Sierra in resolving Sierra's inquiries in the very near future.

For your convenience, I restate below the list of questions Sierra still needs to have answered:

> "The technology penetration tables in the PRIA are not sufficient to show the technology combinations that NHTSA actually assumed. The information contained in the 'decision tree' figures isn't sufficient either. Answers to the following questions would help us determine what combinations were actually modeled[:]
>
> > "1. Why does the MY 2015 penetration rate of VVT technology in Table V-11b and similar tables exceed 100%?
> >
> > "2. On which transmissions is ASL assumed to be used in MY2015?

“3. What other engine technologies are used in combination with Turbo/Downsize? Specifically, is VVLTD, VVLTC, or cylinder deactivation (DISP) assumed?

“4. In the ‘decision tree’ on page V-64, is DISP retained when VVLT is added?

“5. In the ‘decision tree’ on page V-64, is VVLT retained when GDI is added?
“6. In the ‘decision tree’ on page V-65, is ASL retained when the transmission is changed to AMT?

“Answers to the following questions would help clarify the benefit estimates that NHTSA is assuming for specific technologies[:]

“1. Shift Logic — Does NHTSA have a specific definition of baseline non-aggressive shift logic and aggressive shift logic in terms of the upshift and downshift points as a function of engine load in each gear? How did NHTSA determine the percent of vehicles using aggressive shift logic in the baseline?

“2. Understanding Hybrid Benefits — Based on Table V-2, the benefits of 2-mode hybrids and Power Split hybrids over the non-hybrid baseline are 15.2% (1-(1.075*1.035*1.035)) and 22.6% (1-(1.075*1.035*1.035*1.065)), respectively. However, the text says ‘NHTSA estimates that Power Split hybrids can achieve incremental fuel consumption reductions of 25 to 35% over conventionally powered vehicles.’ Is the difference due to the fact that the hybrid estimates in Table V-2 are incremental to the use of something other than ‘conventionally powered vehicles?’ If so, at what point in the ‘decision trees’ are hybrids applied and do the engine technologies already applied at that point carry forward? For example, is hybrid technology used in combination with Turbo/Downsize or VVLTC? Is it correct to assume the transmission technologies do NOT carry forward, but the hybrid benefits are incremental to something other than a baseline transmission? If so, what is the transmission that the hybrid system benefits are incremental to?

“3. Cam Phasers — The decision tree on page V-64 indicates that dual cam phasers are applied subsequent to the use of intake cam phasers. Does that mean that the benefit of dual cam phasers shown in Table V-2 is incremental to intake cam phasing?

“4. In Table V-2, is the benefit for cylinder deactivation incremental to the use of dual cam phasers and are dual cam phasers assumed to still be used?

“5. In Table V-2, are the benefits for VVLT incremental to cylinder deactivation and is cylinder deactivation assumed to still be used when VVLT is added?

6. On the overhead valve branch of Table V-2, does the incremental benefit for ‘continuous VVLT’ assume that coupled cam phasing was in the baseline?

“7. If cylinder deactivation is ever assumed to be used in combination with VVT or VVLT, what "synergy" was assumed?

> "8. If cylinder deactivation or VVLT are ever assumed to be used in combination with Turbo/Downsize, what 'synergies' are assumed?"

Sierra is flexible about the process NHTSA could employ to answer these questions. They could be resolved by way of a written response, or, more profitably, they could be answered by way of a telephonic conference call in which any relevant staff from NHTSA or the Volpe Center are made available so that Sierra's consultants could have an interactive conversation with them. The Alliance's only interest is that the questions be answered, and that they be answered as expeditiously as possible. Sierra may have additional questions as it continues its analysis, and so I would also suggest that NHTSA establish a means for resolving those questions that will not require further letter-writing.

In sum, consistent with its obligations under the law and with the diligence and thoroughness for which the agency is known, NHTSA should quickly initiate a process with Sierra to resolve Sierra's serious questions, and bring such a process to a conclusion as soon as is practicable. Please let me know expeditiously if for some reason NHTSA disagrees with the need to resolve Sierra's questions.

Thank you for your attention to this letter and please contact me (Ph: 202/326-5511; jbecker@autoalliance.org) if you need additional information from the Alliance before you can answer the questions listed above.

Sincerely,

Julie C Becker

Julie C. Becker
Vice President
Environmental Affairs

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

Acc. No. 0575

STATEMENT OF:
THE UNION OF CONCERNED SCIENTISTS

BEFORE THE:
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

BY
ELI HOPSON, WASHINGTON REPRESENTATIVE

AUGUST 4, 2008

First I would like to thank NHTSA for holding this hearing, and for giving us the opportunity to offer comments on the draft EIS. I am the Washington Representative for the Clean Vehicles Program of the Union of Concerned Scientists (UCS). UCS is a leading science-based nonprofit that has been working for a healthy environment and a safer world for over 30 years.

The topic of this hearing, the environmental impact of fuel economy standards, could not be more urgent.

Put simply, global warming is the single biggest environmental threat facing the country and the world. Four dollar a gallon gasoline is strangling our economy. But within these threats are buried opportunities. Increasing fuel economy standards will reduce global warming pollution from our cars and trucks, will cut America's oil addiction, and will save consumers billions. At the same time, the investments we make in our domestic auto industry will strengthen our economy and our ailing domestic auto makers - as we help them build vehicles that are essential to avoiding the worst impacts of global warming.

There are two primary flaws in the draft EIS that must be fixed to give the public a true idea of the potential environmental impact of this rule. First, the fuel economy standards are being measured for their global impact, even though they only affect a portion of all manmade sources of global warming pollution. Second, the methodology of the rule upon which this EIS is based is fundamentally flawed, and improperly limits the potential environmental benefits from increasing fuel economy.

Fuel Economy Provides Dramatic Reductions in Global Warming Pollution

If we are to avoid the worst impacts of climate change, **our nation and the world must adopt a target that will keep global temperature from rising more than 2°C above pre-industrial levels.** That means stabilizing the concentration of global warming pollutants in our atmosphere at no more than 450 parts per million carbon dioxide equivalent. Analysis by UCS shows that **one part of achieving this goal means the United States must cut global warming pollution by at least 80%** compared to emission levels in 2000.[1] In addition, UCS analysis indicates that in order to effectively achieve such a long-term goal, **U.S. global warming pollution must be**

[1] http://www.ucsusa.org/assets/documents/global_warming/emissions-target-report.pdf

cut by more than 20% below 2000 levels by 2020, and at least 50% below by 2030. The need for comprehensive climate policy, both in the near and long term is not properly addressed in the draft EIS, nor is the cost of inaction.

There is no single silver bullet that will dramatically cut U.S. global warming pollution and no single sector will be able to carry the full burden. Instead, **the country will have to put in place a comprehensive climate and energy policy that encourages a diverse portfolio of solutions in every sector**. Transportation, including the cars and trucks consumers drive every day, will have to play a significant role in meeting this essential 80% reduction minimum and all options for cutting pollution from transportation must be on the table.

This brings me to the first major concern with the draft EIS: the analysis done by NHTSA only presents the reductions in the context of their direct impact relative to all man-made global emissions, rather than just the emissions from the sector the policy targets. Just because higher U.S. fuel economy standards alone won't solve global warming does not discount the fact that they are a vital, necessary part of the solution. By stating them in terms of the percent reduction from covered vehicles (approximately 30 percent) rather than in percent of worldwide reductions (0.8-1.1 percent reduction according to the DEIS,) the value of fuel economy in reducing global warming pollution would be clearer, and less misleading to the public. NHTSA's approach in the EIS is like arguing that we shouldn't worry about smoking in 16 year olds because they only represent a small portion of all smokers. This argument could be applied to any sector of the economy to argue for inaction. Instead we must begin to reduce global warming pollution from every sector as soon as possible.

NHTSA's Modeling and Analysis for the Base Rule is Flawed, and Undervalues Fuel Economy Increases

To tackle global warming, reduce America's oil addiction, and save consumers tens of billions of dollars, we must give consumers and corporations new vehicle options to use fuel more efficiently when they travel.

Through the Energy Independence and Security Act (EISA), **Congress led the nation forward on fuel economy for cars and light trucks for the first time in more than three decades**.

The projected benefits of just the minimum required for fuel economy highlight the importance of keeping efficiency a top priority. Meeting the minimum fuel economy requirement of 35 miles per gallon would cut global warming pollution for new cars and trucks nearly 30% by 2020. The minimum will also reduce oil consumption by nearly 9 billion barrels through 2030, rising to about 30 billion barrels saved through 2050. And finally, boosting fuel economy from today's 25 mpg average to 35 mpg will save consumers the equivalent of reducing the price of today's $4 per gallon gasoline by more than one dollar.

Instead of doing the bare minimum to satisfy the law, **NHTSA should put cars and trucks on a path to 42 mpg by 2020 and at least 50 mpg by 2030. This would cut global warming pollution from new cars and trucks in half by 2030 and would save about 50 billion barrels of oil through 2050.**

A recent UCS report indicates that automakers can cost-effectively boost the fleetwide average fuel economy of cars and trucks to 42 mpg by 2020 and to more than 50 mpg by 2030,[2] with a modest 25% penetration of hybrids by 2020. Yet the recent notice of proposed rulemaking just barely gets cars and trucks on the road to the 35 mpg minimum by 2020,[3] and assumes that hybrids don't enter the market until 2014. Let me just reiterate that – despite the fact that there are more than one million hybrids on the road today, in 2008, and that the Toyota Prius is the 9th best-selling car in America, the analysis NHTSA used assumes hybrids won't reach the market until 2014. People are not sitting around waiting for a hybrid to show up on a dealer's lot in six years. They are on six month wait lists to buy one because they are already so popular.

There are a number of additional flaws in the base analysis that unnecessarily limit the benefits from the rule by limiting the application of available technology:

- While gasoline prices soared above $3 per gallon this winter and have hovered around $4 per gallon this summer, NHTSA relied on projections of $2.25-$2.50 per gallon.

- While carbon dioxide futures are currently trading at more than $40 per metric ton in Europe, NHTSA used a value of $7 per ton. NHTSA even considered $0 per ton to be in the range of possible values. In the face of numerous economic analyses which indicate that combating global warming will greatly reduce the cost of adapting to climate change, factoring a $0 value into the rule is unacceptable.

- NHTSA left out the military and strategic costs of America's oil addiction.

- NHTSA assumed light trucks would grow in market share, but between 2005 and 2008 the market share of light trucks sold from January to May dropped from 54% to 48%.

- NHTSA based its rulemaking on costs and benefits on the margin rather than the total costs and benefits of improved standards.

- For more details on these, and other flaws in the base analysis, please see UCS's formal comments on the NPRM.[4]

Changes along these lines would redirect NHTSA's rule and EIS to illustrate the full potential of fuel economy standards. **NHTSA's own analysis confirms that simply using more realistic gas prices or switching to an analysis based on total benefits would have led them to propose a fleetwide average of at least 35 mpg by 2015—five years earlier than the required minimum**.[5] Given the urgency of global warming, and the fact that removing CO2 early on is essential to reducing the risks of dangerous climate change, NHTSA is significantly underestimating the potential environmental impact of increased fuel economy simply because they are failing to exercise their legal obligation to set standards at maximum feasible levels.

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[2] http://www.ucsusa.org/assets/redesign-documents/clean_vehicles/UCS-Setting-the-Standard.pdf
[3] http://www.ucsusa.org/news/press_release/new-fuel-economy-proposal-star-0111.html
[4] http://www.ucsusa.org/assets/documents/clean_vehicles/UCS-2011-2015-CAFE-Comments.pdf
[5] Pages III-6, IX-12 and IX-13. in NHTSA's Preliminary Regulatory Impact Analysis for their proposed fuel economy standards for Model Year 2011-2015 cars and light trucks.

Conclusion

If left unchecked, climate change will have direct and significant impacts on our transportation system. But that same system can be an essential part of the solution set to help avoid the worst impacts of climate change.

Yes, U.S. fuel economy standards alone will not prevent the worst affects global warming. But they can dramatically lower global warming pollution, save consumers billions, create new jobs in America and ultimately cut our addiction to oil. NHTSA's draft EIS and the underlying rule should both reflect these facts.

Public Citizen

August 18, 2008

Mr. Stephen Kratzke
Associate Administrator
National Highway Traffic Safety Administration (NHTSA)
1200 New Jersey Ave., SE
Department of Transportation, West Building
Washington, DC 20590

Comments on Draft Environmental Impact Statement (EIS) for New Corporate Average Fuel Economy Standards, 73 FR 37922, July 2, 2008, Docket No. NHTSA-2008-0060

Dear Associate Administrator Kratzke:

Public Citizen respectfully submits these comments on the draft Environmental Impact Statement (EIS) prepared by the National Highway Traffic Safety Administration (NHTSA) to accompany the new Corporate Average Fuel Economy (CAFE) standards proposed May 2, 2008.[1] These CAFE standards have been proposed pursuant to the Energy Independence and Security Act, and the EIS has been prepared consistent with the findings of the Ninth Circuit Court of Appeals in *Center for Biological Diversity v. National Highway Traffic Safety Administration*.[2]

NHTSA has not completed this draft EIS in accordance with the requirements under the National Environmental Policy Act (NEPA).[3] This document does not put the potential impacts of fuel economy standards in a context that allows for a meaningful comparison of alternatives, which unfairly biases judgment in favor of NHTSA's preferred action. The purpose of the EIS process is to provide an analysis of the environmental impacts that allows decision makers to consider whether the preferred action is also the action that produces the greatest environmental benefits.

The implications of this draft EIS extend beyond its impact on the CAFE rulemaking. The agency has a responsibility to develop this document thoughtfully and with appropriate attention to the unique challenges of tackling an EIS that treats a global problem. Putting the impacts of each alternative into the proper context is absolutely vital to comparing regulatory alternatives. Because the scope of global warming is great, and action will be required by multiple actors and policies, it is impossible for this single action to resolve the problem. However, it is wrong to take the perspective that because this action alone is inadequate that it is unnecessary to compare regulatory alternatives and take the action that puts us on the correct path to reducing greenhouse gas emissions from light duty vehicles.

The need for appropriate and decisive action in reducing greenhouse gas emissions across the entire economy requires that each sector identify its role in achieving these reductions, which is why it is particularly troubling that NHTSA has not effectively contextualized the role that fuel economy standards play in reducing global warming pollution.

Public Citizen has the following concerns with the draft EIS:

- NHTSA has not considered a full range of alternatives to the agency's proposed action.
- NHTSA has not placed the impacts into a meaningful or useful context to aid decision makers and the public in selecting the proper course of action.
- NHTSA has constrained the evaluation of the various impacts of different alternative scenarios in its use of the CAFE Compliance and Effects Model (commonly, the Volpe model).

Range of Alternatives

The range of alternatives is the "heart" of the EIS, with comparisons of the impacts of various alternatives "sharply defining the issues and providing a *clear basis* for choice among options by the decisionmaker and the public."[4] To this aim, NHTSA has neither sharply defined the issues, nor has it provided a clear basis for choice among the options. Furthermore, NHTSA has not fulfilled the obligation to "rigorously explore and objectively evaluate all reasonable alternatives," "[i]nclude reasonable alternatives not within the jurisdiction of the lead agency," or "[i]nclude appropriate mitigation measures not already included in the proposed action or alternatives."[5] NHTSA's range of alternatives is unreasonably constrained by the Volpe model's assumptions regarding the inputs, and NHTSA does not consider other reasonable alternatives out of its jurisdiction.

The National Environmental Policy Act (NEPA) requires that the EIS "serve as an *action-forcing* device to insure that the policies and goals defined in the [National Environmental Policy] Act are infused into the ongoing programs and actions of the Federal Government."[6] NHTSA provides a range of alternatives for this draft EIS which amount to merely tweaking the economic assumptions that are used in the Volpe model. NHTSA has obfuscated the relative benefits of the alternatives it considered by not putting the impacts in context.

NHTSA has unreasonably constrained its range of alternatives, omitting a number of reasonable options. For example, NHTSA considered but did not analyze in detail more aggressive or accelerated standards. Instead, the agency asserts that it requires standards be raised by 4.5 percent per year, a rate fast enough that extended to 2020 would exceed the 35 by 2020 mandate of Congress. The agency explains, "other alternatives that would establish higher CAFE standards would result in larger fuel savings and emission reductions than those resulting from the preferred alternative. However, they would also result in lower net benefits than the preferred alternative due to higher costs to society. As such, NHTSA is already considering accelerated fuel economy standards."[8]

NHTSA does not consider impacts of extending fuel economy standards beyond the mandated 35 mpg by 2020, although there is clear need and a Congressional mandate to continue to improve efficiency to make the reductions that are needed, which serves to minimize the value of action when NHTSA extrapolates the benefits to 2100. However, EISA requires that NHTSA set fuel economy standards that are the maximum feasible for each model year from 2021-2030. Standards that exceed the 2020 level should be considered to increase at least until 2030, when the statutory mandate ends. It is also reasonably foreseeable that fuel economy standards or some combination of policies will be employed to continue to reduce oil consumption beyond 2020.[9]

The agency also does not include a technology-forcing alternative as required by Energy Policy and Conservation Act (EPCA).[10] While EPCA does not provide explicit guidance, NHTSA has been chided in its interpretation of the balance of the four factors in the statute. In *Center for Biological Diversity v. NHTSA*, the Ninth Circuit Court of Appeals found that NHTSA's weighing the value of consumer choice over the "need of the nation to conserve energy" was arbitrary and capricious. The courts have affirmed the idea that technology-forcing statutes can impose standards that are at the technology horizon – levels which only the most advanced facilities in an industry may only achieve some of the time.[11]

Consideration of alternatives not within the jurisdiction of the lead agency and mitigation measures not included in the proposed action or alternatives are particularly important in addressing the implications of fuel economy standards on reducing greenhouse gas emissions. NHTSA must therefore consider actions that fall outside the scope of the proposed action, and outside of the agency's jurisdiction – something it specifically failed to do when it stated in the draft EIS: "NHTSA emphasizes to the reader of this DEIS that the proposed action does not directly regulate the emissions from passenger cars and light trucks. NHTSA does not have that authority."[12]

In *Center for Biological Diversity v. NHTSA* the Ninth Circuit cites *Center for Auto Safety v. NHTSA*: "Congress intended energy conservation to be a long term effort that would continue through temporary improvements in energy availability. Thus, it would clearly be impermissible for NHTSA to rely on consumer demand to such an extent that it ignored the overarching goal of fuel conservation."[13] Climate policy will also be a long term effort that will require consistent policy to achieve goals with a long horizon and whose benefits are even further in the future. For any action we take to meet greenhouse gas emission reduction targets to be meaningful, the policy must be consistent through periods of variability.

Context

An EIS is meant to aid decision makers and the public in assessing the relative value of a proposed action or alternative. For this draft EIS to be useful as a decision-making tool, it must compare the impacts of various alternatives in the proper context. Light duty vehicles built for sale in the United States are part of the whole set of greenhouse gas-emitting sources, regulation of which, as NHTSA has stated, cannot alone stop global warming from happening.[14] However, the agency has not established a meaningful context, instead choosing to extrapolate the benefits of each alternative over the entire globe 90 years into the future. NHTSA must discuss the benefit of any action in terms of its impact on climate change and it must be placed into a context that includes other strategies to reduce greenhouse gas emissions. This perspective allows for decision makers and the public to judge whether the agency's proposed action results in emissions reductions that are consistent with the contribution to emissions from light duty transportation in light of the technological feasibility of making those emissions reductions.

The draft EIS states that none of the proposed alternatives actually result in absolute reductions in greenhouse gas emissions, but instead result in a reduced rate of greenhouse gas emissions from light duty passenger vehicles.[15] NHTSA must therefore consider fuel economy standards as part of a comprehensive strategy to reduce greenhouse gas emissions from light duty transportation that may include policies that are not within its jurisdiction. NEPA requires "considerations of both context and intensity. . . . [Context] means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action. For instance, in the case of a site-specific action, significance would usually depend upon the effects in the locale rather than in the world as a whole. Both short- and long-term effects are relevant."[16] In this case, significance requires that NHTSA consider impacts in the context of multiple strategies for reducing greenhouse gas emissions from light duty transportation as part of a comprehensive strategy to achieve atmospheric concentrations of greenhouse gases that will prevent the most harmful effects of global warming.

For the context to be meaningful, NHTSA needs to establish a target for greenhouse gas reductions. It can then show how the various proposed alternatives fit into the reductions that are necessary from the U.S. light duty transportation sector to meet that target. Public Citizen supports reduction of atmospheric concentrations of CO_2 to 350 parts per million (ppm) to prevent the most catastrophic effects of climate change.[17] The policy debate surrounding global warming has considered other targets for atmospheric concentrations, such as 450 ppm or 550 ppm. Public Citizen does not seek to resolve the question of a target for atmospheric concentrations of greenhouse gases at this time, nor does it expect that NHTSA resolve this question in the draft EIS. However, NHTSA must present the regulatory alternatives for fuel economy standards required under EISA such a way as to present a clear choice to decision makers and the public. The agency must therefore select a target or range of atmospheric concentrations of greenhouse gases to provide a framework within which it can discuss the relative benefit of different regulatory options.

NHTSA cannot dictate national and international climate policy through this draft EIS, nor would it be desirable that it do so. When the Environmental Protection Agency (EPA) completed an analysis of pathways to reduce greenhouse gas emissions from the transportation sector it modeled scenarios for 450, 550, 650 and 750 ppm.[18] In its analysis, EPA also looked at three approaches to reducing greenhouse gases from the transportation sector: improvements in vehicle technology, reducing greenhouse gas emissions from transportation fuels, and employing tactics to achieve reductions in travel demand.

NHTSA has also influenced the context by choosing a baseline that is too low. The agency's baseline is the no action alternative; however, the agency assumes fuel economy levels of 27.5 mpg for passenger cars and 23.5 mpg for light trucks.[19] NHTSA's most recent report on the level of fuel economy performance of vehicles estimates that passenger cars are getting 31.2 mpg and light trucks are getting 23.4 mpg.[20] However, even this level of fuel economy is unlikely to capture a real baseline, considering the intense shift in consumer demand for fuel efficient vehicles and the auto industry's scrambling to produce and market more efficient vehicles.[21]

Volpe Model

Public Citizen opposes the use of marginal cost-benefit analysis in estimating the maximum feasible level of fuel economy, as this type of economic analysis structurally fails to set the maximum feasible level. We acknowlege that the Ninth Circuit Court of Appeals reserved judgment: "[EPCA] is silent on the precise question of whether a marginal cost-benefit analysis may be used;" however, the Court also admonished the agency for not putting enough emphasis on the need of the nation to conserve energy.[22] The structure of the Volpe model is such that the standards it prescribes are heavily influenced by the economic assumptions and product plans provided by the auto industry.

The Volpe model for fuel economy is structured in such a way that it undercuts the maximum feasible level of fuel economy statutorily mandated by EPCA. This is because the model is designed to minimize the estimate of what is technologically feasible and economically practicable. The fuel economy targets set by the Volpe model are a direct product of the economic assumptions made in the inputs to the model. The model also constrains the level of fuel economy by excluding technologies judged not to be cost efficient, and applying phase-in caps on certain technologies, which skews the impacts across the entire range of alternatives.

Since the economic assumptions NHTSA makes in the Volpe model are the single biggest factor in determining the level of fuel economy standards, it is vitally important that its estimates be as accurate as possible. NHTSA's sensitivity analysis of the model shows that the model is most sensitive to changes in the price of gasoline; however, the assumptions the agency makes about the future price of fuel have been the source of significant controversy. Public Citizen commented more extensively about the economic assumptions made in the Volpe model for NHTSA's Notice of Proposed Rulemaking (NPRM) for the CAFE standards, but we would like to make the following comments on the economic assumptions:[23]

- The future fuel price assumptions are unjustifiably low, assuming at 2030 price of gasoline at $2.51. The administrator of the Energy Information Administration has publicly stated that NHTSA should use the high-end estimate in setting fuel economy standards.[24]
- NHTSA has set the price of CO_2 arbitrarily and too low. The agency chose a value of \$7/ton CO_2 based on a 2005 meta-analysis of estimates of the price per ton of carbon by Richard S. J. Tol, from which NHTSA estimated prices per ton of carbon, and NHTSA converted the range to \$0-14 per ton CO_2. In comments to NHTSA's NPRM, Tol commented that NHTSA has improperly indexed the values in the Tol paper, as they were in 1995 dollars instead of 2005 dollars, and also that a 2007 paper he authored found larger estimates than the 2005 paper.[25]

- NHTSA has assumed a very high rebound effect, which also influences its assumptions both in the appropriate level of standards and the potential environmental benefits of each of the range of alternatives.

The Volpe model inappropriately constrains NHTSA from considering a reasonable range of alternatives. As we have described above, and in our comments to the NPRM, the economic assumptions NHTSA makes in the Volpe model inaccurately underestimate the maximum feasible level of fuel economy. Each of the alternatives proposed by the agency are based on the preferred action proposed by NHTSA, and the benefits of each alternative are estimated using the assumptions contained in the Volpe model.

The Volpe model also uses incomplete and inaccurate inputs from the auto industry to make projections about the future fleet mix and market preference. NHTSA solicited the automakers to provide product plans with which it could complete the modeling to set the fuel economy standards. However, many of the automakers solicited provided incomplete data, or no data at all. In these cases, NHTSA assumed that automakers would make no change from model year to model year, which skews the model to prefer no change in vehicle characteristics or fleet mix. In recent months, several major automakers have announced plans to substantially change their product plans.[26]

The Volpe model does not estimate market shifts, and therefore cannot predict the experience of recent months, where sales of light trucks have plummeted and sales of small cars have skyrocketed in response to high oil prices.[27] The vehicles automakers are offering do not achieve a level of fuel economy consumers want, and vehicles that comply with the 2011-2015 standards will not achieve a level of fuel economy that consumers want.[28] NHTSA's failure to effectively regulate the industry has resulted in a market that offers too few choices to consumers, and the Volpe model will exacerbate this problem rather than correct it, by relying on outdated information from the automakers.

The assumptions made as part of the Volpe model serve to resist aggressive fuel economy improvements, and even the most aggressive alternative considered falls short of what American consumers want, and what other countries are requiring. The minimizing effect of the economic assumptions used Volpe model serves to obscure the relative benefits of its proposed alternatives.

Conclusion

Public Citizen would like to express disappointment that the agency is furthering the Bush administration's policy of inaction on global warming. The agency has crafted its draft EIS in such a way to obscure the relative benefit of a limited range of regulatory options, which is contrary to legal requirements in developing the document. Rather than present options in a context that allows for clear comparison between regulatory alternatives, it has obfuscated the relative benefits by extrapolating them to global impacts until 2100. NHTSA's promotion of inaction is consistent with the Bush administration's inaction on all global warming action.

EPCA was passed at a time of national anxiety about oil prices, energy security, and environmental consequences of petroleum. Congress intended that this new policy would encourage not just a reduction in petroleum consumption, but it would encourage energy policy to include principles of conservation into the future. The implementation of EPCA in the years between 1985 and the enactment of EISA have not been consistent with these goals. NHTSA incorrectly based the need of the nation to conserve energy on the price of oil. The agency's failure to appropriately intervene and raise fuel economy standards during the period of relatively low oil prices during the 1980s and 1990s has made consumers and the auto industry vulnerable to exactly the kind of market shift that has happened in the past year.

In the face of spiking oil prices, Congress acted in 2007 to mandate that NHTSA raise fuel economy standards again. However, as the House Select Committee on Global Warming and Energy Independence explained in a July 2008 report, had Congress acted in 1994 to raise fuel economy standards again, the fleet of passenger cars and light trucks would have already been getting 35 miles per gallon in 2006.[29]

History has shown that energy policy requires a long view, and consistency of policy that extends far into the future. NHTSA's role as a regulatory agency is to require incremental increases in conservation and efficiency to give consumers and the auto industry more flexibility to respond to a volatile and competitive energy market, and also to play its appropriate role in protecting against the most harmful effects of global warming. This draft EIS fails to promote consistent, effective policy both in terms of energy and the environment.

[1] *See* 73 FR 24352, 24487. (May 2, 2008).
[2] Energy Independence and Security Act (EISA). P.L. 110-140 (Dec. 19, 2007). & *Center for Biological Diversity et al., v. NHTSA.* 508 F. 3d 508. (Nov. 15, 2007).
[3] 42 U.S.C. §4321 et seq., Pub. L. 91-190 (Jan. 1, 1970).
[4] 40 CFR 1502.14. emphasis added.
[5] *Id.*
[6] 40 CFR 1502.1. emphasis added.
[8] *See Draft Environmental Impact Statement, Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015*. National Highway Traffic Safety Administration. (June 2008). at 2-11.
[9] *See* Comments of Natural Resources Defense Council to NHTSA-2008-0060 at 0557. (Aug. 14, 2008).
[10] Energy Policy and Conservation Act. Pub. L. 94-163 (Dec. 22, 1975).
[11] *See Kennecott Greens Creek Mining Co. v. Mine Safety and Health Administration*. 476 F.3d 946, 957 (D.C. Cir. 2007). & *United Steelworkers of America, AFL-CIO-CLC v. Marshall* 647 F.2d 1189, 1246 (D.C. Cir. 1980).
[12] Draft EIS at S-4. *Supra* note 6
[13] *Center for Auto Safety v. NHTSA*. 793 F.2d 1322, 1338. (Jun. 20, 1986).
[14] DEIS at S-4. *Supra* note 6.
[15] *Id.*
[16] 40 CFR 1508.27
[17] *See* James Hansen et al. "Target Atmospheric CO_2: Where Should Humanity Aim?" (April 2008). Available at < http://www.columbia.edu/~jeh1/2008/TargetCO2_20080407.pdf>
[18] "A Wedge Analysis of the U.S. Transportation Sector." Environmental Protection Agency. EPA420-R-07-007. (April 2007).
[19] Draft EIS at 2-7. *Supra* note 6.
[20] "Summary of Fuel Economy Performance." National Highway Traffic Safety Administration. (Mar. 2008).
[21] *See* Leslie Allen. "GM Expands Fuel Efficient XFE Lineup for 2009." *Automotive News.* (Aug. 12, 2008). & Bill Vlasic. "As Gas Costs Soar, Buyers Flock to Small Cars." *New York Times*. (May 2, 2008).
[22] *Center for Biological Diversity v. NHTSA. Supra* note 2.
[23] *See* Comments of Public Citizen to NHTSA-2008-0089 at 0187. (Jul. 2, 2008).
[24] *See* letter from Rep. Rahm Emmanuel and Rep. Edward Markey to President Bush. (Jun. 18, 2008) & David Shephardson. "House committee chair urges NHTSA to set tougher fuel economy requirements." *The Detroit News*. (Jun. 26, 2008).
[25] S*ee* Comments of Richard S.J. Tol to NHTSA-2008-0089 at 0152 (Jun. 30, 2008)
[26] *See* Tom Krishener. "GM to close 4 plants, focus on small cars." Associated Press. (Jun. 3, 2008). & Christine Tierney. "Even Toyota must retool in the U.S." *The Detroit News*. (Aug. 11, 2008).
[27] 73 FR 24394.
[28] *See* Consumer Federation of America. "Consumers Want Fuel Economy They Can't Find." (Apr. 21, 2008).
[29] *See* House of Representatives, Select Committee on Energy Independence and Global Warming. "Republican Regret: What if a Republican Congress had passed, not blocked, higher fuel economy standards?" (Jul. 29, 2008). Available at < http://globalwarming.house.gov/tools/2q08materials/files/0123.pdf>

ATTORNEYS GENERAL OF THE STATES OF CALIFORNIA, MASSACHUSETTS, NEW JERSEY, NEW MEXICO, NEW YORK, AND OREGON, SECRETARY OF THE COMMONWEALTH OF PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION, AND NEW YORK CITY CORPORATION COUNSEL

Via Upload to Docket No. NHTSA-2008-0060 at www.regulations.gov

August 18, 2008

The Honorable James F. Ports, Jr.
Deputy Administrator
National Highway Traffic Safety Administration
U.S. Department of Transportation
West Building
1200 New Jersey Ave., SE
Washington, D.C. 20590

RE: Comments Regarding Draft Environmental Impact Statement for New Corporate Average Fuel Economy Standards [Docket No. NHTSA-2008-0060]

Dear Administrator Ports:

The Attorneys General of the States of California, Massachusetts, New Jersey, New Mexico, New York, Oregon, the Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, and the Corporation Counsel of the City of New York submit these comments regarding the Draft Environmental Impact Statement ("DEIS") for the New Corporate Average Fuel Economy ("CAFE") Standards for Model Years 2011-2015.[1]

SUMMARY

In the past, the National Highway Traffic Safety Administration ("NHTSA") dismissed the impact of its fuel economy rulemaking on global warming by stating that the relatively small changes in greenhouse gas ("GHG") emissions caused by the CAFE rule, when compared to global emissions overall, were insignificant. Having been instructed by the Ninth Circuit Court of Appeals that this approach is improper,[2] NHTSA has now issued a DEIS addressing GHG

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[1]A number of state attorneys general and state agencies, and several municipalities, have previously provided comments to NHTSA on the scoping of the DEIS and on the substance of the new CAFE rule. We are providing copies of the earlier submissions as attachments to this letter.

[2]*See Center for Biological Diversity v. National Highway Traffic Safety Administration (NHTSA)*, 508 F.3d 508, 554, 556, 558 (9th Cir. 2007). The Ninth Circuit today withdrew its former opinion and filed a new opinion in this matter. *Center for Biological Diversity v. NHTSA*,

emissions from the CAFE rule and the impact on global warning.

While we commend the Agency for beginning the steps toward preparing an Environmental Impact Statement in compliance with the National Environmental Policy Act ("NEPA"), 42 U.S.C. §§ 4232 *et seq.*, and, in particular, addressing the impact of the CAFE rule on GHG emissions and global warming, we have significant concerns about the manner in which the DEIS analyzes and presents the information. We believe that the deficiencies in the analysis and presentation make the document violative of NEPA.

As discussed below, NHTSA has presented the data on GHG emissions and global warming in a manner that emphasizes that relatively small changes in GHGs, when viewed in isolation, cause relatively modest effects in global warming. Thus, NHTSA underplays the significance of its CAFE rulemaking by stating that the alternatives "do not prevent climate change from occurring, but only result in small reductions in the anticipated increases in CO_2 concentrations, temperature, precipitation, and sea level." DEIS at S-4. As the Ninth Circuit, however, pointed out, global warming is by nature a phenomenon that can only be addressed through the cumulative impact of numerous small changes. "Any given rule setting a CAFE standard might have an 'individually minor' effect on the environment but these rules are 'collectively significant actions taking place over a period of time.'" *Center for Biological Diversity,* 508 F.3d at p. 550 (quoting 40 C.F.R. § 1508.7). Thus, while the effects of the CAFE rule in isolation may be relatively insignificant, in combination with other actions, they are what will determine the future of our world.

The critical question that must be addressed in the DEIS is not whether relatively modest changes in carbon dioxide ("CO_2") concentrations and temperature will result from one or even two iterations of the CAFE rule, but rather whether the CAFE rule and reasonably anticipated future CAFE rules, when combined with actions that are being taken and will be taken globally, put us on a path to keeping GHG emissions below the level required to prevent catastrophic climate change. If the new CAFE rule continues a trajectory of emissions and CO_2 concentrations that scientists anticipate will lead to environmental cataclysm, the DEIS must reveal and explain that to the public.

Further, the answer to this question is required as much by the Energy Policy and Conservation Act ("EPCA"), 49 U.S.C. §§ 32902 *et seq.*, as it is by NEPA. As NHTSA acknowledges, environmental effects, including global warming, are an aspect of our need to conserve energy, and are therefore a component of the factors that NHTSA must consider under EPCA in setting the CAFE standard. DEIS at 1-2. Ultimately, therefore, the DEIS must disclose

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No. 067181, slip. op. at 10773 (9th Cir. August 18, 2008). While the citation references will change, the new opinion does not affect any of the analysis set forth in this comment letter.

whether NHTSA has adequately considered the environmental impacts of its new CAFE rule, and determined whether the need to reduce GHG emissions is of such critical importance that it requires the Agency to place more emphasis on energy conservation and to set the CAFE standard at a significantly higher level than proposed. In this case, the higher level would be represented either by the 25% above optimized, 50% above optimized, total cost equal total benefits, or technology exhaustion level alternatives.[3] The DEIS does not answer this question.

Because NHTSA has not performed the analysis necessary for either the decisionmakers or the public to understand the ramifications of the Agency's decision, the DEIS is inadequate. The Agency should therefore issue a new draft document and circulate it for public review and comment prior to finalizing an environmental impact statement and proceeding with the rulemaking.

DISCUSSION

NEPA has a two-fold purpose. In addition to ensuring that the agency has available and considers information concerning significant environmental impacts, NEPA "also guarantees that the relevant information will be made available to the larger audience that may also play a role in both the decisionmaking process and the implementation of that decision." *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 349 (1989); *see also Marsh v. Oregon Natural Resources Council*, 490 U.S. 360, 371 (1989) (NEPA focuses both "Government and public attention on the environmental effects of proposed agency action.").

The DEIS for the proposed CAFE rule fulfills neither purpose, since it does not provide the critical information that must be considered by both the decisionmaker and the public.

1. The DEIS Misleads the Public

In order to fulfill NEPA's goal of informing the public of the environmental impacts of the agency's decision, the EIS must "be written in plain language and may use appropriate graphics so that decisionmakers and the public can readily understand them" 40 C.F.R. § 1502.8. Further, the EIS "must be organized and written so as to be readily understandable by governmental decisionmakers and by interested non-professional laypersons likely to be affected by actions taken under the [FEIS]." *Earth Island Institute v. U.S. Forest Service*, 442 F.3d 1147, 1160 (9th Cir. 2006) (quoting *Oregon Environmental Council v. Kunzman*, 817 F.2d 484, 494

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[3] The "optimized" alternative, which is NHTSA's preferred alternative is based on "applying technologies until net benefits (discounted at 7 percent) are maximized." Technology exhaustion includes "all technologies NHTSA considered to be available without regard to cost . . . ." DEIS at 2-8.

(9th Cir. 1987).) The DEIS fails to meet this standard.

a. The DEIS Must Clarify that GHG Emissions from Passenger Cars and Light Trucks Will Continue to Increase From Past Levels

One of the most significant pieces of information that must be clarified in the DEIS is that, under the new CAFE rule, GHG emissions from passenger cars and light trucks will continue to rise over past levels, because the increase in miles per gallon ("mpg") mandated by the rule will not completely offset the increase in vehicle miles traveled ("VMT").

Rather than making this increase clear, the DEIS buries the information in the text of the document (*e.g.*, DEIS at 3-57) and repeatedly refers to the *reductions* in emissions, CO_2 concentration, and temperature.[4] In fact, the only reduction is in the amount of growth in each of these measures over what would otherwise occur without the new rule. The absolute levels are rising and will continue to rise. This distinction must be made clear both in the labeling of the graphs and figures, and in the text of the DEIS.

b. The DEIS Improperly Compares the Decrease in Growth of Emissions From the CAFE Rule with the Absolute Decrease in Emissions From the U.S. Regional Programs, Creating a False Impression of the Benefits of the Rule

The DEIS further misleads the public by setting up a false comparison between the reduction in growth of GHG emissions from the CAFE alternatives, and the absolute decrease in emissions from the climate programs created by groups of states such as the Western Climate Initiative ("WCI") and the Regional Greenhouse Gas Initiative ("RGGI"). DEIS at 3-57, 4-28 to 4-29. For example, in the cumulative impacts section, the DEIS states that the WCI has a goal of reducing CO_2 equivalent emissions by 350 million metric tons ("MMT") from 2009 to 2020, and the CAFE rule will reduce CO_2 emissions by 455-830 MMT over the same time period. The DEIS further states that the RGGI will reduce CO_2 emissions by 268 MMT from 2006 to 2024 and the CAFE rule will reduce CO_2 emissions by 1,100-1,834 MMT over the same time frame. The DEIS therefore concludes that "the alternatives analyzed here deliver GHG emission reductions that are on the same scale as many of the most progressive and ambitious GHG emission reduction programs underway in the United States." DEIS at 4-29.

[4] *See, e.g.*, DEIS at 2-14, 2-16 and Table 2.5-3, 2-20, 3-54 (referring to GHG "emissions reductions"); DEIS at 2-17 and Table 2.5-5 ("Reductions in Global Mean Precipitation"); DEIS at 4-27 ("Cumulative emissions reductions," "cumulative CO_2 reductions"); DEIS at 4-28 ("Total emission reductions").

The above analysis, and in particular, the latter statement, are affirmatively misleading. The regional goals represent absolute reductions from prior levels. In reducing CO_2 equivalents by 350 MMT, the WCI is actually committed by 2020 to bringing its level of emissions *15% below the levels that existed in 2005*. *See* Western Climate Initiative, Statement of Regional Goal, 2007 at 1.[5] Similarly, the RGGI will result in a 2018 emissions budget that is 10% smaller than the 2009 emissions budget. *See* Overview of RGGI CO_2 Budget Training Program, October 2007 at 2.[6] In contrast, the emission figures cited by NHTSA as attributable to the CAFE rule actually represent a significant increase above previous levels. In order to be "on the same scale as many of the most progressive and ambitious GHG emission reduction programs underway in the United States," the CAFE rule would have to reduce the level of GHG emissions below existing levels. Clearly, no such reduction is envisioned. In fact, a more accurate statement would be to say that the increase in GHG emissions from previous levels allowed by the CAFE rule would wipe out reductions in emissions achieved by the various regional climate coalitions.

2. The DEIS Fails to Consider the Cumulative Impacts of CAFE Rulemakings After 2020 and of Actions By Other Agencies

A federal agency is required to evaluate whether a project's impacts, though individually limited, are cumulatively significant. A cumulative impact

> is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions *regardless of what agency (Federal or non-Federal) or person undertakes such other actions*. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Id. § 1508.7 (emphasis added).

The Ninth Circuit emphasized the necessity and scope of a cumulative impacts analysis in the context of the CAFE rulemaking when it held that NHTSA must assess the "effects of *its* actions on global warming within the context of other actions that also affect global warming." *Center for Biological Diversity*, 508 F.3d at p. 550 (emphasis in original). The court further noted that NHTSA must therefore "provide the necessary contextual information about the cumulative and incremental environmental impacts of the Final Rule in light of other CAFE rulemakings and other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions." *Id.*

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[5]Available at www.westernclimateinitiative.org/ewebeditpro/items/O104F13006.pdf.

[6]Available at www.rggi.org/docs/program_summary_10_07.pdf.

NHTSA's cumulative impacts analysis fails to comply with this mandate and is flawed in several respects. On the one hand, in projecting the impact of the CAFE rule through 2100, NHTSA considers only the CAFE rules for 2011-2015 and 2016-2020, and assumes that miles per gallon will remain the same from 2020 through 2100. DEIS at 4-19, 4-27. On the other hand, it appears that NHTSA assumes that VMT will continue to increase through 2100. DEIS at 3-57. The combination of these assumptions understates NHTSA's ability to contribute cumulatively to GHG reduction efforts through more stringent CAFE standards. In the same way that it can be anticipated that VMT will continue to increase after 2020, it can also be anticipated that future CAFE rulemakings after 2020 will continue to increase the miles per gallon required for cars and light trucks, and that improved technology will enable car manufacturers to meet those increases. Thus, NHTSA must recalculate its cumulative projections to take into account the impact of future CAFE rulemakings after 2020 on the anticipated emissions through 2100.

Further, in its cumulative impacts analysis, NHTSA takes into account only the impact of its own rulemaking and ignores actions that can be anticipated in the transportation sector overall, and in other energy sectors in the United States and globally. *See., e.g.,* WCI Statement of Regional Goal; Overview of RGGI CO_2 Budget Trading Program, *supra*. The DEIS then compares the limited changes in the CAFE sector with worldwide emissions to determine the effect of these changes on CO_2 concentrations and temperature. *See, e.g.,* DEIS at 4-24, 4-31. The analysis demonstrates, not surprisingly, that the change in CO_2 concentrations and temperature caused solely by the CAFE rules will be relatively modest, ranging from 3.5 to 4.9 parts per million ("ppm") CO_2 concentration, and 0.012 to 0.018 degrees Celsius temperature. Table 4.4-3 at DEIS 4-31.

This comparison is invalid because it considers only the very limited change from the CAFE rules, while ignoring the cumulative impact of all other reasonably anticipated actions that will reduce GHG emissions both in the United States and globally. A proper cumulative impacts analysis requires the agency to consider reasonably anticipated actions by other agencies along with the impact of the CAFE rules, to determine the impact on GHG emissions and global warming.

We recognize that a cumulative impacts analysis is complex in the context of climate change because the problem is global and is being addressed at many levels worldwide. While it is difficult to determine the expected emissions reductions on a global scale, this uncertainty should not result in NHTSA understating the significance of its role in helping to resolve the climate problem. NHTSA thus must make an effort to determine whether better decisionmaking on its part, and a more stringent CAFE standard, will help to put this country on a path to climate stabilization, even if the Agency, standing alone, cannot resolve the problem.

One reasonable way to approach the analysis is to use the "stabilization wedge" concept relied on by the U.S. Environmental Protection Agency ("EPA") in discussing transportation emissions. ("EPA Transportation Wedge Analysis").[7] The wedge analysis permits evaluations based on cumulative reductions over longer time frames:

> [T]he wedge approach . . . provides a metric to make evaluations based on *cumulative* emission reductions over a longer timeframe rather than the more commonly used metrics: percent GHG reduction or absolute GHG reductions for a specific analysis year. From a climate perspective, it is *cumulative* emission reductions over longer time frames that are of primary significance. Discussions of reductions have tended to focus almost exclusively on incremental rather than cumulative emission reductions. Issues of timing and staging of the approaches can also be considered using the wedge analysis (*e.g.* the impact of near-term versus long-term technologies). Finally, the wedge analysis can be scaled to fit any analysis level of interest, including a specific emissions category, economic sector, or national and global levels.

EPA Transportation Wedge Analysis at 9-10 (emphasis in original). This analysis is discussed in more detail in Section 3.b below.

3. The DEIS Fails to Present the Data in a Meaningful Context

a. The DEIS Fails to Consider the Scientific Consensus that CO_2 Concentrations Must Be Kept Below the Level of "Dangerous Anthropogenic Interference"

While the DEIS provides a significant amount of raw data, the data are meaningless unless they are put into context. For example, simply reporting that the new CAFE rule puts us on a trajectory to reaching CO_2 levels of over 700 ppm and an increase in temperature of over 2.7 degrees Celsius by 2100 (DEIS at 4-31), is meaningless to the uninitiated because it does not provide the context related to the "tipping point" beyond which devastating and irreversible climate change impacts may occur.

While the DEIS mentions the concept of a climate "tipping point" and the fact that some climate scientists believe that a CO_2 level exceeding about 450 ppm is dangerous (DEIS at 3-52 to 3-53), it then dismisses these concepts as "still a matter of scientific investigation" (DEIS at 1-10), and claims that "the state of the science does not allow for a characterization of how the

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[7]Miu, S., J. *et al.*, A Wedge Analysis of the U.S. Transportation Sector, U.S. EPA, Transportation and Climate Division, Office of Transportation and Air Quality, EPA 420-R-07-007, April 2007 available at www.epa.gov/oms/climate/420r07007.pdf.

CAFE alternatives influence these risks, other than to say that the greater the emission reductions, the lower the risk of abrupt climate change." DEIS at 3-53 to 3-54, 4-26.

This perfunctory discussion is unacceptable. To put the raw data into a meaningful context, the DEIS should emphasize the scientific consensus that we must lower our GHG emissions significantly in order to keep CO_2 concentrations in the atmosphere below a threshold that represents "dangerous anthropogenic interference" ("DAI"). In the words of the Ninth Circuit, there is "compelling scientific evidence concerning 'positive feedback mechanisms' in the atmosphere" that could lead to abrupt and non-linear changes. *Center for Biological Diversity*, 508 F.3d at p. 554. While the precise level for DAI is not known, scientists generally agree that the threshold is *below* 550 ppm CO_2.[8] At higher levels it is likely we will have reached an irrevocable "tipping point" and the Greenland ice sheet and part of the west Antarctic ice sheet will ultimately melt, causing a 5 to 10 meter rise in global sea level, which will cause flooding of all major coastal cities, and ensure global cataclysm. Further, it is plausible that DAI will be reached even at CO_2 concentrations of 450 ppm or substantially lower.[9] The risk of environmental cataclysm, even if uncertain, is so enormous, that it cannot simply be ignored, as NHTSA does.

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[8] The United Nations Intergovernmental Panel on Climate Change ("IPCC") B1 scenario anticipates that CO_2 emissions will be stabilized at about 550 ppm. *See* Nakicenovic, N.& Swart, R. Special Report of the Intergovernmental Panel on Climate Change on Emissions Scenarios (Cambridge Univ. Press, 2000), Summary for Policymakers available online at http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf; IPCC Third Assessment Report, Climate Change 2001, The Scientific Basis, Chapter 3, Figure 3-12, available at http://www.grida.no/climate/ipcc_tar/wg1/fig3-12.htm; I.C. Prentice *et al.*, "The Carbon Cycle and Atmospheric Carbon Dioxide," in *Climate Change 2001: The Scientific Basis*, J.D. Hougton *et al.*, Eds. (Cambridge Univ. Press, Cambridge, 2001) pp. 183-237, available at http://www.grida.no/CLIMATE/IPCC_TAR/WG1/index.htm. The most recent Fourth Assessment of the IPCC (*see* note 18, *infra*) indicates a best estimate under this scenario of warming just under two degrees Celsius. However, the IPCC also recognizes that, under this scenario, there is a significant (nearly 50%) probability of greater warming. If two degrees Celsius represents dangerous anthropogenic interference, then CO_2 emissions must be stabilized at 450 ppm or lower to guarantee that we will stay below the level of DAI.

[9] *See* Hansen, J. *et al*, Global Temperature Change, Proceeding of the National Academy of Sciences, doi:10.1073/pnas.0606291103, 2006, available at www.pnas.org/content/103/39/14288.full.pdf ; Hansen, J., *et al.*, Dangerous human-made interference with climate: a GISS ModelE study, Atmos. Chem. Phys., 7, 2287-2312, 2007, available at http://pubs.giss.nasa.gov/abstracts/2007/Hansen_etal_1.html.

At the very least, the DEIS must inform the agency and the public that scientists agree that there is an area of dangerous anthropogenic interference in the range of 500 $\pm$ 50 ppm CO_2, or possibly lower, that must be avoided. This information must be incorporated into and direct the analysis. Without such information, it is clear that NHTSA has, in fact, not considered the issues in a meaningful way.

b. The DEIS Does Not Answer the Ultimate Question of Whether the Agency Has Adequately Considered Our Need to Reduce GHG Emissions and to Stabilize CO_2 Concentrations

In the end, neither the Agency nor the public can assess the impact of the CAFE rule on global warming unless the data are put into a meaningful context, which the DEIS has failed to do. One way to remedy this fundamental defect would be to refer to the various emissions scenarios modeled by the IPCC as a kind of a comparative baseline. These scenarios include the "business as usual" scenario, usually represented by the IPCC's A1B scenario, which assumes rapid economic growth, peak population by 2050, declining thereafter, rapid introduction of new, more efficient technologies, and a balanced use of both fossil and non-fossil fuels.[10] The A1B scenario stabilizes CO_2 concentrations at 720 ppm by 2100 and is associated with additional warming of 2 to 4 degrees Celsius,[11] which puts us well into the region of likely dangerous anthropogenic interference.[12]

The IPCC's "alternative" scenarios, are those in which human inputs to global warming are constrained to varying degrees and the effects of global warming are mitigated to greater and lesser extent. In particular, the B1 scenario will reduce GHG emissions below 1990 levels well before 2100 and will maintain CO_2 concentrations below 550 ppm.[13] Under this alternative scenario, GHG emissions could continue to increase briefly, but would need to level out quickly, and decline before 2050, in order to allow for the possibility of adaptation that will avoid a catastrophic disruption of life on Earth. In order to stabilize CO_2 concentrations below 450 ppm,

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[10] IPCC Summary for Policy Makers at 22, note 10, *supra.*

[11] *See* IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, at 13, 14, and Figure SPM.5 and Table SPM.3, available at http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

[12] *See* note 9, *supra.*

[13] *See* note 8, *supra.*

emissions would have to be lowered even sooner, with emission levels peaking by 2020 and then declining sharply. Even at this level, scientists predict warming of 2.0 degrees Celsius and sea level rise of half a meter or more by 2100.[14]

In the DEIS, NHTSA views the IPCC A1B scenario as representing the "no-action alternative." DEIS at 3-51, 4-24. As noted above, NHTSA simply subtracts the changes in GHG emissions attributable to the various CAFE alternatives from the A1B emissions scenario to determine the effect on CO_2 concentration and temperature. *See* DEIS at 4-22, 4-51.

This analysis, however, is not meaningful, because it does not inform the reader whether the actions of the Agency, coupled with anticipated actions of other agencies, will be sufficient to change our trajectory from the A1B "no-action" scenario, to the B1 scenario of stabilized CO_2 concentration and temperature. Thus, neither the agency nor the public can determine whether NHTSA has considered and given sufficient weight to the dangers of global warming in setting the CAFE standard at the "optimized" level, rather than at a higher level.

In order to answer the latter question, NHTSA must consider its actions within the context of the steps that are being taken or are reasonably foreseeable to be taken by all agencies, organizations, nations, and localities to prevent CO_2 concentrations in the atmosphere from reaching a level of dangerous anthropogenic interference. As noted above, it is generally agreed that, in order to maintain CO_2 concentrations at the 500 ± 50 ppm level, emissions must stabilize and begin to decline either by 2020 or 2050. Given this consensus, the DEIS should calculate what CAFE mileage standard would have to be reached by those dates, taking into account anticipated increases in VMT, in order to stabilize and reduce GHG emissions from passenger cars and light trucks. The DEIS must then determine whether the new CAFE rule moves us forward sufficiently so that we will be poised to reach the required future goals. If the proposed CAFE rule will not enable us to stabilize and begin to reduce emissions by 2020 or 2050, then what CAFE standard is necessary now to enable us to achieve the future reductions?

In making this determination, the DEIS could also make use of the concept of "stabilization wedges," first advanced by Pacala and Socolow.[15] Pacala and Socolow envisioned the 50-year reductions scenario as a triangle, with the sides of the stabilization triangle

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[14] Ramhstorf, S., A Semi-Empirical Approach to Projecting Future Sea-Level Rise, *Science*, 315, 368-70, 2007, available at www.pik-potsdam.de/~stefan/Publications/Nature/rahmstorf_science_2007.pdf.

[15] Pacala, S. and R. Socolow, Stabilization Wedges: Solving the Climate Problem for the Next 50 years with Current Technologies, *Science*, Vol. 305, August 13, 2004, 968-72, available at http://solo.colorado.edu/~jaburns/Astr4800Fall07/Readings/pacalasocolow.pdf.

delineated by a flat emissions trajectory of 7 gigatons carbon per year ("GtC/year") by 2054, with a decline to zero emissions by sometime after 2100, and a "business as usual" scenario represented by a straight-line ramp rising to 14 GtC/year in 2054. (*Id.* at p. 968)[16] They then divided the stabilization triangle into seven equal wedges representing reductions in GHG emissions. Filling all seven wedges results in reducing GHG emissions sufficiently to stabilize CO_2 concentrations at 500 ppm. (*Id.*) In particular, they note that we will achieve one wedge of the stabilization triangle if cars in 2054 averaged 60 miles per gallon globally. (*Id.* at 969.)

The wedge analysis was applied by the EPA in discussing GHG emissions from the U.S. transportation sector. The EPA calculated that nine transportation wedges, each representing a reduction of 5,000 million metric tons of CO_2 equivalents ("MMTCO_2e") between now and 2050 would be enough to flatten emissions in the transportation sector. Of the nine wedges, about half (4.3) would be enough to flatten emissions from passenger vehicles. EPA Transportation Wedge Analysis at 2. The EPA analysis notes that the reductions in emissions from passenger vehicles will come from vehicle technology, alternative fuels, and travel demand reduction, acting in concert. The document then presents various vehicle technologies and the "reduction potential" for the technology in terms of wedges. *Id.* at 11, 12.

NHTSA could, consistent with the EPA analysis, compare the GHG emissions from the proposed CAFE alternatives with the 4.3 wedges of reductions needed from the passenger car sector to reach emission stabilization by 2054 and begin the necessary decline in emissions.[17] This will enable the Agency to determine whether the proposed alternative will slow emissions growth sufficiently from the passenger car and light truck sector to flatten emissions as anticipated by the EPA analysis. If it will not, NHTSA must reassess the alternatives.

We present these related proposals as suggestions for how the Agency can analyze and present the data contained in the DEIS to make it meaningful. Ultimately, however NHTSA chooses to present the data, there must be some analysis that enables the Agency and the public to determine whether the proposed CAFE rule, when combined with other anticipated actions, is sufficiently stringent to reduce, over time, GHG emissions and stabilize CO_2 concentrations at levels that will prevent us from reaching the area of dangerous anthropogenic interference. If the

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[16]We note, however, that the analysis was performed in 2004. Four years later, the amount of emissions reductions per wedge will have increased, so that the 7 GtC/year is likely too low an estimate.

[17]Additional reductions may be created by other actions, such as those that reduce travel demand or VMT. However, these further reductions will be necessary to lower GHG emissions even further in order to reduce CO_2 concentrations below 500 ppm. (EPA Transportation Wedge Analysis at 7.)

proposed CAFE rule is not sufficiently stringent to reach those goals, then NHTSA has not properly considered whether our need to conserve energy and lower GHG emissions outweighs the remaining factors under EPCA, and requires a stricter CAFE standard and higher fuel economy.

c. The DEIS Fails to Make Clear the Connection Between Anticipated CO_2 Concentrations and Extreme Environmental Impacts

Finally, the DEIS contains a qualitative discussion in chapter 4 of the potential impacts of global warming, but avoids linking the CAFE rule with particular impacts, noting that the impacts from the rule in isolation are too small to quantify. DEIS at 2-13. While technically correct that the GHG emissions from the CAFE rule in isolation cannot be linked to particular environmental impacts, the DEIS should make clear that the levels of CO_2 concentrations and temperature increase that it anticipates, more than 700 ppm CO_2 and 2.7 degrees Celsius (Table 4.43 at DEIS 4-31), are directly associated with some of the more extreme environmental effects.

One way to explain the connection between the atmospheric concentrations of CO_2 and the increased temperatures anticipated by the DEIS on the one hand, and the real environmental effects on the other, would be to rely on the materials presented by the IPCC. For example, Figure SPM.2[18] illustrates graphically how various extreme environmental effects become increasingly likely as temperature rises. Notably, the figure demonstrates that the increase in temperature of 2.7 degrees Celsius anticipated by the DEIS may result in the extinction of more than 20 to 30% of the species on earth, coastal flooding affecting millions of people, increasing burdens from malnutrition and disease, and increased mortality from heatwaves, floods, and droughts. This type of graphic representation will, consistent with the purposes of NEPA, enable the reader to understand that, in setting the CAFE standard, NHTSA anticipates that we are potentially on the path to dangerous anthropogenic interference and cataclysmic climate change.

CONCLUSION

The DEIS is a step forward in acknowledging the impact of GHG emissions on climate change and the environment. The document contains a significant amount of raw data. The data are, however, presented in a confusing manner and without the necessary context. Ultimately, the DEIS does not enable either the Agency or the public to assess accurately the cumulative

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[18] IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22, at 16, available at http://www.ipcc.ch/ipccreports/ar4-wg2.htm .

impact of the CAFE rulemaking, coupled with other anticipated actions affecting GHG emissions, and does not enable either the Agency or the public to determine whether the proposed CAFE rule does its part to enable us to achieve the significant energy savings generally recognized as necessary to prevent environmental disaster. We therefore urge NHTSA to comply with its duties under NEPA and to issue a new DEIS that corrects the deficiencies in the existing document.

Sincerely,

Edmund G. Brown Jr.
Attorney General of California

Joseph R. Powers, Acting Secretary
Commonwealth of Pennsylvania
Department of Environmental Protection

Martha Coakley
Attorney General of Massachusetts

Michael A. Cardozo
New York City Corporation Counsel

Anne Milgram
Attorney General of New Jersey

Gary King
Attorney General of New Mexico

Andrew M. Cuomo
Attorney General of New York

Hardy Myers
Attorney General of Oregon

Attachments
1. Letter from state attorneys general, state agencies, and municipalities dated May 27, 2008
2. Letter from state attorneys general, state agencies, and municipalities dated July 1, 2008

PEOPLE OF THE STATE OF CALIFORNIA,
EX REL. EDMUND G. BROWN JR., ATTORNEY GENERAL
CONNECTICUT ATTORNEY GENERAL RICHARD BLUMENTHAL
STATE OF NEW JERSEY, ATTORNEY GENERAL ANNE MILGRAM AND COMMISSIONER LISA P. JACKSON
NEW MEXICO ATTORNEY GENERAL GARY K. KING
STATE OF OREGON, ATTORNEY GENERAL HARDY MYERS
RHODE ISLAND ATTORNEY GENERAL PATRICK C. LYNCH
COMMONWEALTH OF PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION
NEW YORK CITY CORPORATION COUNSEL MICHAEL A. CARDOZO

May 27, 2008

BY OVERNIGHT
Docket Management Facility, M-30
U.S. Department of Transportation
West Building, Ground Floor, Room W12-140
1200 New Jersey Ave., SE
Washington, DC 20590

RE: Docket No. NHTSA-2008-0060
Comments on Supplemental Notice of Public Scoping for an Environmental Impact Statement for New Corporate Average Fuel Economy Standards

Dear Sir or Madame:

This letter contains the comments of the Attorneys General of the States of California, Connecticut, New Jersey, New Mexico, Oregon, and Rhode Island, the Commissioner of New Jersey, the Commonwealth of Pennsylvania Department of Environmental Protection, and the New York City Corporation Counsel regarding the Supplemental Notice of Public Scoping for an Environmental Impact Statement ("EIS") for New Corporate Average Fuel Economy ("CAFE") Standards published by the National Highway Traffic Safety Administration ("NHTSA").

Pursuant to the instructions in the Supplemental Notice, we have provided Internet citations to the documents referenced and are also providing the Agency with two CDs containing copies of the documents themselves. Please provide us with notice of publication of the NEPA documents, along with a URL to access the documents and the executive summary.

Summary

NHTSA is mandated to prepare an EIS to address the global warming impacts of its proposed CAFE standard. This is more than a mere formality. In order to satisfy the requirements of the National Environmental Policy Act ("NEPA"), 42 U.S.C. §§ 4321 *et seq*, and to provide the "hard look" at global warming legally required, the EIS must do more than simply present raw data on tons of greenhouse gases ("GHG") emitted from the relevant vehicles. It must educate the Agency and the public to the reality of global warming and the contribution made by the emissions from the CAFE standard, coupled with other foreseeable GHG emissions. The EIS must answer a critical question, informing the public in plain English[1] whether the Agency's decisions in setting the CAFE standard keep us on the "business as usual" trajectory toward increased global warming and inevitable environmental disaster, or whether NHTSA will take necessary steps to moderate the levels of GHG emissions in a manner that, when coupled with actions taken by other entities, will slow global warming sufficiently to avoid environmental disaster.

NHTSA Has a Legal Duty to Prepare an EIS that Addresses Greenhouse Gas Emissions and Global Warming

NEPA requires all federal agencies, such as NHTSA, to analyze the environmental impacts of proposed major actions in order to promote better environmental decision-making. "[T]he comprehensive 'hard look' mandated by Congress and required by the statute. . . must be taken objectively and in good faith, not as an exercise in form over substance, and not as a subterfuge designed to rationalize a decision already made." *Metcalf v. Daley*, 214 F.3d 1135, 1142 (9th Cir. 2000). As the courts have repeatedly noted, while NEPA does not require an agency to reach a particular result, it "ensures that the agency, in reaching its decision, will have available, and will carefully consider, detailed information concerning significant environmental impacts; it also guarantees that the relevant information will be made available to the larger

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[1]See 40 C.F.R. § 1502.8 (EIS must "be written in plain language and may use appropriate graphics so that decisionmakers and the public can readily understand them"); *Earth Island Institute v. U.S. Forest Service*, 442 F.3d 1147, 1160 (9th Cir. 2006) (EIS "must be organized and written so as to be readily understandable by governmental decisionmakers and by interested non-professional laypersons likely to be affected by actions taken under the [EIS]" (quoting *Oregon Environmental Council v. Kunzman*, 817 F.2d 484, 494 (9th Cir. 1987).)

audience that may also play a role in both the decision making process and the implementation of that decision." *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 349 (1989).

In recent years the legal consensus on global warming has caught up with the scientific consensus. In *Massachusetts v. EPA*, 127 S.Ct. 1438 (2007), the Supreme Court acknowledged that the "harms associated with climate change are serious and well recognized." Impacts include a "precipitate rise in sea levels," "severe and irreversible changes to natural ecosystems," "significant reduction in water storage in winter snowpack," "increase in the spread of disease," and more extreme weather events. *Id.* at 1455-56 (citations omitted, quoting Declaration of Michael MacCracken).

Following on the Supreme Court's decision, the Ninth Circuit observed that the phenomenon of global warming is "non-linear," and incremental increases in CO_2 can lead to abrupt, catastrophic, and irreversible changes, particularly in light of the "compelling scientific evidence concerning 'positive feedback mechanisms' in the atmosphere." *Center for Biological Diversity v. National Highway Traffic Safety Administration*, 508 F.3d 508, 554 (9th Cir. 2007) [*"CBD"*].[2] Thus, "even a small increase in greenhouse gases could cause abrupt and severe climate changes." *Id.* at 557. As the Ninth Circuit noted, NHTSA is in control of a significant portion of the GHGs emitted in the United States, and the CAFE standards "will affect the level of the nation's greenhouse gas emissions and impact global warming." *Id.* at 522, 547; see also *id.* at 554-55.

The need for prompt and decisive action has only become more urgent since the Ninth Circuit's decision. The atmospheric concentration of CO_2, the leading GHG, is now at least 385 parts per million (ppm),[3] higher than any time in the last 650,000 years, and rising at about 2 ppm per year.[4] According to experts, an atmospheric concentration of CO_2 exceeding 450 ppm is

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[2]A Petition for Rehearing is pending, but only on the issue of whether the Ninth Circuit had the authority to order NHTSA to prepare an EIS, or was limited to remanding the matter to the Agency to reconsider its Environmental Assessment.

[3] U.S. Department of Commerce, National Oceanic & Atmospheric Administration, "Trends in Atmospheric Carbon Dioxide - Mauna Loa," available at http://www.esrl.noaa.gov/gmd/ccgg/trends/. (CD1, Doc. 1)

[4]Fourth Assessment Report of the Intergovernmental Panel on Climate Change (4th IPCC Report) WGI, Frequently Asked Question 7.1, *Are Increases in Atmospheric Carbon Dioxide*

almost surely dangerous because of the catastrophic climate changes it will cause.[5] We may be fast approaching a "tipping point," where the increase in temperature will create unstoppable, large-scale, disastrous impacts for the planet.[6]

In its rulemaking, NHTSA recognized the "need to take action to reduce greenhouse gas emissions, *e.g.*, motor vehicle tailpipe emissions of CO_2, in order to forestall and even mitigate climate change . . . ." 73 Fed. Reg. at 24357 (footnote omitted). The Agency correctly acknowledged that addressing climate change is not simply part of the NEPA analysis. Rather, NHTSA must consider GHG emissions and climate change when balancing the various factors mandated by the Energy Policy and Conservation Act ("EPCA") in setting the CAFE standard. See *id.* at 24364, 24456, 24465.[7]

Thus, both in setting the CAFE standard under EPCA and in evaluating environmental consequences consistent with NEPA, NHTSA must take the mandated "hard look" at the GHG emissions that will result from its CAFE standard, and the effects that these and other emissions will have on our environment.

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and Other Greenhouse Gases During the Industrial Era Caused by Human Activitites? http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-faqs.pdf. (CD1, Doc. 2)

[5] See Hansen, J.H. *et al.*, Dangerous human-made interference with climate: a GISS modelEstudy, *Atmos. Chem. Phys.*, 7, 2287–2312, 2007, available at http://pubs.giss.nasa.gov/docs/2007/2007_Hansen_etal_1.pdf; Hansen, J.H., *et al.* Climate change and trace gases, *Phil. Trans. R. Soc. A*, 365, 1925-1954, 2007, available at http://pubs.giss.nasa.gov/docs/2007/2007_Hansen_etal_2.pdf . (CD1, Docs. 3, 4)

[6] See *ibid.* See also discussion of tipping point in *Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie,* 508 F.Supp.2d 295, 313-14 (D. Vt. 2007).

[7]The proposed rule states that, in setting the CAFE standard, to the extent NHTSA gives greater weight to mitigating global warming, it would "put increasingly more emphasis on reducing energy consumption and CO_2 emissions, given their impact on global warming, and less on the other factors, including the economic impacts on the industry." 73 Fed. Reg. at 24465; see also *id.* at 24473, noting that the "25% below optimized alternative" is not the maximum feasible CAFE standard under the statute, in light of the need of the nation to conserve energy and reduce global warming.

The EIS Must Discuss the Scientific Consensus on Global Warming and Describe the Impact of Global Warming on the Environment Under the Various Climate "Scenarios"

In the Supplemental Notice of Public Scoping, NHTSA calculated that its proposed CAFE standard will avoid a total of 521 million metric tons of CO_2 over the lifetime of the regulated vehicles, compared to the emissions that would have resulted without the new standard. 73 Fed. Reg. at 24456. Based on these calculations, NHTSA reports that "[f]uel savings from stricter CAFE standards . . . result in lower emissions of carbon dioxide (CO_2). . ." *Id.* at 24413.

NHTSA's calculation of tons of GHG saved by the proposed CAFE standard, while necessary, is insufficient to inform the public about the impacts of GHG emissions from the vehicles. In order to make the raw data meaningful, NHTSA must, as a preliminary matter, describe and discuss the scientific consensus on global warming, including all of the following in the EIS:

- The phenomenon of global warming overall, as discussed in the 4th IPCC Report and subsequent research, including the causes of global warming, current and historic levels of CO_2 in the environment, the projected levels of CO_2 if GHG emissions are not abated, the effect of increased levels of CO_2 on temperature, and the effect of temperature changes on the environment;

- The potential "tipping points" associated with ongoing global warming that could create unstoppable, large-scale, disastrous impacts for the planet;[8]

- What must be done to reduce CO_2 emissions in order to avoid reaching the tipping point. There is widespread agreement among scientists that global warming of 2 degrees Celsius (3.6 degrees Fahrenheit) above global temperatures in 1990 "has effects that may be highly disruptive." In fact, it has recently been argued that the level of dangerous interference with the climate is as little as 1 degree Celsius above 1990 levels, and thus that "the world is already close to the

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[8]See Center for Health & the Global Environment, Climate Change Futures, Health Ecological and Economic Dimensions, 26-30 (2005), available at http://www.climatechangefutures.org/pdf/CCF_Report_Final_10.27.pdf (CD1, Doc.5)

dangerous level." To avoid such warming we would likely need to hold CO_2 levels below 450 ppm.[9]

- The various climate scenarios that may result based on different levels of atmospheric GHGs. The first, is the "business as usual" scenario in which human inputs continue to push global temperature to higher ranges until the tipping point is reached and cataclysmic results ensue, including dramatic climatic disruptions and extermination of a substantial portion of the animal and plant species on the planet. "Business as usual" scenarios would result in additional global warming of 2 to 4 degrees Celsius (3.6 to 7.2 degrees Fahrenheit) by 2100 (relative to 1990). The "alternative scenarios," are those in which human inputs on global warming are constrained to varying degrees to keep temperature increases below 2 degree Celsius, and the effects of global warming are mitigated to greater and lesser extents. Under these alternative scenarios, CO_2 emissions would need to level out quickly, and decline before 2050, in order for there to be a possibility that adaptation can occur that will avoid a catastrophic disruption of life on earth;[10]

- The legal and regulatory efforts being made to slow and reduce the levels of CO_2 in the environment including the Kyoto Accord which requires industrialized countries to reduce GHG emissions in the vicinity of 6% to 8% below 1990 levels; California's Global Warming Solutions Act of 2006,[11] which requires California to reduce CO_2 emissions to 1990 levels by 2020; the New Jersey Global Warming Response Act,[12] which calls for reducing greenhouse gas emissions in New Jersey to 1990 levels by 2020, followed by a further reduction

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[9]See Hansen, J.H. et al., Dangerous human-made interference with climate: a GISS modelE study, *Atmos. Chem. Phys.*, 7, 2287–2312, 2007, *supra*, at n.5. (CD1, Doc. 3)

[10] See *Ibid.*; See also Figure SPM.5, IPCC Fourth Assessment Report of the Working Group I, "The Physical Science Basis," Summary for Policy Makers, available at http://www.ipcc.ch/ipccreports/ar4-wg1.htm. (CD1, Doc. 6)

[11]California Health & Safety Code, § 38500 *et seq.*

[12] N.J.S.A. 26:2C-37 et seq. (P.L. 2007, c. 112).

of emissions to 80 percent below 2006 levels by 2050; and other significant state and regional efforts to reduce GHG emissions.[13]

This "context" section of the EIS should ensure that both the Agency and the public understand that, while we cannot stop the effects of global warming that are already underway, we are capable of avoiding outright cataclysm, and there are major benefits to be achieved in limiting climate change.

The EIS Must Discuss How the Emissions from the CAFE Standard, Coupled with Emissions from Other Foreseeable Sources, Will Affect Global Warming

In addition to being insufficient, NHTSA's presentation of the expected GHG emissions from the proposed standard, and its characterization of the CAFE Standard as representing a reduction in GHG emissions (73 Fed. Reg. at 24413), is affirmatively misleading. As the Ninth Circuit noted in the *CBD* case, it is not enough to report that GHG emissions are reduced from what they would otherwise have been, absent the new rule. Rather, the Agency must inform the public that, because of the expected increase in vehicle miles traveled (VMT) (see 73 Fed. Reg. at 24407), the actual amount of GHGs emitted for the model years will *increase* above past years' emissions. *CBD*, 508 F.3d at 549 ("The new rule will not actually result in a decrease in carbon emissions, but potentially only a decrease in the rate of growth of carbon emissions").

Further, the Agency must discuss the GHG emissions that will result from the CAFE standard, coupled with expected GHG emissions from other foreseeable sources, and describe how the projected emissions relate either to the "business as usual" or alternative scenarios. Thus, the EIS must:

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[13]See Lutsey, N., Sperling, D., America's bottom-up climate change mitigation policy, *Energy Policy* 36, 673-685, 2008 (discussing local and state level actions to reduce GHG emissions), available at http://pubs.its.ucdavis.edu/publication_detail.php?id=1135 (CD1, Doc. 7); Dernbach, J.C. et al., Developing a Comprehensive Approach to Climate Change Policy in the United States that Fully Integrates Levels of Government and Economic Sectors, *Virginia Environmental Law Journal*, 26, 227-69, 2007, Widener Law School Legal Studies Research Paper No. 08-20, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1020740. (CD1, Doc. 8)

- Quantify and discuss the amount of GHG emissions emitted from vehicles subject to the proposed CAFE standard combined with other anticipated GHG emissions from United States sources, and compare these emissions to levels in past years;

- Present graphs demonstrating how the overall increase, leveling off, or decrease in emissions from past years will affect temperature. The public should be able to determine from the charts presented whether the trajectory of GHG emissions from the proposed CAFE standard and the alternative standards, coupled with other foreseeable emissions, will enable us to reduce GHG emissions sufficiently to keep CO_2 below the "tipping point" level of 450 ppm and to keep temperature change below an increase of 2 degrees Celsius.

Ultimately, the critical piece of information that the EIS must disclose is whether the proposed CAFE standard puts us on target to meet the goals that are required to slow global warming sufficiently to avoid global disaster. It is that single piece of information that will best inform the Agency and the public about the consequences of decisions made by NHTSA in setting the CAFE standard.

Response to NHTSA's Requests for Information in the Notice of Public Scoping:

Below are the responses to NHTSA's specific requests for comments in its scoping notice (NHTSA's requests are in bold):

(1) Peer-reviewed scientific studies issued since the IPCC's Fourth Assessment Report that address (a) the impacts of CO_2 and other greenhouse gas ("GHG") emissions on temperature and the temperature changes likely to result from the proposed standards or the alternatives; (b) the impacts of changes in temperature on the environment, including water resources and biological resources and human health and welfare; or (c) the time periods over which such impacts may occur.

Nothing published subsequent to the IPCC report undermines the consensus range of how much warming can be expected to arise from a given increase in greenhouse gas concentrations ("climate sensitivity"), published in that report.[14] A number of new studies, however, suggest the

[14] Papers purporting to undermine that consensus have been refuted in the peer reviewed literature. See *e.g.*, Foster, G., et al., "Comment on 'Heat Capacity, Time Constant, and Sensitivity of Earth's Climate System' by S.E. Schwartz," *J. Geophys. Res.* (in press), available

likelihood that various climate change impacts could be significantly more serious than suggested in the IPCC report. These include:

- Rahmstorf, S., et al., Recent Climate Observations Compared to Projections, *Science* 316, 709, 2007 (models used by IPCC for climate change may underestimate potential rate and magnitude of climate change), available at http://pubs.giss.nasa.gov/docs/2007/2007_Rahmstorf_etal.pdf (CD1, Doc. 10);

- Barnett, T.P, et al., Human-Induced Changes in the Hydrology of the Western United States, *Science*, 319, 1080-1083, 2008 (coming crisis in water supply for the western United States), available at http://tenaya.ucsd.edu/~dettinge/barnett08.pdf (CD1, Doc. 11);

- Barnett, T.P., and D.W. Pierce, When will Lake Mead go dry?, *Water Resources Research*, doi:10.1029/R006704, 2008 (major and immediate water supply problem on the Colorado system) (CD1, Doc.12);

- Rahmstorf, S., A Semi-Empirical Approach to Projecting Future Sea-Level Rise, *Science,* 315, 368-370, 2007 (projected sea-level rise in 2100 of 0.5 to 1.4 meters above 1990 level), available at http://www.pik-potsdam.de/~stefan/Publications/Nature/rahmstorf_science_2007.pdf (CD1, Doc. 13);

- Rignot, E. et al, Recent Antarctic ice mass loss from radar interferometry and regional climate modeling, *Nature Geoscience,* 1, 106-110, 2008 (changes in glacier flow at the periphery of the Antarctic Ice Sheet appear to be leading to a net loss of Antarctic ice, implying the potential for more rapid loss of Antarctic ice and accelerated global sea level), available at http://www.nature.com/ngeo/journal/v1/n2/pdf/ngeo102.pdf;jsessionid=89C973CCC639FF018AE9571AE6394A1F (CD1, Doc. 14).

In addition, there is significant new research on the health related effects, both direct and indirect, of global warming.

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at http://www.jamstec.go.jp/frsgc/research/d5/jdannan/comment_on_schwartz.pdf. (CD1, Doc. 9)

- Jacobson, Mark Z., On the causal link between carbon dioxide and air pollution mortality, *Geophysical Research Letters*, 35 L03809, 2008, available at http://www.fypower.org/pdf/stanford_CO2_Jacobson.pdf (global warming is likely to exacerbate ozone levels in the most polluted areas, increasing U.S. annual air pollution deaths by about 1,000 and cancers by 20 to 30 per 1 degree Celsius rise in CO_2-induced temperature) (CD1, Doc. 15);

- Jacobson, Mark Z., Testimony to Select Committee on Energy Independent and Global Warming, United States House of Representatives (2008), available at: http://www.stanford.edu/group/efmh/jacobson/Testimony0408%202.pdf; (CD1, Doc. 16)

- Jacobson, Mark Z., Effects of Local Versus Global Carbon Dioxide Emissions on Local Air Quality and Health, Presentation to EPA-Stanford Symposium on Impacts of Climate Change in Air Quality (2008) (effects of locally emitted CO_2 on California air pollution, including modeled quantification of additional ozone and particulate matter death rates due to local CO_2)[15] (CD1, Doc. 17);

- Statement of Howard Frumkin, M.D., DrPH, Director, National Center for Environmental Health, Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Service, available at http://www.cdc.gov/washington/testimony/2008/t20080409.htm, (describing direct health effects of heat, as well as indirect effects from extreme weather events, air pollution, water and food borne infectious diseases, vector-borne and zoonotic diseases, and differential burden on different populations, with greater risks to children, home-bound, elderly, poor, minority and migrant populations) (CD1, Doc. 18);

- American Lung Association, State of the Air: 2008, Protect the Air you Breathe, available at http://www.lungusa2.org/sota/SOTA2008.pdf (describing heat related risks of decreased lung function, respiratory infection, lung inflammation etc., by region of the country and at-risk groups) (CD1, Doc. 19).

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[15]The results presented are as of May 6, 2008 and the calculations are ongoing (personal communication from Dr. Jacobson to California Deputy Attorney General Fiering, May 9, 2008).

NHTSA must take into account all of the above new research in preparing its EIS.

(2) How NHTSA should estimate potential changes in temperature that may result from changes in CO_2 emissions projected from the proposed standards and reasonable alternatives and how NHTSA should estimate potential impacts of temperature changes on the environment.

NHTSA's question is framed too narrowly, focusing only on the changes wrought by the new rule or alternatives and ignoring the cumulative changes that will occur from the CAFE emissions combined with GHG emissions from other anticipated sources. The *CBD* court held that the impact of the CAFE standard must be assessed "within the context of other actions that also affect global warming." 508 F.3d at 550 (quoting brief of the State of California *et al.*) (See discussion of cumulative impacts, Request (5), *supra.*)

There is a simple and objective methodology for estimating the potential changes in temperature that are expected to result from increases in CO_2 emissions. It relies on the approach outlined in Wigley (2005),[16] which employs a publicly available climate model ("MAGICC") which can be calibrated to the greenhouse warming responses of the more complex, state-of-the-art climate models used in the most recent IPCC report.[17] Users can then specify arbitrary future emissions scenarios and compute the global mean surface temperature changes in response to those emissions scenarios from the model. In conjunction with an additional model ("SCENGEN"), regional climate change scenarios (surface temperature and precipitation changes) can also be generated. Both models can be downloaded from the National Center for Atmospheric Research (NCAR) website at http://www.cgd.ucar.edu/cas/wigley/magicc/ .

The EIS can then compare the predicted emissions and warming scenarios that will result from the CAFE standard combined with other foreseeable emissions, with the various scenarios forecast by the IPCC. This will enable the Agency and the public to determine whether or not

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[16]Wigley, T.M.L., The Climate Change Commitment, *Science*, Vol. 307, pp. 1766 - 1769, 2005. (CD1, Doc 20)

[17]See Figure 3 of the Summary for Policy Makers of the IPCC Special Report on Emissions Scenarios, 2000 and Figure SPM.5 of the Working Group I Summary for Policy Makers of the IPCC Fourth Assessment Report, available at http://www.ipcc.ch/ipccreports/sres/emission/index.htm and http://www.ipcc.ch/ipccreports/ar4-wg1.htm (CD1, Docs. 21 and 6)

anticipated emissions and warming will remain below the danger levels and will be consistent with the various governmental efforts to reduce global warming.

(3) Reports analyzing the potential impacts of climate change in particular geographic areas of the United States.

The regional differences in global warming impacts are not directly relevant to NHTSA's setting of the CAFE standard, but certainly can inform the Agency and the public of the wide range and severity of impacts that exist, thus highlighting the importance of curbing GHG emissions and slowing global warming. We note that there are significant variations in the impacts of global warming that occur in different regions of the country. In fact, California is particularly hard-hit by the effects of global warming, and has submitted substantial documentation of these effects to the Environmental Protection Agency (EPA), in support of its request for a waiver under the Clean Air Act of its GHG emission regulations. Copies of the reports submitted by the California Air Resources Board's ("CARB") to the EPA, concerning the compelling and extraordinary effects of global warming in California, are provided to NHTSA on a separate CD2 accompanying this letter.[18] In addition to the documents submitted by California to the EPA, current reports issued by government agencies dealing with the global warming impacts in different regions of the United States include:

National Research Council of the National Academies, Potential Impacts of Climate Change on U.S. Transportation (2008), available at http://www.trb.org/news/blurb_detail.asp?ID=8794 (discussion of climate change and impacts on transportation including effect of global warming on transportation in the following regions: Metropolitan East Coast Assessment, Metro Boston, Seattle, Alaska, Gulf Coast) (CD1, Doc. 22);

The Rocky Mountain Climate Organization and NRDC, Hotter and Drier, The West's Changed Climate, 2008, available at http://www.nrdc.org/globalWarming/west/west.pdf (CD1, Doc. 23);

Governor's Delta Vision Blue Ribbon Task Force, Delta Vision: Our Vision for the California Delta, 2008, available at http://deltavision.ca.gov/DeltaVision-DraftTaskForceVision.shtml (discussion of climate change impacts on California's Delta region) (CD1, Doc. 24);

[18] A list of the documents contained on CD2 is attached to this letter.

U.S. Climate Change Science Program Synthesis and Assessment Product 4.7, Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I (2008) available at http://climate.dot.gov/publications/impact_of_climate_change/ (effect of global warming and sea level rise on transportation in Gulf Coast) (CD1, Doc. 25);

New York City Department of Environmental Protection, Assessment and Action Plan: A Report Based on the Ongoing Work of the DEP Climate Change Task Force (May 2008), available at http://www.nyc.gov/html/dep/pdf/climate/climate_complete.pdf (effects of climate change on New York City) (CD1, Doc. 26);

National Research Council of the National Academy of Sciences, Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability at 73-111, 2007, available at http://www.nap.edu.catalog/11857.html (discussion of climate change on Colorado River Basin) (CD1, Doc. 27);

ICF International, The Potential Impacts of Global Sea Level Rise on Transportation Infrastructure, Phase 1 - Final Report: the District of Columbia, Maryland, North Carolina and Virginia, 2007, available at http://www.bv.transports.gouv.qc.ca/mono/0965210.pdf (effect of global warming and sea level rise on transportation in certain regions of country) (CD1, Doc. 28);

Frumhoff, P.C. et al, Northeast Climate Impacts Assessment Synthesis Team, *Confronting Climate Change in the U.S. Northeast: Science, Impacts and Solutions* (July 2007), at http://www.climatechoices.org/assets/documents/climatechoices/confronting-climate-change-in-the-u-s-northeast.pdf (synthesis report based on new research projects; underlying peer-reviewed papers are in press, available at http://www.northeastclimateimpacts.org/#papers) (CD1, Doc. 29);

Center for Integrative Environmental Research at the University of Maryland, The U.S. Economic Impacts of Climate Change and the Costs of Inaction (2007) (discussion of economic impacts of climate change as they will be felt in different regions of the country), available at http://www.cier.umd.edu/climateadaptation/index.html (CD1, Doc. 30);

Climate Change Research Center, University of New Hampshire, Indicators of Climate Change in the Northeast, 2005, available at http://cleanair-coolplanet.org/information/pdf/indicators.pdf (CD1, Doc. 31);

Columbia Earth Institute, Climate Change and a Global City: The Potential Consequences of Climate Variability and Change (July 2001), available at http://www.ccsr.columbia.edu/cig/mec/ (climate change research in New York Metropolitan Region) (CD1, Doc. 32);

Princeton University, *The Garden State in the Greenhouse: Climate Change Mitigation and Coastal Adaptation Strategies for New Jersey* (January 2007), available at http://www.princeton.edu/~mauzeral/teaching/wws59a_report.pdf (recommending ways to reduce New Jersey's GHG emissions and adapt to climate change impacts along New Jersey's coast, which is at risk of losing up to 9% of its land area by 2100) (CD1, Doc. 33);

Gutierrez, S. et al, *Potential for Shoreline Changes Due to Sea-Level Rise Along the U.S. Mid-Atlantic Region* (U.S. Geological Survey, U.S. Dep't of Interior, Report Series 2007-1278), available at http://woodshole.er.usgs.gov/pubs/of2007-1278/images/report/pdf (assessing potential mid-Atlantic shoreline change due to rising sea level) (CD1, Doc. 34);

New Jersey Department of Environmental Protection, *Climate Change in New Jersey: Trends in Temperature and Sea Level* (November 2006), available at http://www.nj.gov/dep/dsr/trends2005/pdfs/climate-change.pdf (long-term data document a significant increase in average temperature in New Jersey and significant rise in sea level) (CD1, Doc. 35);

Union of Concerned Scientists, *Confronting Climate Change in the U.S. Northeast; Union of Concerned Scientists - New Jersey* (2007), available at http://www.climatechoices.org/assets/documents/climatechoices/new-jersey_necia.pdf (summarizing New Jersey's changing climate and potential effects of climate change, including impacts on coastal communities due to coastal flooding and shoreline change, and impacts on human health due to extreme heat, air quality and vector-borne disease) (CD1, Doc. 36);

Stanley, A. et al., *Holocene Sea Level Rise in New Jersey: An Interim Report* (September 15, 2004), available at http://www.state.nj.us/dep/dsr/climate/holocene.pdf (human-induced effects on sea-level in New Jersey are 1-2 mm/year, which is up to ½ of the total observed rate of rise) (CD1, Doc. 37);

U.S. National Assessment of the Potential Consequences of Climate Variability and Change for the Nation, U.S. Global Change Research Program, *Climate Change and a Global City: An Assessment of the Metropolitan East Coast Region* (June 19, 2000), available at http://www.metroeast_climate.ciesin.columbia.edu/reports/assessmentsynth.pdf (continuation of average warming trend of past century will result in increase of average annual temperature for metropolitan east coast region, including New York, New Jersey and Connecticut, by almost 1.0°F by the 2020s, 1.5 °F by the 2050s, and over 2.5 °F in the 2080s) (CD1, Doc. 38);

Environment New Jersey Research & Policy Center, *An Unfamiliar State: Local Impacts of Global Warming in New Jersey* (May 2007), available at http://www.environmentnewjersey.org/uploads/-z/wV/-zwV3Jt9hnScxAwZbMymqQ/An-Unfamiliar-State---Local-Impacts-of-Global-Warming-in-New-Jersey.pdf (impacts of global warming, if unchecked, on New Jersey include inundation of low-lying shore lands, beach erosion between 160-500 feet and increased flooding due to forecasted sea-level rise of 16-31 inches, an increase by more than 6% of smog-related deaths, and decline of migratory bird species) (CD1, Doc. 39);

Office of Policy, Planning and Evaluation, USEPA, *Climate Change and New Jersey* (EPA 230-F-97-008dd, September 1997), available at http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BVJH3/$File/nj_impct.pdf (temperatures in New Jersey could increase about 4°F by 2100, with increases in heat-related deaths and illnesses, alternation of coastal wetlands and forested Pine Barrens, contamination of aquifers and decline in water quality, and loss of and extensive damage to coastline, the protection of which would require significant resources and planning) (CD1, Doc. 40);

Mid-Atlantic Regional Assessment Team, U.S. Global Change Research Program, *Preparing for a Changing Climate – The Potential Consequence of Climate Variability and Change – Mid-Atlantic Overview* (March 2000), available at http://www.cira.psu.edu/mara/results/overview_report/index.html#report (last visited

May 22, 2008) (assessing impacts on mid-Atlantic region by climate change) (CD1, Doc. 41);

New Mexico Office of the State Engineer/Interstate Stream Commission, The Impact of Climate Change on New Mexico's Water Supply and Ability to Manage Water Resources (2006), available at www.nmenv.state.nm.us/cc/ (CD1, Doc. 42).

These sources should be considered and discussed by NHTSA in preparing its EIS.

(4) Other reasonable alternatives that NHTSA might consider in its NEPA analysis.

One of the primary means of achieving better fuel economy is by making vehicles lighter in weight. To date, NHTSA has considered weight reduction only for vehicles weighing greater than 5,000 pounds, with the weight reductions amounting to no more than 5 percent. The Agency states that it believes that downweighting of lighter vehicles makes them less safe. 73 Fed. Reg. at 24375, 24456.

There is strong evidence that this view is wrong. According to the Rocky Mountain Institute, lighter vehicles can achieve substantial fuel economy without compromising safety, size, performance, or comfort.[19] There have been significant advances in light weight steels and polymer composites that are stronger and tougher than steel but one-fourth as dense,[20] and can achieve fuel economy of up to 45 mpg for non-hybrid cars and 62.4 mpg for hybrid cars at costs within the range of normal variations in the market.[21]

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[19]See Lovins, B. et al, Winning the Oil Endgame, 45-46, 2004 (Rocky Mountain Institute) (hereafter "Oil Endgame Report"), available at http://nc.rmi.org/NETCOMMUNITY/Page.aspx?pid=269&srcid=269 (CD1, Doc. 43)

[20]*Id.* at 55-72,

[21]*Id.* at 68, 72.

A recent expert report by David L. Greene,[22] submitted by California to the U.S. EPA describes new research[23] that demonstrates that there is no statistically significant effect on traffic fatalities of reducing the weight of passenger cars and light trucks by 100 pounds. Rather, the recent research indicates that weight reduction is estimated to *decrease* fatalities. In contrast, wheelbase and track reduction is estimated to increase the overall number of fatalities. The Greene report notes that, based on recent studies, "automobile manufacturers have the option to use carefully designed material substitution to reduce vehicle weight in order to increase fuel economy while improving occupant safety."

Thus, as one of the alternatives, NHTSA should consider a standard that includes downweighting for all vehicles, not just vehicles greater than 5,000 pounds.

Finally, for each alternative, including the proposed CAFE standard, NHTSA should report, not only the emissions that will result if each manufacturer meets the standard, but the emissions that will result if a series of other reasonably foreseeable events occur, including: (1) if

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[22]On Vehicle Weight, Fuel Economy and Safety, Expert Report by David L. Greene, *Central Valley Chrysler-Jeep v. Witherspoon* (E.D. CA) No. CIV-F-04-6663 (April 30, 2006). (CD1, Doc. 44) Dr. Greene is one of the authors of the dissent to the National Academy of Sciences Report, National Research Council, "Effectiveness Impact of Corporate Average Fuel Economy (CAFE) Standards Appendix A, Dissent on Safety Issues: Fuel Economy and Highway Safety, which stated that there has been no documented link between increased fuel economy and traffic fatalities.

[23]Van Auken R.M. and J.W. Zellner, Supplemental Results on the Independent Effects of Curb Weight, Wheelbase, and Track on Fatality Risk in 1985-1998 Model Year Passenger Cars and 1985-1997 Model Year LTVs, DRI-TR-05-01, *Dynamic Research, Inc., Torrance, California*, 2005 (CD1, Doc. 45); Van Auken, R.M. and J.W. Zellner, A Review of the Results in the 1997 Kahane, 2002 DRI, 2003 DRI and 2003 Kahane Reports on the Effects of Passenger Car and Light Truck Weight and Size on Fatality Risk, DRI–04-02, *Dynamic Research, Inc., Torrance, California*, 2004 (CD1, Doc. 46);Van Auken, R.M. and J.W. Zellner, An Assessment of the Effects of Vehicle Weight and Size on Fatality Risk in 1985 to 1998 Model Year Passenger Cars and 1985 to 1997 Model Year Light Trucks and Vans, 2005-01-1354, *Dynamic Research, Inc., Torrance, California*, 2004 (CD1, Doc. 47); Van Auken, R.M. and J.W. Zellner, A Further Assessment of the Effects of Vehicle Weight and Size Parameters on Fatality Risk in Model Year 1985-98 Passenger Cars and 1985-97 Light Trucks, DRI-TR-03-01, *Dynamic Research, Inc., Torrance California*, 2003. (CD1, Docs, 48, 49, 50)

manufacturers do not meet the standard for particular model years, and decide to use credits stored from previous years or pay penalties instead, see 73 Fed. Reg. at 24461-64, 24473-75; (2) if manufacturers use the additional "dual-fuel" incentive to raise their average fuel economy up to 1.2 miles a gallon higher than it would otherwise be; or (3) if manufacturers respond to market demand by upsizing their light trucks beyond what is anticipated by NHTSA. Under each of these circumstances, or a combination of all three circumstances, the GHG emissions will be larger than estimated by NHTSA. NHTSA must therefore report, not just a single level of emissions based on the standard, but a range of emissions based on how the standard may operate in the real world.

(5) How the Agency should assess cumulative impacts:

A federal agency is required to evaluate whether a project's impacts, though individually limited, are cumulatively significant. *See* 40 C.F.R. § 1502.16. A cumulative impact:

> is the impact on the environment which results from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Id. § 1508.7.

The assessment of cumulative impacts is critical within the context of global warming. As the Ninth Circuit noted, "[t]he impact of greenhouse gas emissions on climate change is precisely the kind of cumulative impacts analysis that NEPA requires agencies to conduct. Any given rule setting a CAFE standard might have an 'individually minor' effect on the environment, but these rules are 'collectively significant actions taking place over a period of time.'" *CBD*, 508 F.3d at 550 (quoting 40 C.F.R. § 1508.7). The Ninth Circuit ultimately held that NHTSA "must provide the necessary contextual information about the cumulative and incremental environmental impacts of the [CAFE rule] in light of other CAFE rulemakings and other past, present and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions." *CBD*, 508 F.3d at 550.

Here, an examination of other projects that substantially contribute to GHG emissions would be more than "useful"; it is absolutely essential. GHG emissions from the U.S. transportation sector overall represents over a third of all transportation emissions worldwide and

10% of all energy related GHG emissions worldwide.[24] NHTSA itself notes that

> since 1999, the transportation sector has led all U.S. end-use sectors in emissions of carbon dioxide. Transportation sector CO_2 emissions in 2006 were 407.5 million metric tons higher than in 1990, an increase that represents 46.4 percent of the growth in unadjusted energy related carbon dioxide emissions from all sectors over the period. Petroleum consumption, which is directly related to fuel economy, is the largest source of carbon dioxide emissions in the transportation sector.

Fed. Reg. at 24455. Further, GHG emissions from the United States overall grew by more than 16 percent from 1990 to 2005.[25]

As required by NEPA, the impact of NHTSA's CAFE decision can only be fully evaluated in combination with these other emissions. Thus, the EIS must combine the anticipated GHG emissions from the CAFE standard over the lifetime of the model year cars, with other anticipated emissions from the United States overall during this same time period. NHTSA must then input into the Wigley *et al.* model the cumulative emissions in order to calculate the potential change in temperature that will result, and compare the temperature change with the climate scenarios outlined by the IPCC. See discussion *supra* at p. 11 & n. 16.

CONCLUSION

As noted by James Hansen, one of the preeminent researchers on climate change, the "stark conclusions about the threat posed by global climate change and implications for fossil fuel use are not yet appreciated by essential governing bodies. . . . In our view, there is an acute need for science to inform society about the costs of failure to address global warming, because of a fundamental difference between the threat posed by climate change and most prior global

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[24]U.S. EPA, A Wedge Analysis of the U.S. Transportation Sector, 2007, at 1, available at http://www.epa.gov/oms/climate/420f07049.htm. (CD1, Doc. 51)

[25]UNFCCC Framework Convention on Climate Change, National greenhouse gas inventory data for the period 1990-2005, available at http://unfccc.int/resource/docs/2007/sbi/eng/30.pdf. (CD1, Doc. 52)

threats."[26] The EIS presents both a challenge and an opportunity for NHTSA to begin to bridge the gap noted by Dr. Hansen between the scientific reality and the governmental and public understanding of climate change. While NEPA does not require NHTSA to reach a particular conclusion about the CAFE standard, it does require the Agency to analyze fully and inform the public about the implications of its decision. As set forth above, we urge NHTSA to comply with NEPA by issuing an EIS that enables the Agency and the public to determine whether NHTSA has done its part to reduce GHG emissions, or whether the Agency has made decisions that will keep us on a "business as usual" trajectory that will lead to environmental disaster.

Sincerely,

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[26]Hansen, *supra* note 9, at 2308.

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Comments of Attorney General of California *et al.* to NHTSA Scoping Notice May 27, 2008

EXHIBIT 1
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011	Westerling, A. *et al.*, Warming and Earlier Spring Increases Western U.S. Forest Wildfire Activity, *Science Express*, July 2006
012	Mott, J. *et al.*, Wildland forest fire smoke: health effects and intervention evaluation, Hoopa, California, 1999, West J Med, 176, 2002
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Attorneys General of the States of California, Arizona, Connecticut, Illinois, Iowa, Maryland, Massachusetts, New Jersey, New Mexico, Oregon, and Vermont, the Commissioner of the New Jersey Department of Environmental Protection, the Secretary of the New Mexico Environment Department, the Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, the Director of the District of Columbia Department of the Environment, and the Corporation Counsel of the City of New York

July 1, 2008

The Honorable Nicole R. Nason
Administrator
National Highway Traffic Safety Administration
U.S. Department of Transportation
West Building
1200 New Jersey Avenue, SE
Washington, DC 20590

RE: Notice of Proposed Rulemaking (NPRM) for Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011–2015
[Docket No. NHTSA-2008-0089]

Comments Regarding CAFE Standard-Setting

Dear Administrator Nason:

We are pleased to submit these comments of the Attorneys General of the States of California, Arizona, Connecticut, Illinois, Iowa, Maryland, Massachusetts, New Jersey, New Mexico, Oregon, and Vermont, the Commissioner of the New Jersey Department of Environmental Protection, the Secretary of the New Mexico Environment Department, the Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, the Director of the District of Columbia Department of the Environment, and the Corporation Counsel of the City of New York regarding the corporate average fuel economy (CAFE) standards proposed by the National Highway Traffic Safety Administration (NHTSA) for passenger cars and light trucks for model years 2011 through 2015. *See* 73 Fed. Reg. 24,352 (May 2, 2008).

We commend the agency's efforts to comply with the congressional mandate of the Energy Independence and Security Act of 2007 (EISA). If the goal of maximizing energy conservation can be fulfilled, the federal government will have taken concrete steps to reduce oil dependence on foreign nations, lower gasoline prices, and address global warming. NHTSA's proposal takes steps in that direction. We are pleased that the agency has issued a draft environmental impact statement for public review and comment. And we are gratified that the agency is not just mechanically marching towards meeting the absolute floor established by Congress of 35 miles per gallon in model year 2020. In its proposal, NHTSA appears in large part to be using the most reliable information available to date on the costs and benefits of particular vehicle technologies. All of these are positive steps.

We believe, however, that there is room for significant improvement of these rules. The purpose of these comments is to raise several important fuel economy issues that we hope NHTSA is open to reviewing and improving.[1] Given the significance of this rulemaking, it is important that the agency give serious consideration to the issues and develop a final rule that both maximizes the energy conservation purpose of EISA and is based on scientifically defensible inputs and analysis. The agency proposal does not do so yet.

The issues discussed below are: (1) the choice of maximizing the quantifiable net economic benefits, instead of maximizing energy conservation, as a goal for these regulations; (2) the need to complete a legally adequate environmental impact statement; (3) the critical need for NHTSA to update the baseline it uses for its analysis; (4) the out-of-date and underestimated forecast of gasoline prices; (5) the use of a 7% discount rate; (6) the failure to consider Clean Air Act emission standards; (7) the failure to consider a backstop for all vehicle categories; (8) the underestimate of the global warming benefits of these regulations; and (9) the failure to give any estimate of the military security and Strategic Petroleum Reserve benefits of these regulations.

<u>Setting a Goal</u>

The agency acknowledges that the Energy Policy and Conservation Act (EPCA) and EISA's "overarching purpose" and "overall goal" are "energy conservation." 73 Fed. Reg. at 24,451-1, 24,456-1. As the agency says, "The need to conserve energy is, from several different standpoints, *more crucial today*" than when the statute was originally enacted. *Id.* at 24,454-3 (emphasis added).

NHTSA, of course, has some discretion to set these fuel economy standards based on the statutory factors of "technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy." 49 U.S.C. § 32902(f). However, as the Ninth Circuit explained, this discretion exists only "so long as NHTSA's balancing does not undermine the fundamental purpose of the EPCA: energy conservation." *Center for Biological Diversity v. NHTSA*, 508 F.3d 508, 527 (9th Cir. 2007). As NHTSA itself understands, the Ninth Circuit "raised the possibility of tilting the balance more toward reducing energy consumption and CO_2." 73 Fed. Reg. at 24,465 n.228.

In its proposal, NHTSA proposes to set the standards at a level where the net economic

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1. We are separately commenting on the issue of preemption, which is a legal issue irrelevant to the setting of these standards.

benefit it has calculated is maximized. But maximizing economic benefit is not the goal of the statute. It is not, for example, a law the purpose of which is to protect the status quo in the automobile industry. Rather, it is an energy conservation statute, designed to decrease oil dependence with technology-forcing regulations set at the maximum level possible without causing substantial adverse consequences. As the courts have determined, Congress has already made the judgment that energy conservation is the highest priority among the factors for NHTSA to balance. *Center for Biological Diversity*, 508 F.3d at 527-28 (discussing *Center for Auto Safety v. NHTSA*, 793 F.2d 1322 (D.C. Cir. 1986)). To achieve this goal, NHTSA should set the standards at a level where the total costs equal total benefits.[2] From a societal point of view, there cannot be substantial adverse consequences if the costs do not outweigh the benefits. We urge NHTSA to set the standard at a level where total costs equal total benefits.

This is especially true given that not all of the benefits of energy conservation are quantifiable. Higher fuel economy, while separate from the federal government's obligations under the Clean Air Act, *Massachusetts v. Environmental Protection Agency*, 127 S. Ct. 1438 (2007), will set our country on a course to address global warming, a phenomenon that threatens the country's environmental and economic well-being. Greater fuel economy will also help our country move away from the economic and political consequences of being dependent on oil-rich countries, as EPCA intends. Many of these benefits cannot be fully quantified through simple economic valuation. How does one value, for example, avoiding the forced relocation of Native American villages, the loss of hundreds of miles of coastline, or the extinction of polar bears? These unquantifiable benefits should tilt the scales towards more stringent standards.

Compliance with the National Environmental Policy Act

NHTSA appears to be moving towards completing an environmental impact statement (EIS), a necessary precondition to finalizing of these standards. Issuing final rules without a legally sufficient final EIS – and consideration of the information in that EIS – would be a violation of the National Environmental Policy Act (NEPA). *Center for Biological Diversity*, 508 F.3d at 553-58.

The purpose of NEPA is to provide additional information to the agency and the public to help inform the eventual decision. NHTSA has, just in the last couple of days, issued a draft EIS

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2. NHTSA should also double-check its calculations. For example, some of the numbers in the text of pages 24,355 and 24,356 of the NPRM do not match the numbers in the footnotes on those pages. Also, if total costs equal total benefits, the net total benefits should be zero. Yet, on table X-3, on page 24,472 of the NPRM, the "TC = TB" line shows both positive and negative numbers (and does not total to zero). These errors do not appear to be insignificant. In light of the needed corrections and other changes, NHTSA should re-issue an updated and corrected notice of proposed rulemaking and re-open public comment.

for public comment that is over 400 pages. However, because the EIS analysis and the substantive analysis are linked, we assume that EIS analysis will inform the decision making of the agency. Otherwise, it has the appearance of simply being a rote exercise to justify the agency's proposal. Thus, we urge NHTSA to release an updated cost-benefit analysis (based on the analysis in the draft EIS, and perhaps on public comment to date) and re-open public comment in this docket.

Baseline

It is important that the agency's analysis starts with an accurate baseline (that is, the manufacturers' product mix, technology use, and fuel economy without these improved rules). Without an accurate baseline, the agency cannot accurately gauge the costs and benefits from this rule. NHTSA's analysis is based entirely on those costs and benefits.

As proposed, NHTSA's baseline is fundamentally based on product information provided by the manufacturers. However, with some limited exceptions, this information appears to assume a static automobile industry. According to the agency's baseline information, the fuel economy of many manufacturers is not expected to change *at all* between model year 2011 and model year 2015. NHTSA's Preliminary Regulatory Impact Analysis (PRIA) at VI-3, VI-13 (April 2008) (tables VI-1a and VI-2a). This is not reasonable.[3] The automobile industry is changing constantly, introducing improved technology consistently. NHTSA needs to have a more realistic baseline.

It should come as no surprise to the agency that the baseline has changed dramatically in the last two years. The public and trade press is full of articles discussing the fact that buyers are now moving away from large cars and trucks in favor of more fuel efficient models. *See, e.g.*, Bill Vlasic & Nick Bunkley, The Smaller the Better, Automakers are Finding, N.Y. Times, June 20, 2008; Byron Pope & Diane Elnick, U.S. Small-Car Demand Outpacing North American Capacity, WardsAuto.com, June 12, 2008; Matthew Dolan & Jeff Bennett, Ford Looks to Go Smaller Faster; Some Truck Factories May Make Cars Instead As Sense of Alarm Grows, Wall Street Journal, June 12, 2008; Dale Buss & Michelle Krebs, Big Three, Big Vehicles Taken to the Watershed in May, Edmunds.com, June 3, 2008; Bill Vlasic, As Gas Costs Soar, Buyers Flock to Small Cars, N.Y. Times, May 2, 2008. General Motors's and Ford's chief executives

3. Assuming an out-of-date baseline is but one of many reasons why NHTSA should not give very much weight, if any, to the analysis provided by Sierra Research for the Alliance of Automobile Manufacturers in this docket. That analysis is based on a 2006 baseline which does not change. However, the federal judge presiding over a 16-day bench trial in Vermont found that these kinds of assumptions are unreliable. *See Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie*, 508 F.Supp.2d 295, 366-68 (D.Vt. 2007) (discussing testimony of Tom Austin).

are calling this change *permanent*. Nick Bunkley, Ford Delays New Pickup and Reduces Production, N.Y. Times, June 21, 2008; Bill Vlasic, G.M. Shifts Focus to Small Cars in Sign of Sport Utility Demise, N.Y. Times, June 4, 2008.

This is true as to particular technologies, as well. In the NPRM, however, the agency does not consider this changed baseline. It does not apply plug-in hybrids in its model at all despite the fact that General Motors and Toyota have recently stated that they will have a plug-in hybrid in 2010. Yuri Kageyama, Toyota Promises Plug-in Hybrid Vehicle in U.S., Japan and Europe by 2010, L.A. Times, June 11, 2008; Bill Vlasic, G.M. Closing 4 Plants in Shift From Trucks Toward Cars, N.Y. Times, June 4, 2008. Perhaps most egregious is that NHTSA does not start applying other hybrids (including the simple, low-cost integrated starter generator version) until 2014. 73 Fed. Reg. 24,381-1. The federal government's own fuel economy website, www.fueleconomy.gov, shows that hybrids have been on the road for almost ten years, there are several hybrid models on the road now (selling over 100,000 vehicles a year), and more are planned by manufacturers.

We understand that the agency has requested updated product information from manufacturers, 73 Fed. Reg. 24,190 (May 2, 2008), but it is essential that the agency update its baseline, regardless of whether the manufacturers provide this information. Failure to provide such an update calls into question NHTSA's entire analysis.

It is also essential that the agency provide transparency in its analysis so that members of the public can review and comment on the agency's baseline. We understand that there may be some confidential business information used in calculating the baseline, but the agency should provide sufficient summaries or aggregations of this information or make special arrangements so that interested parties such as the state Attorneys General can view this confidential information under a confidentiality agreement.

<u>Gasoline Prices</u>

NHTSA acknowledges that a significant factor in the agency's analysis of maximum fuel economy is the price of gasoline. 73 Fed. Reg. at 24,476-1; *see also* PRIA at IX-12 (table IX-5a). As such, it is important that future gasoline price estimates be the best available estimates. NHTSA used gasoline prices of between $2.25 and $2.51 per gallon, depending on the future year. PRIA at VIII-20 (table VIII-3). This is startling, given that in June 2008 the national average price for gasoline reached $4.13 per gallon. *See* Energy Information Administration, Weekly Retail Gasoline and Diesel Prices (downloaded June 25, 2008 and enclosed). Unless NHTSA can provide publicly-available, mainstream documentation supporting an almost fifty percent drop from current prices, it must substantially re-calibrate those estimates.

While we recognize that NHTSA relied on gasoline price projections from its sister agency, the Energy Information Administration (EIA), NHTSA acknowledges that EIA's "reference case" has consistently underestimated gasoline prices in recent years. 73 Fed. Reg. at 24,405-06. In fact, NHTSA's most recent estimate of gasoline prices appears to continue this trend, with even the "high price case" only reaching $3.52 per gallon in 2030 and the reference case being much lower. *See* EIA, Annual Energy Outlook 2008 (June 2008) (table C5). Even EIA agrees that NHTSA should have not used its reference case for the analysis in this rulemaking, but instead should have used EIA's high price case. On June 11, 2008, the Administrator of EIA testified before the U.S. House of Representatives's Select Committee on Energy Independence and Global Warming. The Administrator testified unequivocally that NHTSA should use the high price case estimates for this rulemaking. EIA's most recent high price case estimates – which, again, appear to be underestimates – range from $2.87 per gallon in 2011 to $3.52 per gallon in 2030. *See* Annual Energy Outlook 2008 (high price case table 12). If NHTSA insists on relying on EIA's analysis, it must, at least, use the high price case.

NHTSA should also consult with EIA to obtain more up-to-date estimates before it finalizes these rules. EISA requires that NHTSA consult with the Department of Energy. 49 U.S.C. § 32902(i). The estimates NHTSA used in its proposal were released in March 2008, and obviously developed prior to that time. In March, EIA was projecting gasoline prices for 2008 to average $3.26 and for 2009 to average $3.11. EIA, Short-term Energy Outlook at table 2 (Mar. 11, 2008). EIA's most recent estimates for these time periods are $3.83 and $3.97, respectively. EIA, Short-term Energy Outlook at table 2 (June 10, 2008). The facts prove that EIA was seriously incorrect in its estimates made in March, by as much as 86 cents per gallon (and perhaps more if EIA is incorrect that prices will come down over the next year-and-a-half). At the time NHTSA finalizes these rules, the agency should obtain from EIA a truly current projection for gasoline prices over the relevant period. Given the President's executive order requiring coordination between federal agencies on issues relating to greenhouse gas emissions, 72 Fed. Reg. 27,717 (May 16, 2007), EIA should be able to provide relevant, up-to-date data directly to NHTSA specifically for the docket in this rulemaking. At a minimum, NHTSA should wait for EIA's public, final 2008 estimates, which are scheduled to be released in December.

Discount Rate

Another significant driver in the agency's analysis is the selection of a discount rate. The discount rate is used to adjust the future costs and benefits attributed to this regulation. NHTSA uses a 7% discount rate in its proposal. However, the agency appears to understand that there are flaws to this figure, for it explicitly requests comment on the *appropriateness* of using a lower discount rate. 73 Fed. Reg. at 24,416-2.

NHTSA uses an Office of Management and Budget (OMB) circular to guide its discount rate choice. 73 Fed. Reg. at 24,415-16 (referring to OMB, Circular A-4, "Regulatory Analysis," Sept. 17, 2003). OMB recommends a 7% discount rate "'whenever the main effect of a regulation is to displace or alter the use of capital in the private sector.'" 73 Fed. Reg. at 24,415-

3 (quoting Circular A-4 at 33). In contrast, OMB recommends a 3% discount rate when the regulation "primarily and directly affects private consumption." 73 Fed. Reg. at 24,416-1 (referring to Circuit A-4). This lower 3% discount rate is "the rate at which *society* discounts future consumption." 73 Fed. Reg. at 24,416-1 (emphasis added). NHTSA's analysis looks at this cost-benefit analysis from a societal view. Thus, for example, fuel savings are calculated based on the entire life of a vehicle, not just the period considered by consumers at the purchase time. 73 Fed. Reg. at 24,405-1, 24,406-2. Also, costs are calculated using a retail price equivalent figure, which estimates the cost to consumers and thus takes into account more than just the manufacturers' costs for technology improvements. 73 Fed. Reg. at 24,367-2. As NHTSA assumes in its analysis, the effect of these increased fuel economy standards will be increased use of technology, which will both increase the costs of new motor vehicles and decrease their operating costs (by increasing fuel economy). In its cost-benefit analysis, NHTSA assumes that the overall costs and benefits will be borne by private consumers, not manufacturers, because the costs will be passed on through higher vehicle purchase prices and the benefits will be less gasoline use, a better environment, and a more secure energy future. Thus, assuming that NHTSA is bound by the OMB circular, we believe it is only appropriate for NHTSA to use a discount rate appropriate for society-wide evaluation and for regulations that affect private consumption, such as a 3% discount rate, rather than one based on the cost of capital.

While NHTSA's to-date cost benefit analysis does not place a high value on addressing global warming, the agency does tout those benefits as a primary reason for doing this rulemaking. Thus, the agency should take into account the discount rates that scholars and economists are using to evaluate the costs and benefits related to global warming. As an example, we are enclosing a presentation made by Professor Michael Hanemann of the University of California at Berkeley.[4] As Prof. Hanemann relays, the discount rates used by the two most prominent competing economic evaluations of the costs of global warming are 4% and 1.4%. Thus, even the more conservative economist would not use a 7% discount rate.

We urge the agency to use a lower discount rate.

Consideration of Emission Standards

As the agency is aware, one of the statutory factors that it must consider is the "effect of other motor vehicle standards of the Government on fuel economy." 49 U.S.C. § 32902(f). In previous rulemakings, NHTSA has consistently considered both federal Clean Air Act emission standards adopted by the U.S. Environmental Protection Agency (EPA) and California emission

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4. This presentation was made on April 1, 2008, at the 9th Swiss Global Change Day conference, held in Bern. *See* http://www.proclim.ch/Events/2008/9CHGCDay/9thSGCD.html.

standards that have received a waiver of preemption from EPA pursuant to Clean Air Act section 209(b), 42 U.S.C. § 7543(b).

NHTSA's notice of proposed rulemaking does not analyze the effects of *any* federal or California emission standards. The omission of an analysis of California's zero emission vehicle (ZEV) standards is particularly noteworthy.[5] EPA has granted a waiver for California's ZEV standards through model year 2011. 71 Fed. Reg. 78,190 (Dec. 28, 2006). A number of other States have adopted standards identical to these standards. Those standards are likely to increase the number of hybrids sold in our nation. The California Air Resources Board's 2004 estimate of the number of hybrids to be sold just in California in model year 2011 under the 2003 version of those regulations was 133,217 vehicles. *See* Air Resources Board, 2003 Amendments to the California Zero Emission Vehicle Program Regulations; Final Statement of Reasons at 38 (January 2004). The Board is in the process of adopting additional amendments to these regulations (which for model year 2011 would be within-the-scope of the existing Clean Air Act waiver), which would also likely increase the number of plug-in hybrids sold in these States; the Board's original estimate for model years 2009 through 2011 was 30,000 plug-in hybrids in California. Air Resources Board, Staff Report: Initial Statement of Reasons; 2008 Proposed Amendments to the California Zero Emission Vehicle Program Regulations at 29 (Feb. 8, 2008). Comparable increases will occur in the States that have adopted regulations identical to California's. But these regulations are also likely to spur increases in other States, simply because of the nationwide marketing of vehicles. NHTSA needs to take these technological advances into account.

Backstop

In *Center for Biological Diversity*, the Ninth Circuit ruled that NHTSA had been arbitrary and capricious in not considering a backstop to the footprint-based standards adopted for light trucks for model years 2009 through 2011. 508 F.3d at 537-39. Such a backstop

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5. Potentially, there is also the issue of California's greenhouse gas emission standards. Because a waiver has not yet been granted for these emission standards, NHTSA need not consider these standards under 49 U.S.C. § 32902(f). However, should a waiver be granted in the future (*see California v. EPA*, Nos. 08-70011 & 08-70030 (9th Cir. filed Jan. 2, 2008) (challenging denial of waiver); *California v. EPA*, Nos. 08-1178, 08-1179 & 08-1180 (D.C. Cir. filed May 5, 2008) (same, protective filing)), NHTSA must then consider those emission standards in setting its fuel economy standards. NHTSA cannot rely on its position that California's standards are preempted, particularly since two federal courts have already ruled to the contrary. *See Central Valley Chrysler-Jeep, Inc. v. Goldstene*, 529 F.Supp.2d 1151 (E.D. Cal. 2007), *Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie*, 508 F.Supp.2d 295 (D.Vt. 2007). Thus, California's standards will be enforced by California and other States should the district court decisions remain standing and a waiver be granted.

"would prevent manufacturers from upsizing their vehicles or producing too many large footprint vehicles, if the backstop were set high enough." *Id.* at 537. The Court ruled that while nothing in the fuel economy statute required a backstop, NHTSA's failure to consider one violated the requirement that NHTSA consider the four "maximum feasible" factors in setting fuel economy standards. *Id.* at 538.

NHTSA makes the same mistake here. The agency admits that it did not consider a backstop for light trucks and non-domestic passenger cars. *See* 73 Fed. Reg. at 24,447. NHTSA claims that it is barred from establishing a regulatory backstop because EISA requires attribute based standards and enacted a limited backstop just for domestic passenger cars. *Id.*

But Congress evidenced no such intent in the statute or the legislative history. Repeals by implication are disfavored, and must be based on clear evidence. *Nat'l Ass'n of Home Builders v. Defenders of Wildlife*, 127 S. Ct. 2518, 2532 (2007). As the Supreme Court has said repeatedly: "We will not infer a statutory repeal unless the later statute expressly contradict[s] the original act or unless such a construction is absolutely necessary . . . in order that [the] words [of the later statute] shall have any meaning at all." *Id.* (brackets and ellipses in original and internal quotation marks omitted) (quoting *Traynor v. Turnage*, 485 U.S. 535, 548 (1988), in turn quoting *Radzanower v. Touche Ross & Co.*, 426 U.S. 148, 153 (1976), in turn quoting T. Sedgwick, The Interpretation and Construction of Statutory and Constitutional Law 98 (2d ed. 1874)). In EISA, Congress did not repeal – or even change – the definition of maximum feasible fuel economy. Based on that definition, NHTSA remains obligated to consider a backstop – as ordered by the Ninth Circuit. To do otherwise would be arbitrary and capricious.

The reasons for establishing a backstop still exist. There is still a risk that attribute-based standards will cause a "race to the bottom" by manufacturers. Thus, we urge the agency to consider and adopt an appropriate backstop for all vehicles.

Estimating the Benefits Regarding Global Warming

In assessing the benefits of addressing global warming, NHTSA assigned a value of $7 for each metric ton of reduced carbon dioxide. 73 Fed. Reg. at 24,414-3. In choosing that number, NHTSA simply halved an estimate derived from a 2005 *Energy Policy* article by Prof. Richard S.J. Tol. *Id.* This is not a reasoned judgment. If the agency believes that estimates provided by Prof. Tol are the best available, it should use those, after providing a reasoned explanation for doing so. If the agency believes there is a better estimate, it should use that better estimate. It seems likely that there are better estimates, since Prof. Tol's article is now three years old, and it itself explains in detail the many deficiencies in the economic literature at that time. Richard S.J. Tol, The Marginal Damage Costs of Carbon Dioxide Emissions: an Assessment of the Uncertainties, 33 Energy Policy 2064, 2065-67 (2005). NHTSA should consult with EPA on this issue, and conduct a review of the current scientific and economics literature.

Estimating the Benefits Regarding Energy Security

NHTSA assigned a value of *zero* to the government outlay aspect of energy security (increased military spending and purchases for the Strategic Petroleum Reserve). This finding is quite astounding because one of the primary purposes of EISA is to achieve energy security. The agency says that these costs are "unlikely to vary significantly in response to changes in the level of oil imports." 73 Fed. Reg. at 24,411-2.

This is akin to what NHTSA did with the benefits to reducing global warming in *Center for Biological Diversity*, when it refused to assign a non-zero number to the benefits of reducing greenhouse gas emissions. *See* 508 F.3d at 531-35. In that case, the court held that the agency "cannot put a thumb on the scale by undervaluing the benefits and overvaluing the costs of more stringent standards." *Id.* at 531. Uncertainty about a benefit's value is not a valid reason to assign that value at zero. *Id.* at 533-35.

It is true that an increase in CAFE standards will not, in and of itself, eliminate these energy security costs. The same could be said as to global warming costs. It is also the case, however, that the impact of higher CAFE standards on energy security is not zero. Energy security costs are a necessary piece of the puzzle in assessing all of the costs and benefits of a CAFE standard. In fact, a recent peer-reviewed economic analysis did assign values to the military savings attributable to decreased oil imports. *See* Mark A. DeLucchi & James J. Murphy, US Miliary Expenditures to Protect the Use of Persian Gulf Oil Imports, 36 *Energy Policy* 2253 (2008) (assigning a cost of between $0.03 and $0.15 per gallon, and referencing earlier work on this issue).

We urge NHTSA to assign an economically sound number to all of the energy security costs.

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At a time when Congress and the public are calling for reduced oil dependence, and with the enactment of EISA, NHTSA has a special opportunity. If the agency acts, as required by law, with energy conservation as its primary purpose, and with realistic assumptions about the costs and benefits of conservation, it can create a legacy that moves us in the right direction. Otherwise, the agency's actions will be seen as simply as another vestige of a past, disgraced era of oil dependence.

We urge NHTSA to revisit these issues with an open mind, and to make the significant changes discussed above. Given the magnitude of the changes and additional analysis that is necessary, we also urge NHTSA to re-issue the notice of proposed rulemaking.

Thank you for the opportunity to comment on these proposed new fuel economy standards.

Sincerely,

Edmund G. Brown Jr.
Attorney General of California

Terry Goddard
Attorney General of Arizona

Richard Blumenthal
Attorney General of Connecticut

Lisa Madigan
Attorney General of Illinois

Tom Miller
Attorney General of Iowa

Douglas F. Gansler
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Hardy Myers
Attorney General of Oregon

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Attorney General of Vermont

Ron Curry
Secretary of the New Mexico Environment Department

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Commissioner of the New Jersey
Department of Environmental Protection

Kathleen McGinty
Secretary of the Commonwealth of
Pennsylvania Department of Environmental
Protection

George S. Hawkins
Director of the District of Columbia
Department of the Environment

Michael A. Cardozo
Corporation Counsel of the City of New York

Enclosures
cc: Docket Management Facility

Acc. No. 0595

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DEPT. OF TRANSPORTATION DOCKETS

2008 AUG 19 A 9:04

OFFICE OF ENFORCEMENT AND COMPLIANCE ASSURANCE

AUG 18 2008

Docket Management Facility, M-30
U.S. Department of Transportation, West Building
Ground Floor, Room W12-140
1200 New Jersey Avenue, SE
Washington, DC 20590

RE: Draft Environmental Impact Statement for New Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, MY 2011-2015, Docket Number NHTSA-2008-0060

To Whom It May Concern,

In accordance with our responsibilities under the National Environmental Policy Act (NEPA) and Section 309 of the Clean Air Act, the Environmental Protection Agency has reviewed the National Highway Traffic Safety Administration's (NHTSA) Draft Environmental Impact Statement (DEIS) for Corporate Average Fuel Economy Standards. In this DEIS, NHTSA considers the potential environmental impacts of new fuel economy standards that NHTSA is proposing pursuant to the Energy Independence and Security Act of 2007 for model year 2011-2015 passenger cars and light trucks.

For the purposes of the DEIS, NHTSA has evaluated a "No Action" alternative, an "Optimized" alternative, representing the proposed CAFE standard by which net benefits are maximized given the assumptions used in the document, and five other alternatives ranging from less stringent to more stringent than the "optimized" alternative. While the range of alternatives evaluated appears to be broad, EPA has several concerns with the methodology used to determine the relative benefits and costs of the alternatives analyzed. EPA believes that the EIS can be improved and a more accurate determination of benefits and costs would result.

We rate the document EC-2 (Environmental Concerns – Insufficient Information). A summary of EPA's rating criteria is enclosed. While EPA is supportive of the effort to raise fuel economy standards and believes that all of the action alternatives would result in environmental benefits when compared to the no-action alternative, we do have significant concerns with the data used in the DEIS and the range of alternatives found therein.

We appreciate the opportunity to review and provide comment on the DEIS and are prepared to provide assistance to NHTSA as the environmental review process moves forward. If you have any questions please contact Robert Hargrove at 202-564-7157 or James G. Gavin at 202-564-7161.

Sincerely,

for Susan E. Bromm
Director
Office of Federal Activities

Enclosures (2):

Detailed Comments
EPA's Summary of NEPA Rating Definitions

Detailed Comments

A: Comments on NHTSA Corporate Average Fuel Economy Standards DEIS

Fuel Price Assumptions

The DEIS uses official 2008 AEO Early Release fuel price projections of $2.04-$3.37 per gallon in the relevant timeframe. EPA's work with the Volpe Model, as well as the High Fuel Price sensitivity analyses presented in Section IX of the Preliminary Regulatory Impact Analysis (PRIA) associated with the CAFE Notice of Proposed Rulemaking (NPRM), indicates that the Volpe model is very sensitive to fuel price projections. Using projections at the high end of the AEO range would change the base case (as the market reacts to higher fuel prices) and the projected net benefits, and it would likely increase the level of the "optimized" fuel economy standard. EPA urges NHTSA to carefully consider projections for fuel prices and notes the important nexus between this estimate and future projections for the Final EIS.

Discount Rate

NHTSA uses a 7 percent discount rate to future benefits in determining the "optimized" fuel economy standard. The sensitivity analysis performed in the DEIS using a discount rate of 3 percent shows that a lower discount rate has a substantial effect on future carbon dioxide reductions. As such, using a 3 percent discount rate significantly increases the projected societal benefits, as shown in Section IX of the PRIA, indicating a higher "optimized" fuel economy standard. EPA recommends that NHTSA consider using a 3 percent discount rate for GHG benefits as part of its primary analysis. While a 7 percent discount rate may be reasonable to apply to the cost savings realized by consumers who invest in fuel economy, EPA questions whether such a high discount rate can be justified for the long-term benefits associated with GHG reductions.

Climate Change and the Social Cost of Carbon

NHTSA selected a single marginal benefits value of \$7.00/tCO_2 to represent the social cost of carbon (SCC) for their main analysis. This value and the \$0-14/tCO_2 range NHTSA considers are characterized as domestic SCC estimates. While OMB guidance instructs Agencies to consider benefits that accrue to US residents, it does allow for the additional consideration of global benefits. Given that US emissions have global externalities, NHTSA should analyze global SCC estimates in addition to any domestic estimates to more fully capture all of the externalities. This could be justified from the fact that US citizens may value impacts felt outside our borders. Moreover, to the extent that the United States regards the CAFE standards as a component of its contribution to a global effort to address climate change, a global SCC is needed to accurately characterize that contribution. It is also important that NHTSA recognize that the current monetized estimates of marginal benefits are incomplete and very likely underestimated.

Therefore, EPA recommends that NHTSA do Volpe runs with a range of domestic and global SCC estimates that capture the uncertainty in estimates and the potential risks of significant climate change impacts. The ranges and growth rates should be based in the peer reviewed literature and should cover a substantial range, given the wide uncertainties in estimates of the SCC. For example, see the estimates and discussion in the "Technical Support Document on the Benefits of Regulating GHG Emissions" developed in support of EPA's Advanced Notice of Proposed Rulemaking (found at www.regulations.gov; search on "Technical Support Document – Benefits").

It should also be noted that SCC estimates are only a partial accounting of the social costs of carbon. NHTSA does not currently account for the non-monetized impacts and potential catastrophic risks of climate change in its decision-making approach. The IPCC WGII (2007) report states that SCC values are "very likely" underestimated, where the report defines "very likely" as a greater than 90% probability. The models used to generate the SCC estimates cited by NHTSA leave out major types of climate change damage that have been identified by the IPCC.

Furthermore, most SCC estimates exclude the value of avoiding or reducing the risk of potential catastrophic effects of climate change, due to scientific and economic uncertainties. It is noteworthy that the risk of such effects is one of the major policy considerations for Congress, the public, and the executive branch in developing a climate change mitigation policy, yet is excluded in most economic analysis. Risk increases with increases in the rate and magnitude of climate change, due to a greater chance to stress systems. NHTSA should clearly note in the DEIS that emissions reductions reduce the probability of higher climate outcomes and therefore reduce the level of associated risk and acknowledge that benefits estimates do not include a risk premium, i.e., the value people have for greater certainty and the reduced risk of more extreme outcomes.

Finally, EPA is concerned that NHSTA has not accounted for non-CO_2 GHG emissions changes that would be expected with the policy, e.g., changes in fuel use will bring changes in non-CO_2 GHG emissions associated with fossil fuel extraction, production, transportation, refining, and combustion. Also, the social cost of a non-CO_2 GHG can be quite different from the social cost of carbon dioxide emissions (IPCC WGII, 2007). NHTSA should estimate the global changes in non-CO_2 GHG emissions and apply, or at least acknowledge, non-CO_2 marginal benefits estimates.

Additional Climate Change-Related Comments

While EPA believes that the overall methodology used by NHTSA to model climate effects for the different CAFE scenarios using MAGICC is sound, EPA does have some recommendations that would strengthen the analysis performed. EPA would recommend re-running the analysis using the revised version (5.3) of MAGICC, which incorporates climate models used in IPCC's Fourth Assessment Report. We would also suggest running MAGICC using a range of climate sensitivities to reflect the 2.0-4.5° C range projected in the IPCC report. Finally, for the emissions scenarios analyzed, EPA would suggest using A2, A1B, A1FI, and B2. We would suggest adding some text indicating that recent socioeconomic and emissions trends are higher than those captured by SRES and even more recent scenarios.

Additionally, EPA has the following questions and comments regarding the climate projections used by NHTSA:

1. Why was the SRES A1B chosen as the baseline scenario? How does it compare to current trends? Other potential futures should be considered.

2. What climate sensitivity was used? If only a climate sensitivity of 3 was considered, then NHTSA has ignored the implications for the distribution of potential climate outcomes in 2030, 2060, and 2100.

3. There are inconsistencies in the treatment of climate and other analyses:
   a. NHTSA is using an SRES A1B emissions scenario for climate projections, yet using a mean SCC estimate based on a variety of climate projections;
   b. NHTSA is combining a domestic estimate of the SCC with global climate variables; and
   c. NHTSA is using SRES A1B emissions for global climate, yet is using US EPA emissions for transportation which are not consistent with A1B.

Finally, EPA recommends that the DEIS discussion of climate change tipping points be expanded somewhat in the FEIS to include a brief discussion of the impacts associated with a given tipping element, and to include a reference to additional tipping elements identified by the scientific community (see Lenton, T. M., Held, H., Kriegler, E., Hall, J. W., Lucht, W., Rahmstorf, S. and Schellnhuber, H. J. (2008). Tipping elements in the Earth's climate system. Proceedings of the National Academy of Sciences, Online Early Edition. February 4, 2008), including:

- Increase in the El Nino Southern Oscillation
- Collapse of the Indian summer monsoon
- Greening of the Sahara/Sahel and disruption of the West African monsoon
- Dieback of the Amazon rainforest
- Dieback of the Boreal Forest

Other Environmental Concerns

EPA believes the DEIS could be strengthened (page 3-88) by adding supporting information on the topic of hazardous materials. We recommend the DEIS document in more detail that future efforts at downweighting of vehicles by substitution of aluminum, plastics, composites, and synthetic materials for steel and ductile iron parts, will not result in a net (overall) increase in the hazardous waste stream, and that if there are any increases, these will be manageable under current technologies.

Some published studies have also suggested that the trend toward substitution of lighter weight aluminum for steel in autos increases energy demands and may result in increased pollution from bauxite mining, alumina refining, and aluminum smelting operations. The DEIS should cite current research on how the substitution of lighter weight materials can avoid significant effects on water or biological resources, and reduce CO_2. The DEIS simply states that the "projected reduction in fuel production and consumption as a result of the proposed action and alternatives may lead to a reduction in the amount of hazardous materials and wastes created by the oil extraction and refining industries." No mention is made of the consequences/impacts of the increasing substitution to lighter weight materials.

Finally, the DEIS states that impacts to land use and development "could include increased agricultural land use" due to increasing use of biofuels. As mentioned above, increased mining is also a potential impact as the search grows for raw materials to create new lightweight materials and hybrid structures. Mining and related land disturbance activities could also have an impact on water resources and aquatic health, particularly where increasing sediment runoff in rivers and streams is an issue.

Characterization of Mobile Source Air Toxics

In several locations in section 3.3.1, the description of hazardous air pollutants emitted by mobile sources (mobile source air toxics, or "MSATs") analyzed in the DEIS is mischaracterized and incorrectly cited. EPA recommends the following revisions and clarifications:

Page 3-11: As Section 112(b) of the Clean Air Act is not relevant to mobile sources and the analysis in the DEIS does not include all of the hazardous air pollutants, EPA recommends the following edit:

"The air quality analysis assesses the impacts of the alternatives with respect to criteria pollutants and some hazardous air pollutants from mobile sources (also known as mobile source air toxics.) ~~Hazardous Air Pollutants (HAPs, also known as toxic air pollutants or air toxics) as defined under Section 112(b) of the CAA.~~"

Page 3-13: As EPA has not identified a specific list of priority MSATs, including in the MSAT final rule, we recommend the following edit to the fourth paragraph:

"~~The relevant air toxics for this analysis are referred to by EPA and Federal Highway Administration (FHWA) as the priority Mobile Source Air Toxics (MSAT). The priority MSATs~~ The MSATs included in this analysis are acetaldehyde, acrolein, benzene, 1,3-butadiene, diesel particulate matter (DPM), and formaldehyde ~~(EPA, 2008)~~. DPM is a component of exhaust from diesel-fueled vehicles and falls almost entirely within the PM2.5 particle size class."

In addition, page 3-13 states that the description of the health effects of the six Federal criteria pollutants is adapted from EPA, 2008b. This does not appear to be properly referenced. There is no EPA 2008b listed in the references, and neither of the EPA 2008 references appear to be relevant here.

Page 3-15: Similarly, as EPA has not identified a list of priority MSATs, we request deletion of the word "priority" to describe the MSATS referenced. Furthermore, we believe that Claggett and Houk, 2006 is an inappropriate source for the information presented. A summary of health effects should be referenced to a more primary source (such as EPA's Integrated Risk Information System), or EPA's own synthesis of health effects (such as the 2007 MSAT rule preamble and/or RIA).

Page 3-16 cites EPA, 2008 as the reference for EPA's MSAT rule. This is an incorrect reference. The MSAT rule was published in 2007, and the full details of that reference are in footnote 16.

Page 3-20: For the section on treatment of incomplete or unavailable information, EPA recommends the following addition, indicating the limitations of the modeling done for upstream emissions of MSATs:

> "Data used to estimate upstream emission impacts on air toxics are significantly older than data for criteria pollutants and use of more recent and complete data could affect results. In addition, all upstream toxic emissions were assigned to refinery processes, which could lead to over assignment of air toxic emissions to areas with refineries and an under assignment to areas without them."

Page 3-23 indicates that upstream MSAT emissions were estimated using the DOE GREET model. However, GREET does not include toxics, although in 2000, a version of GREET was developed which estimated air toxics using speciation factors. EPA assumes this was what was used. If that is the case, there are significant limitations which should be discussed. First, ethanol production is not included in the model. The model also used combustion emission factors for vehicles used in transport that are now significantly out of date, and assumed evaporative emissions of benzene were equivalent to levels of benzene in fuel. For refinery processes, the emission factors used are very old. As part of its analyses for last year's draft proposed greenhouse gas rule, and the upcoming rule implementing requirements under EISA, EPA developed air toxic emission factors for upstream processes using the most recent available information. We recommend that NHTSA coordinate with EPA on updating upstream toxic emission factors.

Also, all upstream toxic emissions were assigned to refinery processes. EPA does not believe this assumption is reasonable as it means that there will be an over assignment of emissions to areas with refineries and an under assignment to areas without them.

Page 3-25: In section 3.3.2.2 "Results of the Emissions Analysis," the text states "As discussed in Section 3.31, pollutant emissions from vehicles have been declining since 1970 and EPA projects that they will continue to decline. This trend will continue regardless of the alternative that is chosen for future CAFE standards" (p. 3-25). A similar statement is in 3.3.2.3.2 (p.3-28): "As with the criteria pollutants, current trends in the levels of air toxics emissions would continue, with emissions continuing to decline due to the EPA emission standards despite a growth in total VMT." In fact, Tables 3.3.-3 and 3.3.-5 show increases in VOC between 2025 and 2035 (and in the case of DPM, emissions increase in each analysis year in all scenarios, including the No Action). The incorrect statements in the text should be deleted, and the trend of increasing emissions in the later analysis years should be acknowledged.

Potential Analysis of Model Year 2016-2020 CAFE Standards

In several places throughout the DEIS, the text implies that in addition to evaluating several alternatives for model year 2011-2015 CAFE standards, the DEIS also includes analysis of future model year 2016-2020 CAFE standards (for example, in the third paragraph of the June 24, 2008 DEIS cover letter from Deputy Administrator James F. Ports, Jr., and in the titles to Table 2.5-8 and 2.5-9, and the titles to Figures 2.5-3, and 2.5-4). EPA was unable to determine from reading the DEIS if, in fact, new standards were analyzed for model years 2016-2020. NHTSA should clarify this issue in the final EIS, and to the extent potential CAFE standards were modeled for 2016-2020, such standard scenarios should be described in detail in the final EIS.

Additional Specific Comments

Chapter 1, pg. 1-6, Lines 26-29

In order to address the limitations of the air quality modeling in the EIS, EPA recommends that these lines be revised as follows:

"EPA indicated that many of the factors that affect air quality, such as meteorology and atmospheric processes, will not be taken into account when evaluating human health and environmental impacts without a full-scale photochemical air quality modeling analysis. This limitation needs to be acknowledged. NHTSA agrees with EPA's suggestion, and this limitation is acknowledged in Chapters 3 and 4."

There is also no mention of this limitation in Chapter 4. Please repeat the limitation text in that Chapter.

Chapter 1, pg. 1-7, Lines 20-28

It does not appear that NHTSA undertook a complete health impacts analysis in its analysis of alternatives. Instead, the Volpe model substitutes $/ton values which reflect a measure of the monetized health related benefits associated with criteria pollutant emission reductions. The $/ton numbers omit a number of unquantified health and environmental effects, and are therefore an underestimate of total benefits. A complete health and environmental impacts analysis would begin with full-scale photochemical air quality modeling to demonstrate the changes in ambient air pollution exposure related to the emission changes associated with each alternative scenario. These ambient concentrations would then be fed through a health impacts model (EPA's Environmental Benefits and Mapping Analysis Program – BenMAP) to characterize population exposure and the change in health response associated with various health impact functions derived from the epidemiological literature.

Also, the $/ton source needs to be cited throughout the document and characterized appropriately. EPA used these $/ton estimates in its ozone NAAQS analysis to *supplement* the formal health impacts analysis – they were not used as a substitute for that analysis.

In light of these observations, EPA recommends the text be revised as follows:

"NHTSA's analysis of alternative CAFE standards incorporates the economic value of reduced damages to human health that would result from the reductions in emissions of criteria air pollutants and GHGs estimated to result from each alternative. These reductions in damages to human health are valued using estimates of damage costs per unit of emissions of each pollutant that approximate the chemical composition and geographic distribution of emissions generated by motor vehicle use and by production and distribution of transportation fuels. The dollar-per-ton estimates only provide a screening-level approximation of the potential value of health improvements associated with each alternative. They are not meant to replace a formal health impacts analysis that quantifies and monetizes health incidence such as premature mortality, chronic bronchitis, and respiratory and cardiovascular illnesses, but instead provide an estimate of health-related benefits in the absence of a formal analysis. It should also be noted that the monetized benefits associated with criteria pollutant reductions underestimate total benefits because the dollar-per-ton values used in this analysis omit a number of unquantified human health and environmental impacts.

The dollar-per-ton estimates used in this analysis were developed by EPA for use in a supplemental analysis of the benefits associated with the final ozone NAAQS RIA.[Insert footnote – see below] Human health is further discussed in Chapters 3 and 4.

[footnote] U.S. Environmental Protection Agency. August 2007. Benefit Per Ton Technical Support Document, Docket No. EPA-HQ-OAR-2006-0834, Proposed Regulatory Impact Analysis (RIA) for the Proposed National Ambient Air Quality Standards for Ozone. Prepared by: Office of Air and Radiation, Office of Air Quality Planning and Standards."

Chapter 3, pg. 3-13, line 34

EPA recommends the following sentence be added to the beginning of the paragraph, to clarify that a formal health impact analysis was not done:

"Though we did not conduct a formal analysis of health impacts, the alternatives considered in this EIS will contribute to reductions in criteria pollutants that will improve public health and welfare."

Chapter 3, pg. 3-13, lines 36-40 and pg. 3-14, lines 1-3

In order to accurately characterize ozone-related health impacts, EPA recommends adding the following sentence to the end of the ozone health effects description:

"There is also highly suggestive evidence that short-term ozone exposure directly or indirectly contributes to non-accidental and cardiopulmonary-related mortality."

Chapter 3, pg. 3-17, lines 40-43 & pg. 3-18, lines 1-2

In order to better describe the limitations of the air quality analysis performed by NHTSA, EPA recommends the paragraph be revised as follows:

"Full-scale photochemical air quality modeling was not conducted for this analysis; therefore, the EIS is unable to characterize the ambient air quality impacts associated with each alternative. Instead, the action alternatives were analyzed by calculating the emissions from passenger car and light trucks that would occur under each alternative, and assessing the changes in emissions relative to the No Action Alternative. Lower emissions should result in lower ambient concentrations of pollutants on an overall average basis, which should lead to decreased health effects of those pollutants.

Full-scale photochemical air quality modeling is necessary to accurately project levels of PM2.5, ozone and air toxics. A national-scale air quality modeling analysis would analyze the combined impacts of each alternative on PM2.5, ozone, and air toxics (i.e., benzene, formaldehyde, acetaldehyde, ethanol, acrolein and 1,3-butadiene). The atmospheric chemistry related to ambient concentrations of PM2.5, ozone and air toxics is very complex, and making predictions based solely on emissions changes is extremely difficult."

Chapter 3, page 3-20, lines 7-16

EPA recommends the paragraph be revised as follows in order to more clearly indicate that incomplete/unavailable information limitations affect the air quality and health impacts analysis done:

"As noted above, the estimates of emissions rely on models and forecasts that contain numerous assumptions and data that are uncertain. Examples of areas in which information is incomplete or unavailable include future emission rates, vehicle manufacturers' decisions on vehicle technology and design, the mix of vehicle types and model years, emissions from fuel refining and distribution, and economic factors. *Furthermore, a full-scale photochemical air quality modeling analysis to estimate the ambient concentrations of PM, ozone, and air toxics was not conducted. The lack of air quality modeling data limited the conclusions that could be made about health and environmental impacts associated with each alternative. Instead, a screening-level estimate of monetized health benefits, in the form of dollar-per-ton of criteria pollutant emissions reduced, was used to approximate the health benefits associated with each alternative. The use of such dollar-per-ton numbers, however, does not account for all potential health and environmental benefits, which leads to an underestimate of total criteria pollutant benefits.* Where information in the analysis included in the DEIS is incomplete or unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable information. See 40 CFR § 1502.22(b). NHTSA has used the best available models and supporting data. The models used for the DEIS were subjected to scientific review and have received the approval of the agencies that sponsored their development. NHTSA believes that the assumptions that the DEIS makes regarding uncertain conditions reflect the best available information and are valid and sufficient for this analysis."

Chapter 3, page 3-26 and 3-28

NHTSA's estimates of criteria pollutant reductions (e.g., 54,000 - 232,000 tons of NOx in 2020) connected with the proposed CAFE standards appear to be larger than EPA would expect. EPA has not been able to replicate NHTSA's estimate, so we do not know for certain if there is an issue. The magnitude of the resulting inventory reductions suggests that NHTSA may be taking credit for criteria (and possibly toxic) emission benefits that occur internationally during crude oil transport to the U.S., rather than just counting the domestic benefits of reduced refinery and fuel distribution emissions. The lack of details in the DEIS does not allow EPA to comment for certain on how the NHTSA DEIS estimates were calculated, but the text in the Federal Register notice, page 24412, seems to support this suggestion:

"Reductions in domestic fuel refining using imported crude oil as a feedstock are tentatively assumed to reduce emissions during crude oil transportation and storage, as well as during gasoline refining, distribution, and storage, because less of each of these activities would be occurring."

An additional possible cause for the large emission reductions estimated by NHTSA is the use of the GREET model to generate those estimates. EPA has noticed that the heavy-duty truck, rail, and barge emission factors in GREET do not reflect the latest round of EPA emission standards that substantially reduce VOC, NOx, and PM emissions in future years (the heavy-duty highway 2007/2010 standards). Use of these more controlled emission factors would decrease the "No Action" emissions as well as emissions from the various CAFE alternatives, with the net result being smaller benefits from the program than estimated using an unmodified version of GREET. We suggest

NHTSA verify what standards are assumed in the version of GREET used for the DEIS, and modify as appropriate for the final EIS.

Chapter 3, pg 3-27, Figure 3.3-2

This figure, and others like it, suffers from a scale mismatch related to the tons associated with CO vs. each of the other criteria pollutants. The different reductions between alternatives for PM, NOx, SOx, and VOCs are not minor. However, the scale of the table gives this misimpression. EPA recommends that CO be decoupled from this table, shown separately, and the scale of the existing table be revised to more accurately show differences in the alternatives for the other criteria pollutants.

It should be noted that all EPA comments made in regard to suggested Chapter 3 revisions apply to the appropriate sections in Chapter 4 and should be repeated there.

Appendix C

The excerpted Cost and Benefit RIA chapters appear to have been pulled from an outdated version of the RIA. EPA recommends that the text be replaced with that found in the April, 2008 version of the RIA.

SUMMARY OF RATING DEFINITIONS AND FOLLOW UP ACTION*

Environmental Impact of the Action

LO-Lack of Objections
The EPA review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

EC-Environmental Concerns
The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impacts. EPA would like to work with the lead agency to reduce these impacts.

EO-Environmental Objections
The EPA review has identified significant environmental impacts that must be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

EU-Environmentally Unsatisfactory
The EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of public health or welfare or environmental quality. EPA intends to work with the lead agency to reduce these impacts. If the potential unsatisfactory impacts are not corrected at the final EIS sate, this proposal will be recommended for referral to the CEQ.

Adequacy of the Impact Statement

Category 1-Adequate
The EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alterative and those of the alternatives reasonably available to the project or action. No further analysis or data collecting is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category 2-Insufficient Information
The draft EIS does not contain sufficient information for the EPA to fully assess the environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category 3-Inadequate
EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the NEPA and/or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

*From EPA Manual 1640 Policy and Procedures for the Review of the Federal Actions Impacting the Environment

Environmental Defense Fund
finding the ways that work

Comments on the Draft Environmental Impact Statement for: "Corporate Average Fuel Economy Standards for Cars and Light Trucks - Model Years 2011-2015"

National Highway Traffic Safety Administration
Docket No. NHTSA-2008-0089-0002

Environmental Defense Fund (EDF) respectfully submits these comments on the draft Environmental Impact Statement (referred to herein as EIS) for the revised corporate average fuel economy (CAFE) standards for passenger cars and light trucks. Environmental Defense Fund hereby incorporates as part of our comments for the administrative record in this proceeding all of the documents referenced and cited to herein.

We assert that the EIS is conceptually flawed, and as such fails to provide appropriate and relevant information to policy makers and the public as intended by the National Environmental Protection Act (NEPA). Two issues are of particular concern: 1) the inappropriate context used to assess the climate change consequences of the CAFE alternatives, and; 2) the lack of an appropriate health impact assessment of conventional air pollutants. We address these issues at greater depth and provide reasonable solutions in the "Specific Comments" section of this document. Without the rectification of these issues policy makers will be unable to understand the environmental and public health consequences of selecting one alternative over another and therefore cannot meaningfully decide among the proposed CAFE alternatives.

General Comments on the EIS

1. Although the team that created this EIS is well-credentialed in many areas of environmental assessment, we do not believe they had the proper expertise to adequately evaluate the health impacts of the proposed CAFE alternatives. We note that among the team of 47 technical experts, the reviewers, and the project managers not one had obtained a graduate degree in public health. The National Highway Traffic Safety Administration (NHTSA) asserts in its response to comments from the Centers for Disease Control and Prevention (CDC) also calling for inclusion of public health professionals,

> NHTSA feels confident that the consultants retained to assist in the analysis and development of the DEIS, along with its own staff, have the requisite knowledge and skills to effectively incorporate health issues into the document.[1]

[1] p. 1-7. NHTSA. Draft Environmental Impact Statement Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015. National Highway Transportation Safety Administration, 2008.

EDF supports the CDC's recommendation for inclusion of public health professionals in the process of developing the EIS. Given the length and complexity of this EIS, it is unlikely that a teleconference with the CDC was sufficient to obtain the "high degree of understanding" NHTSA asserts, and therefore unlikely that the appropriate disciplinary expertise in public health was applied to this EIS.[2]

2. We strongly support the global scope of the climate change assessment resulting from U.S. vehicle emissions, although as we discuss below there are several conceptual flaws with the actual analysis. However, the EIS fails to account for additional global ramifications of U.S. fuel efficiency standard setting; namely the influence of U.S. CAFE regulations on the global automobile market. Vehicle manufacturers tend to produce cars that comply with one of three dominant regulatory programs, the U.S., the European Union, or Japan, regardless of whether the vehicle is to be sold in that region. Thus U.S. CAFE standards impact the fuel efficiency of vehicles driven in other countries, and subsequently their greenhouse gas emissions. Although we do not have precise figures relating to the influence of the U.S. fuel economy standards on the global automobile market, figures for an analogous impact, that of U.S. vehicle emissions standards, are available. In addition to the approximately 17 million cars and light trucks sold in the U.S. in 2005, another 5.2 million vehicles were sold that year in other countries that met U.S. emissions regulatory standards.[3] The number of cars sold globally that follow U.S. fuel economy standards could be greater or less than those following emissions standards. The cumulative impacts assessment in this EIS must account for the additional non-U.S. vehicles that follow U.S. CAFE standards and the resulting cumulative effect that more stringent standards will exert on global greenhouse gas (GHG) emissions.

Specific Comments on the EIS

<u>I. Objections to the Failure of the EIS to Provide Context for Assessing the Proposed CAFE Alternatives and Climate Change.</u>

The cumulative impacts section in this EIS fails to provide the proper context to evaluate the climate change potential or consequent health impacts of the proposed fuel efficiency standards. In omitting this context NHTSA directly contradicts the Court's instructions in *Center for Biological Diversity v. NHTSA* regarding the agency's obligation to address cumulative impacts under NEPA, explaining that the environmental review must:

> provide the necessary contextual information about the cumulative and incremental environmental impacts of the Final Rule in light of other CAFE rulemakings and other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions.[4]

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[2] p. 1-7 NHTSA

[3] Walsh MP. Ancillary Benefits for Climate Change Mitigation and Air Pollution Control in the World's Motor Vehicle Fleets. 2008. Annual Review of Public Health. 29:1-9.

[4] *Center for Biological Diversity v. National Highway Traffic Administration,* 508 F.3d 508, 550 (9th Cir 2007) (citing 40 C.F.R. § 1508.7 and judicial precedent on cumulative impacts).

The EIS draws heavily upon the most recent Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report in describing the causes of climate change and its impacts on the environment and human welfare. However, the EIS ignores the strong language in the IPCC report that describes appropriate, science-based targets to avoid the most drastic of these impacts. For example, the IPCC states that "avoidance of many key vulnerabilities requires temperature change in 2100 to be below 2.6°C above pre-industrial levels".[5] Key health-related vulnerabilities include the risk of floods, droughts, and deteriorating water quality and supply for hundreds of millions of people.[6] Rising global temperatures increase the likelihood of severe weather events, net declines in world food production, and widespread deglaciation with the resultant loss of reliable summer melt stream flows, all detrimental to human health. In order to avoid passing this dangerous temperature threshold, the IPCC indicates that GHG emissions must peak within 10 years (of 2007) and atmospheric carbon dioxide (CO_2) levels stabilize at less than 440 parts per million (ppm). This corresponds to a 30-60% reduction in global GHG emissions by the year 2050 from the year 2000.[7]

The type of risk management approach, which seeks a reasonable target to avoid severe health, environmental, and other impacts of dangerous climate change, has been proposed by the EPA in its recent "Technical Support Document on the Benefits of Reducing GHG Emissions" and summarized by Environmental Defense Fund in its supplemental comments on the NPRM for the CAFÉ standards. These comments are attached here and we hereby incorporate them as part of EDF's comments on the draft EIS.

In this EIS GHG emissions for the CAFE alternatives are presented primarily in terms of the small relative differences among them, instead of the total GHG from the vehicle categories projected for each alternative. This is misleading because it gives the impression that each alternative will progressively decrease the nation's GHG emissions, when in fact, under each alternative total GHG emissions increase considerably compared to the present. Merely demonstrating the relative reductions of stricter alternatives versus "no action" paints a mirage of future benefits that do not exist.

We have conducted a simple analysis that provides this more appropriate contextual information. It demonstrates, for example, that under the "optimized" alternative, atmospheric CO_2 concentrations will increase by approximately 12 ppm by 2100.[8] This is a more appropriate depiction of its impact than showing, as the current EIS does, the tenths of a ppm variation between the different alternatives by 2100. NEPA requires that each proposal, including the "no action" alternative, be considered against the baseline

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[5] p. 228: Fisher, B.S. et al. 2007: Issues related to mitigation in the long term context. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Inter-governmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge
[6] p. 230, table 3.11: *ibid*.
[7] p. 229, table 3.10: *ibid*.
[8] This estimation relies upon the cumulative greenhouse gas (GHG) emissions presented in section 4 of the EIS and the assumption that oceans and forests will sequester half of the total GHG emissions. Then each 8,000 MMT CO_2e contributes 1 ppm of atmospheric CO_2e. See the EPA's paper, A Wedge Analysis of the U.S. Transportation Sector. EPA 420-R-07-007, U.S., 2007, for more details.

condition so that cumulative impacts, which are defined as both adverse impacts and the enhancement of the environment, can be compared with existing environmental impacts. This comparative analysis is unlawfully omitted from the EIS.

The absence of this critical contextual information prevents policy makers and the public from understanding whether a particular CAFE alternative will support a cumulative strategy to avoid the most serious of health and other climate impacts. A wedge analysis, such as the recent Environmental Protection Agency (EPA) transportation sector analysis, offers a solution to this contextual omission.[9]

Stabilization wedges, as developed by Pacala and Socolow, segment greenhouse gas emissions by source or sector and help to conceptualize the suite of mitigation strategies that would be required to stabilize or reduce cumulative emissions to achieve a future target.[10] In justifying their use of stabilization wedges, the EPA recognizes that this type of analysis "more clearly compare[s] the numerous vehicle technologies, fuels, and travel demand management … provides a metric to make evaluations based on *cumulative* emission reductions over a longer timeframe … [and] can be scaled to fit any analysis level of interest" (emphasis in original).[11] These properties match the aforementioned scope of analysis mandated by the Ninth Circuit court of appeals and provide a framework that can inform decision makers and the public as intended by NEPA.

The EPA's wedge analysis evaluates the cumulative growth in GHG emissions from the U.S. transportation sector between 2006 and 2050, measured as the amount of emissions in excess of a scenario in which yearly emissions continue at 2006 levels. During this timeframe the excess cumulative emissions total 45,000 million metric tons (MMT) of CO_2 equivalents (CO_2e). The EPA divides this into nine wedges of 5,000 MMT CO_2e each (see figure 1). The EPA targets the stabilization of atmospheric CO_2e at less than twice pre-industrial levels (i.e. 560 ppm CO_2 versus 280 ppm). To achieve this target, the EPA calculates that GHG emissions from the U.S. transportation sector must flatten at 2006 levels until 2050 and then undergo further reductions.

The EPA evaluates the contribution of three approaches for reducing GHG emissions: adopting advanced vehicle technology; switching to low-GHG fuels; and utilizing travel demand management. Currently available technologies that increase fuel efficiency, including advanced gasoline and diesel technologies and gasoline hybrid electric vehicles have the potential to provide 2.4 to 3.0 wedges in the EPA's analysis. In order to stabilize passenger vehicle emissions at 2006 levels, the EPA notes that over 4.3 wedges are necessary, or the cumulative avoidance of 21,500 MMT CO_2e.

Each of the three approaches explored by the EPA can significantly contribute to the leveling of emissions, but a strategy involving a mixture of all three is necessary to

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9 Mui S, Alson J, Ellies B, and Ganss D. A Wedge Analysis of the U.S. Transportation Sector. EPA420-R-07-007, U.S. Environmental Protection Agency, 2007.
10 Pacala S and Socolow R. 2004. Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies *Science* 305, 968-972.
11 p. 10 EPA

stabilize or reduce emissions. These findings underscore the importance of providing a cumulative impacts analysis within the EIS that appropriately delineates the contribution of fuel efficiency standards to the transportation sector's and the nation's portfolio of GHG mitigation solutions.

We therefore strongly recommend that NHTSA revise this EIS and incorporate a wedge-type analysis of the cumulative emissions resulting from the proposed CAFE alternatives. The EPA transportation sector analysis can serve as a reference, although we find their stabilization target of 560 ppm CO_2 not sufficient to avoid the 2.6°C increase in global temperature, IPCC's best current estimate of the threshold that avoids serious climate change effects. We believe the EIS must adopt the 440 ppm CO_2 atmospheric stabilization target identified by the IPCC unless the agency can point to other analyses of equal or greater credibility that justify the use of a higher CO_2 target to reach the same temperature goal.

As a demonstration, we have followed the framework of the EPA's wedge analysis and utilized the predicted future GHG emissions provided in the EIS. We demonstrate in a simplistic manner the contributions of the various CAFE alternatives to a U.S transportation sector target of flattening emissions at 2006 levels. Under the "no action" alternative, cumulative GHG emissions beyond the 2006 baseline total 28,000 MMT CO2e by the year 2050. The "optimized" alternative results in 21,000 MMT CO2e and the "technology exhaustion" option releases 18,000 MMT CO2e. These two options contribute 1.6 wedges ("optimized") and 2 wedges ("technology exhaustion") of 5,000 MMT CO2e towards flatlining transportation GHG emissions at 2006 levels (figure 2). We note that the EPA's analysis finds 2.4 to 3.0 wedges result from technology exhaustion, while NHTSA claims that this leads to only 2 wedges. We urge NHTSA to account for this difference in their revised EIS, with special attention given to assumptions regarding hybrid vehicle technology.

Increasing fuel efficiency on its own cannot mitigate U.S. transportation-related GHG emissions to an extent that avoids dangerous climate change. However, the transportation sector can stabilize its GHG emissions with a package of approaches. Rapidly increasing fuel efficiency is a key component to reducing cumulative GHG emissions over the next decades, as the EPA recognizes that "[n]ear-term vehicle technologies can have as much of an impact in terms of GHG reductions as future, longer-term technologies".[12]

II. Objections to the Failure of the EIS to Quantify Conventional Pollutant Health Impacts of the Proposed CAFE Alternatives

NHTSA fails to comply with the NEPA regulations requiring agencies to "present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public" in this EIS.[13] In particular, the EIS fails to disclose the

[12] p. 4 EPA
[13] CEQ 40 CFR 1502.14

likely adverse health effects of conventional air pollutants associated with each alternative, fails to compare alternatives based on their impact on human health, and fails to identify how each alternative considered will eliminate or minimize these health effects. The EIS completely ignores the responsibility under NEPA to provide useful information to the decisionmaker regarding the degree to which each alternative will protect the public from the adverse health effects of air pollution from the transportation fuel cycle.

Council for Environmental Quality (CEQ) regulations require that an EIS assess both the direct and indirect effects of proposed actions and their significance[14], which include those effects related to human health[15] and requires that an EIS consider the "degree to which the proposed action affects public health or safety".[16] Because the proposed alternatives will each significantly change human exposure to transportation fuel cycle emissions for the American public, and the adverse health effects resulting therefrom, a comparison of alternatives based on public health impacts is required. Under the CEQ regulations and settled case law, NHTSA cannot exclude these effects, which are obviously related to the proposed standards, from its EIS analysis.

The proposed CAFE alternatives result in varying levels of future air pollutant emissions that will differentially affect human health. NHTSA asserts that "assessing emissions is a valid approach to assessing air quality impacts because emissions, concentrations, and health effects are connected. Lower emissions should result in lower ambient concentrations of pollutants on an overall average basis, which should lead to decreased health effects of those pollutants".[17] However, the magnitude of this effect requires quantification, even if that quantification is subject to some uncertainty. The rote description of the various air pollutants and their related health impacts provided by the EIS does not satisfy NEPA. In the words of the Ninth Circuit court, "[g]eneral statements about "possible" effects and "some risk" do not constitute a "hard look" absent a justification regarding why more definitive information could not be provided".[18]

The EIS provides the relative future reduction of criteria air pollutants and hazardous air pollutants (HAPs) across the range of proposed CAFE alternatives. Unlike recent EPA regulatory impact analyses (RIAs)[19], however, this EIS fails to specify the relative human health impacts resulting from each emissions scenario.

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[14] CEQ 40 CFR 1502.16 (a) and (b)
[15] CEQ 40 CFR 1508.8
[16] 40 C.F.R. § 1508.27(b)(2)
[17] pp. 3-17 and 3-18, NHTSA
[18] *Neighbors of Cuddy Mountain v. United States Forest Serv.*, 137 F.3d 1372, 1380 (9th Cir.1998)
[19] See for example: *Ozone NAAQS Regulatory Analysis,* available at: http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=EPA-HQ-OAR-2007-0225. Chapter 6 enumerates the averted mortality and morbidity according to various ozone and PM attainment levels. See also the EPA's *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder* and *Regulatory Impact Analysis for the Final Clean Air Interstate Rule*

To demonstrate that such a linkage is possible and to suggest the relative magnitude of the health effects of the various CAFE alternatives, we have used a simple methodology to estimate multiple health outcomes. This method quantifies the relationship between the amount of emitted pollutant and human health effects. Our approach, although slightly different methodologically from that used by the EPA, relies upon much of the same scientific literature and appears to provide similar results. We use the predicted future tonnage of conventional air pollutants in the EIS in association with the intake fraction, a unitless measure of the percent of an emitted pollutant that is inhaled or ingested by the population at large.[20] These two variables, in conjunction with empiric measures of exposure-response relationships, allow us to characterize the health effects related to different quantities of pollutant emissions.[21]

We found striking and troubling differences in the health impacts of the proposed CAFE alternatives, measured in thousands of avoided premature deaths. For example, in comparing the "optimized" (NHTSA's preferred standard) alternative with the more stringent "total costs equals total benefits" ("costs = benefits") alternative, over 1400 excess infant deaths per year result under the "optimized" alternative by 2020. In addition, the "optimized" alternative leads to more than 2800 additional adult premature deaths, 8800 children's emergency room visits for asthma, and 640,000 lost work days yearly by 2020. See table 1 for more details on the health impacts of the various proposed CAFE alternatives.

Our analysis examined the health effects of only two pollutants, particulate matter (PM2.5) and nitrogen dioxide (NOx), of the more than ninety harmful air pollutants emitted by light vehicles.[22] Thus we significantly underestimate the true health protection of higher fuel efficiency.

The EIS, by omitting quantified health benefits, disregards one of its core purposes, namely, to "inform decisionmakers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment".[23] NHTSA must revise the EIS to include calculations of meaningful health outcomes, such that policy makers and the public more fully understand the implications of the proposed CAFE alternatives.

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[20] Bennett DH, McKone TE, Evans JS, Nazaroff WW, Margni MD, Jolliet O, and Smith KR. 2002 Defining Intake Fraction. *Environmental Science Technology* 36(9):207A-211A

[21] Basically the amount of emitted pollutant is multiplied by the intake fraction (calculated for the U.S. using spatial statistics to account for the locations and densities of emissions and people). We then multiply this number by a series of different exposure-response coefficients for different health outcomes, such as lung cancer, cardiovascular mortality, etc. The final product is the number of attributable health events for each pollutant over a year.

[22] See EPA, Master List of Compounds Emitted by Mobile Sources, EPA420-B-06-002, http://www.epa.gov/otaq/regs/toxics/420b06002.xls (identifying a subset of 93 compounds for which health risk data is reported in IRIS).

[23] CEQ 40 CFR Sec. 1502.1

III. Objections to the Failure of the EIS to Address Relevant Factors and the Failure of the EIS to Inform the Preferred Alternative:

A. The EIS Fails to Properly Consider the Relevant Statutory Factors under EPCA

The statutory mandate in the Energy Policy Conservation Act (EPCA) requires NHTSA to set the "the maximum feasible average fuel economy level" while considering "technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy".[24] NHTSA's statutory task is to first determine the "maximum feasible" limits of achievable fuel economy. Then NHTSA has some discretion to require less than the maximum feasible standard if such standard is not "economically practicable," but the agency is not given discretion to balance these statutory factors in a manner that defeats the primary purpose of EPCA. Congress has not given NHTSA discretion to "undermine the fundamental purpose of the EPCA: energy conservation".[25]

The EIS fails to properly weigh the statutory factors because it impermissibly relies upon the assumption that economic considerations may be used to reject the "maximum feasible" alternative without a showing that the economic costs associated with an alternative make that alternative not "economically practicable." Merely showing that the estimated mix of economic costs and benefits are optimized at one alternative level of the standard does not establish a basis for concluding that more stringent standards may be rejected as not "economically practicable."

Congress did not establish the optimization of costs and benefits as the controlling factor for setting the standard. The controlling statutory factor is the "maximum feasible" level, but in this rulemaking NHTSA has impermissibly substituted the level at which costs and benefits are optimized as the controlling factor for setting the standard. The statute only gives weight to economic factors to the extent that the maximum feasible standard is not economically practicable. Here, the EIS does not identify economic factors that make the maximum feasible standard not practicable, and fails to explain why alternatives more stringent than the economically optimized level of the standard are not "economically practicable." The failure of the EIS to explore the limits of what is economically practicable is fundamentally arbitrary and capricious because it fails to consider the factors made relevant by the statute.

Agency action is arbitrary and capricious if the agency did not make a good faith judgment based on its consideration of all relevant factors.[26] The courts will "set aside an agency action if [it] find[s] that the agency has … ignored factors that must be taken into account under any [governing] source[] of law" (citation and quotation omitted).[27] .

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[24] 49 U.S.C. §§ 32902(a), 32902(f).

[25] p. 14865 *Center for Biological Diversity*

[26] *Coalition for Responsible Reg'l Dev't v. Coleman*, 555 F.2d 398, 400 (4th Cir. 1977); see *also Ohio River Valley Envtl. Coalition, Inc. v. Kempthorne*, 473 F.3d 94, 102 (4th Cir. 2006) (noting that an agency must consider all important aspects of the problem)

[27] *Cerillo-Perez v. INS*, 809 F.2d 1419, 1422 (9th Cir. 1987); see also *Envtl. Def. Fund, Inc. v. Envtl. Prot. Agency,* 898 F.2d 183 (D.C. Cir. 1990) (remanding an agency decision for failure to address all statutory factors)

Mere recitation that an agency considered a factor is insufficient to meet the agency's duties.[28] Rather, the agency must take a "hard look" at all relevant factors.[29]

B. Failure of the EIS to Meet the NEPA Intent of Informing Decisionmakers

This EIS is supposed to be "more than a disclosure document"; it should "be used by Federal officials in conjunction with other relevant material to plan actions and make decisions".[30] Instead of informing policy makers, this EIS seems intended to justify a policy decision already made.

Although the EIS assesses a range of CAFE alternatives, NHTSA selected a preferred alternative (the "optimized" alternative) a priori to the environmental analysis. Nowhere does NHTSA provide a reasoned argument for why the findings of the EIS should not alter the choice of the preferred alternative. This blatantly contravenes the purpose that "[e]nvironmental impact statements shall serve as the means of assessing the environmental impact of proposed agency actions, rather than justifying decisions already made".[31]

The limited findings of the EIS suggest alternatives preferential to the "optimized" alternative. Any of the alternatives with higher fuel efficiency than that of the "optimized" alternative better minimize environmental impacts and foster energy conservation. For example, the "costs = benefits" alternative saves 5.5 billion gallons of fuel annually in 2020 compared to the "optimized" alternative. Furthermore, as described in section II, greater fuel efficiency will prevent thousands of premature deaths a year.

In summary, the EIS supports adoption of the most stringent CAFE standard rather than NHTSA's preferred "optimized" standard. NHTSA must adopt the feasible standard that achieves the greatest reduction in fuel use because that standard is mandated by the primary objective of EPCA—energy conservation—, unless the agency can show that such standard is not economically practicable. NHTSA must accordingly revise its preferred CAFE alternative to one of greater fuel efficiency.

<u>IV. Objections to the Balancing of Safety and Health in Attribute-based CAFE Standards</u>

NHTSA acted in an arbitrary and capricious manner by justifying attribute-based standards as a means to "eliminate the incentive for manufacturers to respond to CAFE standards in ways harmful to safety", while simultaneously ignoring the health consequences presented by the lower fuel efficiency permitted in larger vehicles.[32]

NHTSA purports to consider human health in developing CAFE standards through the use of attribute-based standards and rules in the VOLPE model that limit vehicle downweighting as a fuel efficiency technology. However this same health safety concern

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[28] *Getty v. Fed. Savings & Loan Ins. Corp.*, 805 F.2d 1050, 1055, 1057 (D.C. Cir. 1986)
[29] *Hickory Neighborhood Def. League v. Burnley*, 703 F. Supp. 1208, 1219 (W.D.N.C. 1988)
[30] CEQ 40 CFR Sec. 1502.1
[31] CEQ 40 CFR Sec. 1502.2 (g)
[32] p. 137 NHTSA.

is not evident in the choice of fuel efficiency standards. Particularly egregious are the lower fuel efficiencies permitted to larger vehicles, which increase the harm to human health through increased emissions of air pollutants.

NHTSA refers to several reports on safety and vehicle weight reduction and quotes the National Academy of Science's finding that in 1993 between 1,300 and 2,600 traffic accident fatalities occurred as a result of earlier vehicle downsizing and weight reductions.[33] This is less than the estimated number of deaths attributable to air pollution from a less stringent CAFE standard, as compared to a more stringent one (table 1).

We request that NHTSA give the same attention to protecting human health from air pollution as it does to protecting human health in its analysis of crashworthiness. A more stringent CAFE standard will better balance the benefits of health protection with the other statutory considerations and better align with NHTSA's attribute-based safety justifications.

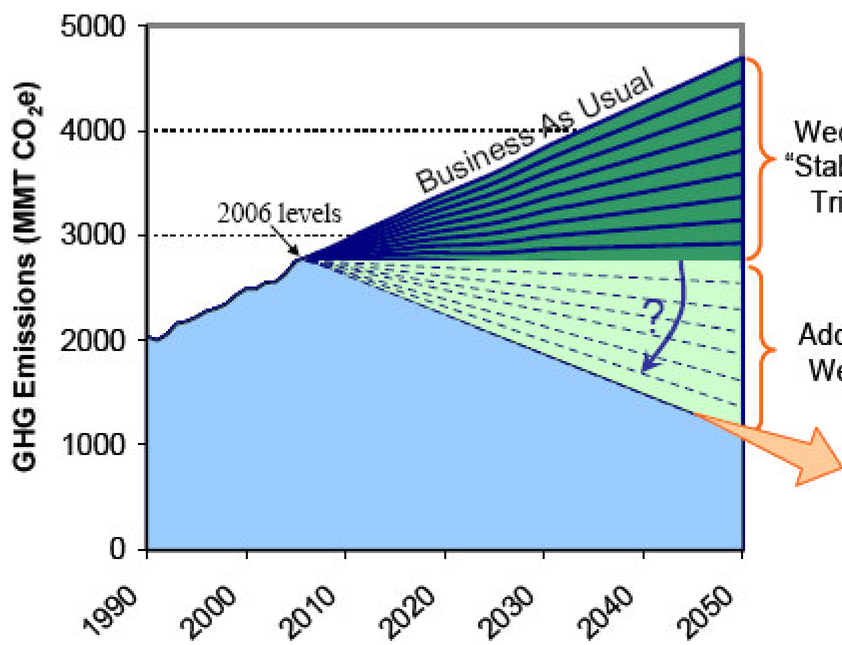

Figure 1. GHG emissions from the U.S. transportation sector. Cumulative emissions above the 2006 baseline are divided into 9 wedges of 5,000 MMT CO2e. (From Mui S, et. al. A Wedge Analysis of the U.S. Transportation Sector., U.S. Environmental Protection Agency, 2007)

[33] p. 3-86 NHSTA EIS

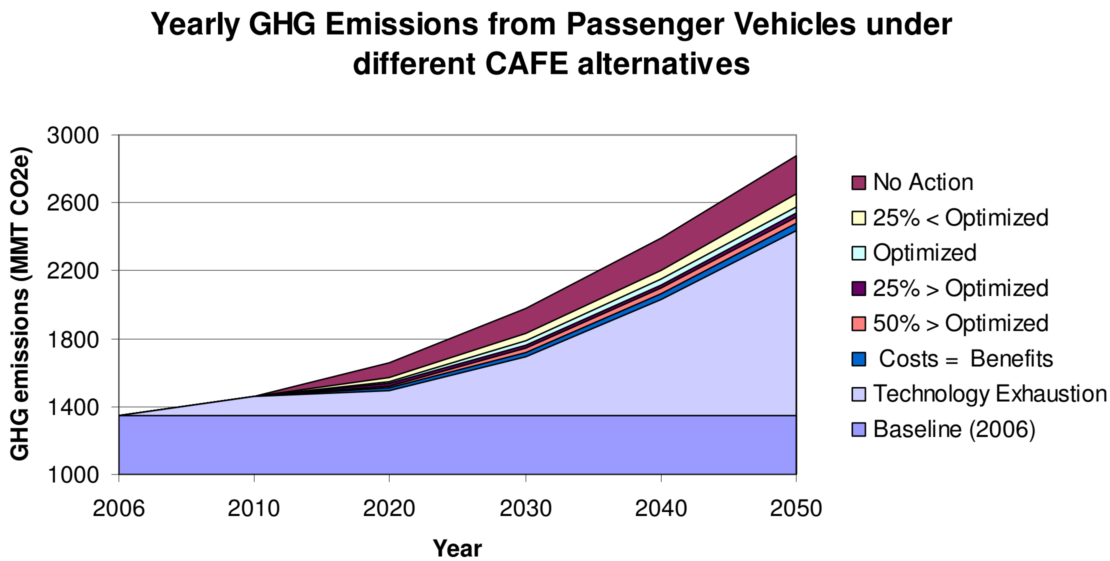

Figure 2. The yearly GHG emissions of passenger vehicles under different CAFE alternatives. The "technology exhaustion" alternative provides two wedges of 5,000 MMT CO2e towards stabilizing emissions at a 2006 baseline level.

	2020	2035
Premature mortality: All-cause (< 1 year)	1,442	3,420
Premature mortality: all-cause (> 29 years)	2,870	6,979
Asthma-related ER visits (0-18 years)	8,811	17,324
Work loss days (18-65 years)	648,301	1,363,934

Table 1. Averted yearly morbidity and mortality due to PM2.5 and NOx under the "total costs equals total benefits" proposed CAFE alternative versus the "optimized" alternative in 2020 and 2035.

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Supplemental Comments on the Notice of Proposed Rulemaking: "Average Fuel Economy Standards for Cars and Light Trucks - Model Years 2011-2015"

National Highway Traffic Safety Administration
Docket No. NHTSA-2008-0089-0002

Environmental Defense Fund (EDF) respectfully submits the following supplemental comments on NHTSA's Notice of Proposed Rulemaking (NPRM) for "Average Fuel Economy Standards for Cars and Light Trucks; Model Years 2011-2015" [Federal Register 73(86): 24352-24487, May 2, 2008], building upon our earlier comments submitted July 1st, 2008. EDF submits the EPA document, "Technical Support Document on Benefits of Reducing GHG Emissions," and the following discussion of the Technical Support Document's (TSD) findings. The TSD was not publicly available at the time comments were due but has central relevance for NHTSA's rulemaking.

EPA has analyzed available research and information on the monetary benefits of reducing greenhouse gas emissions, and EPA has made findings and determinations on the basis of this extensive body of information. EPA's assessment is far more rigorous than NHTSA's proposal, and EPA's determinations are supported by a considerable and well-reasoned volume of information. We respectfully request that the additional comments herein and the supporting information be promptly included as part of the administrative record for this rulemaking proceeding, and that NHTSA's final rulemaking action be adjusted in accordance with EPA's assessment and findings. Indeed, NHTSA has previously erred in its failure to adequately address the societal benefits of carbon dioxide emission reductions. See Center for Biological Diversity v. NHTSA, No. 06-71891 (9th Cir. Decided November 15, 2007).

Any questions or requests for further information on these comments can be directed to Martha Roberts at mroberts@edf.org, or 303-447-7214.

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FINDINGS FROM EPA'S SOCIAL COST OF CARBON ANALYSIS

Based on a meta-analysis of recent peer-reviewed studies, EPA's mean estimate of the marginal benefit of reducing emissions of carbon dioxide is \$40/tCO_2 (3% discount rate) or \$68/tCO_2 (2% discount rate).[i] These figures represent the cost of 2007 emissions, in 2006 dollars. This preliminary meta-analysis built on the methods of Tol 2005 and Tol 2007, but included only recent peer reviewed studies that met a range of quality criteria in its evaluation.

EPA concluded that these estimates likely underestimate the costs of carbon dioxide emission.

- *Studies used in the meta-analysis omit important impact categories, including the potential for catastrophic impacts:* "…it is important to note at the outset that the estimates are incomplete since current methods are only able to reflect a partial accounting of the climate change impacts identified by the IPCC." "Current estimates do not capture many of the main reasons for concern about climate change, i.e., non-market damages, the effects of climate variability, risks of potential extreme weather (e.g., droughts, heavy rains and wind), socially contingent effects (such as violent conflict), and potential long-term catastrophic events."[ii]
- *These figures fail to incorporate findings that climate change is occurring faster than expected, and populations are more vulnerable than expected:* "Underestimation is considered even more likely when one considers that the current trajectory for GHG emissions is higher than typically modeled, which combined with current regional population and income trajectories that are more asymmetric than typically modeled, imply greater climate change and vulnerability to climate change."[iii]

EPA concluded that SCC estimates should represent the global impact of climate change.

- *Greenhouse gases are global pollutants:* "GHG emissions are different in important ways from other emissions regulated under the Clean Air Act. In particular, CO_2 and GHGs have global and very long-run implications compared to conventional air pollutants…Therefore, emissions from the U.S. will contribute to climate change impacts in other countries, and emissions in other countries will contribute to climate change impacts in the U.S."[iv]
- *SCC estimates that reflect only 'domestic' effects will miss important potential impacts on the U.S.:* "…domestic estimates omit potential impacts on the United States (e.g., economic or national security impacts) resulting from climate change impacts in other countries."[v]
- *As a result, global cost of carbon estimates are important in evaluating efficient levels of carbon abatement:* "Because GHGs are a global pollutant, economists point out

that, to achieve an efficient economic outcome (i.e., maximize global net benefits), countries would need to mitigate up to the point where their domestic marginal cost equals the global marginal benefit (Nordhaus, 2006). Net present value estimates of global marginal benefits internalize the global and intergenerational externalities of reducing a unit of emissions and can therefore help guide policies towards an efficient level of provision of the public good."[vi]

EPA concluded that using a low discount rate is most appropriate for SCC estimation.[vii]

- *Government practice supports the use of rates of 3% or lower:* "OMB's Circular A-4 general analytical guidance requests use of constant 3% and 7% discount rates for both intra- and inter-generational discounting and allows for low but positive consumption discount rates if there are important intergenerational benefits or costs (e.g., 1–3% noted by OMB, 0.5–3% by EPA). In this inter-generational context, a three percent discount rate is consistent with observed interest rates from long-term intra-generational investments (net of risk premiums) as well as interest rates relevant for monetary estimates of the impacts of climate change that are primarily consumption effects."[viii]
- *Scientific literature supports the use of rates of 3% or lower:* "A review of the literature indicates that rates of three percent or lower are more consistent with conditions associated with long-run uncertainty in economic growth and interest rates, inter-generational considerations, and the risk of high impact climate damages (which could reduce or reverse economic growth)."[ix]

EPA suggested that a risk assessment framework may be more appropriate in light of the ethical implications of climate change and the difficulty in valuing catastrophic risks to future generations.

- *Decisions about emissions control will involve more than only economic criteria:* "Economics alone cannot indicate the 'correct' amount of GHG mitigation. Judgments about the appropriate mitigation policy can be informed by economics, but also involve important policy, legal, and ethical questions that cannot be answered by economics (as well as consideration of non-quantified benefits). For example, what degree of climate change risk is acceptable for future generations, or people in other countries, when GHG emissions imply irreversible changes in climate? …Answering such questions involves making unavoidable ethical choices (Broome 1992, 2008)."[x]
- *A risk management framework may be more appropriate to determine a strategy for climate change mitigation:* "Furthermore, because current marginal benefits estimates are incomplete and highly uncertain (with many uncertainties outside of observed variability), we cannot use them to identify an economically optimal (or economically efficient) standard, even for incremental changes in global GHG emissions." "In situations with large uncertainties, such as climate change and climate change impacts, economics recommends a risk management framework as

being appropriate for guiding policy (Manne and Richels, 1992; IPCC WGIII, 2007). In this framework, the policymaker selects a target level of risk and seeks the lowest cost approach for reaching that goal."[xi]

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[i] U.S. Environmental Protection Agency, Technical Support Document on Benefits of Reducing GHG Emissions (June 12, 2008), at 12.
[ii] Id. at 11, 15.
[iii] Id. at 15.
[iv] Id. at 1.
[v] Id. at 11.
[vi] Id. at 5.
[vii] A discount rate can be described as the assumed rate at which society is willing to trade off present for future benefits.
[viii] US EPA (2008) at 9.
[ix] Id. at 9.
[x] Id. at 8.
[xi] Id. at 16, 8.

National Highway Traffic Safety Administration (NHTSA)
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August 18, 2008

RE: DOCKET NUMBER NHTSA-2008-0060, Comments submitted on behalf of the Sierra Club
Draft Environmental Impact Statement for New Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, MY 2011-2015.

I. Introduction

If there ever was a need for the nation to conserve oil, it is now. The headlines daily remind us of the consequences of oil dependence. Americans send nearly 2 billion dollars overseas for oil every day. Many can no longer afford to fuel the gas-guzzlers they purchased nor can they resell them as buyers flock to smaller cars. As fuel costs skyrocket, food prices rise, and dollars that should be spent with local businesses and in our communities are being drained from our economy - causing economic havoc.

It took decades, but in December 2007, Congress finally passed the first mandated increase to fuel economy since the original CAFE law was passed. After letting standards languish, NHTSA is finally ramping up mileage standards. In the meantime, however, the industry has become addicted to selling SUVs and we have become addicted to oil. **Raising fuel economy standards to at least 35 mpg by 2015 is a key step to curbing our oil addiction - and reducing global warming pollution**.

II. Overview of Flaws in the DEIS Analysis

The biggest single step we can take to curb global warming, save oil, and help consumers save money at the pump is to make new vehicles go farther on a gallon of gas. But we see in NHTSA’s April 22 Notice of Proposed Rulemaking (NOPR) and the supporting Draft Environmental Impact Statement (DEIS) that fuel economy is only the biggest single step if the right standards are set and evaluated in the right context.

1. The fuel economy standards assessed in the DEIS are too low:
Sierra Club’s written comments on the proposed rule addressed the flawed process for arriving at the 31.6 mpg standard (submitted to Docket No. 2008-0089 on July 1, 2008). The NOPR and Preliminary Regulatory Impact Analysis (PRIA) both show that gas prices are a major factor in setting fuel economy. NHTSA shortchanges America by using gas price assumptions that are far too low, a price for a ton of CO_2 that is randomly selected, and by not fully incorporating the benefits of available technologies. NHTSA must set the right “optimized” standard and then recalibrate the other bounds. The 35 mpg target for 2020 is a floor, not a ceiling – the law directs that the standards should be the maximum that are technologically feasible. The public cannot have confidence that NHTSA is setting the right standards when some of the key inputs in its analysis are flawed.

NHTSA’s own analysis shows that between 2011 and 2015, significantly higher standards are technologically feasible and economically practicable when higher gas prices are used ($3.14 per gallon in 2016). NHTSA’s final rule should be, at a minimum, consistent with the analysis provided in the PRIA. NHTSA's use of below-cost energy estimates is arbitrary and capricious and violates the agency's statutory charter to impose mandatory maximum feasible fuel economy standards based upon a review of economic and technological feasibility.

2. NHTSA's range of fuel economy increases is flawed:
Because NHTSA's proposed standards are based upon flawed assumptions, the range of options considered in the DEIS is incorrect. In the DEIS, NHTSA's basic approach to setting new fuel economy standards is to strictly adhere to hitting, but not exceeding, 35 mpg in 2020. At several points in the DEIS, NHTSA recognizes the two critical words "at least," which precede 35 mpg in the 2007 Energy Independence and Security Act. At other points, NHTSA says the standards must be set to merely hit 35 mpg in 2020. NHTSA should recognize that 35 mpg is the floor that Congress provided and set standards that are not improperly bound to meeting a minimum fleetwide average of 35 mpg in 2020. Because NHTSA's proposed standards are too low, the range of options NHTSA considers in the DEIS are also too low.

Further, NHTSA notes that only the 2016-2020 standards are foreseeable in the DEIS and therefore does not consider increases to the standards after 2020. The law clearly provides for maximum feasible standards in the years that follow. Increases beyond 2020 are foreseeable, perhaps just as foreseeable as the vehicle miles traveled (VMT) increases NHTSA presumes through 2100. NHTSA should first use more accurate values for gasoline prices and carbon values and more realistic assumptions about hybrid penetration and an accelerated introduction of PHEVs and EVs – all of which will justify a standard of at least 35 mpg in 2015. NHTSA should then recalibrate its alternative scenarios to reflect these changes. Finally, in the DEIS NHTSA must presume that fuel economy will continue to rise at a maximum feasible rate. The DEIS is premised upon the flawed proposed standards and scenarios that must be addressed in the final EIS.

3. NHTSA does not meet its obligation to inform the public:
We also have serious concerns that the DEIS fails to meet its primary function to "inform the public that [the agency] has indeed considered environmental concerns in its decision making process." In this case the agency does not give a fair or reasonable evaluation of the environmental impacts of the proposed standards nor does NHTSA provide a context that reasonably informs the public.

The DEIS takes the real differences between the flawed options considered and runs them so far out – to 2100 – that they cannot meaningfully be differentiated or evaluated. Faster fuel economy increases will help the US cut the 20% of CO_2 emissions that come from vehicles. The difference between 35 in 2015 and 35 in 2020 is real and significant. It creates room for reaching 42 mpg in 2020 – and increases beyond (surpassing 50 mpg by 2030). It would also mean saving an additional 880,000 barrels of oil per day in 2020 and further reductions in emissions.

It is worth noting that the DEIS reveals that this one policy is significant enough that it could affect the climate in 2100 assuming no other action is taken. The problem with NHTSA's analysis is that if we hit 700 plus ppm referenced in the DEIS, then we have not acted to prevent dangerous climate change as provided in Article 2 of Framework Convention on Climate Change.

There is no requirement that NHTSA run its analysis though 2100. NHTSA notes that the VOLPE model estimates emission reductions through 2060. The agency provides that "as a simplifying assumption, annual emissions reductions from 2061-2100 were held constant." NHTSA should assess how the correct scenarios will impact emissions from cars and light trucks in a time frame that is meaningful to the public, within the context of science, and not "simplify" its "assumptions."

III. The Correct Context of Carbon Emission Reductions

Fuel economy is only one policy in the tool bag – one which can be effectively utilized to decrease the 20% of US CO_2 emissions that spew from our cars and light trucks. If we are to achieve the goal of the averting dangerous global warming – which requires an 80% reduction in CO_2 below 2000 levels – then we need to assess the CAFE options in this context. In other words, NHTSA should evaluate which of the "right" scenarios will best help the US reduce its emissions to the levels required to avoid dangerous climate change, not whether any of the scenarios will make a difference if we've already gone too far. We must also take measures now to reduce the rate at which emissions are growing. In this context, faster fuel economy increases will result in faster turnover of the fleet, help drive new fuel saving technologies into vehicles, and put the US on the right path to reducing global warming emissions.

For too long the industry has fought higher fuel economy standards and has successfully constrained NHTSA and Congress. We can no longer afford to allow the purpose of the fuel economy law to be undermined. NHTSA must take the lead – and not set tomorrow's standards using yesterday's gas prices. Before NHTSA finalizes its standards and the EIS it must ensure that it is meeting the intent of the CAFE law and of NEPA. We must end our addiction to oil – raising fuel economy standards to at least 35 mpg in 2015 will speed up oil savings and decrease CO_2 emissions. Finally, NHTSA must evaluate the environmental impacts of these standards in a science-based context that informs the public.

The DEIS fails to analyze the benefits of greenhouse gas emission reductions from various fuel economy standards in the proper context. Not surprisingly, when NHTSA tries to determine the global warming impacts in 2100 resulting from a 31.6 mpg in 2015 standard vs. a 35 mpg in 2015 standard, statistically, the difference is very little. But this does not mean that raising fuel economy standards faster will not have a significant impact in our struggle to reduce global warming pollution.

In order to prevent the worst effects of climate change, the U.S. must decrease its carbon emissions by around 80% by 2050 – with meaningful short-term and interim targets. In order to be on-target for reductions such as these, by 2020 the U.S. needs to reduce its carbon emissions back to at least 1990 levels. The Environmental Protection Agency's (EPA) Greenhouse Gas (GHG) emission inventory reports that 1990 levels were 6,147 Million Metric Tons of CO_2 (MMTCO2e). If our emissions continue to grow, along a "business as usual" trajectory, EPA estimates that by 2020, carbon emissions will have grown to 8,264 MMTCO2e. Therefore, in order to return to 1990 emission levels by 2020, we must cut (=8,264-6,147) 2,116 MMTCO2e worth of greenhouse gas pollution from various sources by 2020, or equivalent to a 25% decrease in emissions.

Now, considering that the transportation sector is responsible for nearly a third of all GHG emissions in the U.S., with cars and light trucks accounting for 20%, it would make sense that we must proportionally reduce emissions from cars and light trucks to help meet this overall 2,116 MMTCO2e reduction. Since 20% of emissions come from cars and light trucks, 20% of the 2,116 MMTCO2e target reduction, or 423 MMTCO2e, should come from cars and light trucks.

So how do we get there? If we implement the weak proposed standards that NHTSA has published, which put us on a path to 35 mpg by 2020, we will save around 1.4 million barrels of oil per day in 2020. This is equivalent to keeping almost 220 million metric tons of CO_2 out of the atmosphere. While this is significant, it isn't enough to get us to 423 MMTCO2e. However, if NHTSA speeds up fuel economy standards to 35 mpg by 2015, using a more accurate price of gasoline and fully incorporating all of the current available technology advances, and puts us on a path to 42 mpg by 2020, we will save an additional 880,000 barrels of oil a day in 2020. This brings us to a grand total of 2.28 million barrels of oil saved every single day in 2020 – a number that will increase as the fleet turns over – and will keep at least 360 million metric tons of CO_2 out of the atmosphere. While still short of the target cuts from cars and light trucks, 35 mpg by 2015 gets us significantly closer to these goals.

To simplify this even further, to be on track for necessary carbon reductions, we need to reduce the emissions from cars and light trucks by 25%. NHTSA's proposed 35 mpg by 2020 standards only gets us halfway there. Not nearly enough in a global warming context.

IV. Court Mandate on Global Warming and the Framework Convention on Climate Change

NHTSA should consider the Supreme Court decision in *Massachusetts v. EPA* and that the Court stated, on pages 21-23 concerning vehicle emissions, that "reducing domestic automobile emissions is hardly a tentative step." The Court also noted that cars and trucks account "for more than 6% of worldwide carbon dioxide emissions. To put this in perspective: Considering just emissions from the transportation sector, which represent less than one-third of this country's total carbon dioxide emissions, the United States would still rank as the third-largest emitter of carbon dioxide in the world, outpaced only by the European Union and China. Judged by any standard, U. S. motor-vehicle emissions make a meaningful contribution to greenhouse gas concentrations and hence, according to petitioners, to global warming."

This DEIS turns these words on their head – diminishing the differences between the options (which are too low to begin with) and failing to meaningfully express the role fuel economy can have on US emissions. In addition, by allowing that Massachusetts had legal standing in the findings of *Mass. v. EPA,* the Court also recognized the importance of the remedy – that even a small step provides relief from global warming. We would agree that increasing fuel economy, while an important part of this remedy, cannot be the only solution.

Finally, the Framework Convention on Climate Change – of which the US is signatory – states in Article 2, that: "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, **stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."**

Clearly, taking the largest step possible to reducing global warming pollution from vehicles and reaching a fuel economy standard of 35 mpg by 2015 would most align with both the Court's ruling and the Framework Convention's goals for the U.S.

V. Conclusion

The debate is over on climate change – scientists and the American public have reached the same conclusion – it is happening now, we are already feeling the vast repercussions, and we must act immediately if we are going to stave off the worst effects. The reports on climate change that pour in daily no longer focus on predictions for the far future, but on consequences of global warming we are experiencing today, and how global warming will continue to disrupt our environment, our economy, and our very ability to survive if we don't act quickly to reduce our carbon emissions. It is more important now than ever to curb our greenhouse gas emissions and do our part to mitigate global climate change. The cost exacted on us if we do nothing is guaranteed to be worlds steeper than any possible costs of prevention.

In proposing fuel economy standards, NHTSA not only fails to take full advantage of available fuel saving technologies, and but also fails to fully and fairly evaluate the benefits of greenhouse gas emission reductions associated with higher fuel economy. NHTSA must reconsider the proposed standards and use its statutory authority to meet the United States' urgent need to conserve oil, to satisfy the growing demand of American consumers for vehicles that go farther on a gallon of gas, and to help curb the looming global impacts of climate change. NHTSA's approach – looking at how initial fuel economy increases will impact global warming in 2100 – is fraught with incredible uncertainty that could easily be avoided by narrowing the timeframe. This DEIS not provide the public with a meaningful context for evaluating the options.

NHTSA must first set standards that truly are the maximum technologically feasible – not standards that shortchange America. In the DEIS, NHTSA must foresee reasonable increases to fuel economy beyond 2020 just as the agency does for VMT, and most importantly, must evaluate these crucial reductions in the proper context as we move forward as a country, and as a planet, to prevent the devastating effects of global warming.

August 18, 2008

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Docket No. NHTSA–2008–0060

Mr. Ports and/or Whom It May Concern:

This letter is in response to the Draft Environmental Impact Statement for New Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, MY 2011-2015, Docket No. NHTSA-2008-0060. We are responding on behalf of the Department of Health and Human Services (DHHS), U.S. Public Health Service.

Please consider the following comments as they pertain to adequate analysis of the human environment pursuant to NEPA for CAFE standards development.

We have reviewed NHTSA's June 2008 draft DEIS for the CAFE standards. We commend your effort to create a comprehensive document in a limited time-frame but have concerns that a comprehensive analysis and assessment of the impacts to the human environment was not completed. Specifically, while we applaud the inclusion of human health concerns in the discussions of the CAFE standards' Affected Environment (chapter 3) and Cumulative Impacts (chapter 4), health analysis and modeling of the proposed alternatives is lacking.

Review and Comments: Health Analysis in DEIS

So that comprehensive impact analysis of the human environment for CAFE standards might be carried out and adequately considered in the assessment:

- Collaboration with public health professionals is suggested for assessment and analysis of the CAFE standards' human health impacts.
- Economic analysis should include health costs associated with the environmental impacts of alternatives. This should be described in the EIS.
- Mitigation analysis for projected public health outcomes is necessary. Current mitigation analysis in the DEIS is insufficient.

CAFE standards' impact on climate change deserves special attention. In the magazine *Science* (2004), S. Pacala and R. Socolow articulate the concept of an orchestrated approach to solving climate change with existing technologies, policy change, and behavioral changes. Each component in such an approach is referred to as a *Stabilization Wedge (*Pacala and Socolow, "Stabilization Wedges: Solving the Climate Problem for the next 50 Years with Current Technologies**"** *Science 2004 Aug 13;305: 968-972)*. CAFE standards that increase fuel efficiency is a critical and necessary component in the wedge approach and ought to be assessed in this context.

In Chapter 3, Affected Environment and Consequences, the assumption is stated that, *"the tightened CAFE standards would create an incentive to drive more because they would decrease the vehicle's fuel cost per mile. The total amount of passenger car and light truck VMT would increase slightly due to this 'rebound effect'."* There is substantial uncertainty in this argument and an insufficient analysis in the DEIS of variables affecting VMT projections, such as current and projected fuel costs. A sensitivity analysis is warranted to examine the implications of higher or lower assumptions about rebound effects.

The anticipated effects of increased CAFE standards on the human environment in the United States will occur primarily through the following mechanisms: 1) Fleet emission changes 2) Fuel consumption changes 3) Fleet design changes. To adequately assess the potential impact of CAFE standards on the human environment:

- Health impact analysis and modeling of each mechanism is necessary for each of the proposed alternatives.

Fleet Emission Changes and Human Health:

Transportation-related emissions contribute to climate change. CAFE standards can promote the use of alternative technologies in the US and abroad that reduce harmful emissions and, in turn, reduce contributors to climate change and improves human health outcomes. Although some health outcomes of climate change are difficult to predict, others are supported by considerable evidence. Health impacts affected by increasing or reducing contributors to climate change are appropriate for analysis of the human environment pursuant to NEPA.

- Health outcomes from climate change, for which quantitative or qualitative impact analysis is possible, should be included in predictive modeling.

Automobile contributions to criteria air pollutants are affected by CAFE standards and such emissions directly affect human health outcomes. Asthma, bronchitis, chronic obstructive pulmonary disease, and cardiovascular disease are some of the most common health outcomes triggered or exacerbated by air pollutants from motor vehicles. Reducing ozone forming emissions, NOx, and hydrocarbons can improve human health outcomes and reduce medical care costs. The DEIS fails to discern among alternatives regarding the health impacts from emissions/air pollutants. For adequate analysis of impacts to the human environment pursuant of NEPA:

- Analysis of the potential health effects from fleet emissions, both acute and chronic, is critical to include in the analysis of alternatives pursuant to NEPA.
- Adequate cost/benefit analysis of alternatives should include health costs associated with the acute and chronic effects from auto emissions at each level in the range of alternatives to show both current associated costs and potential savings from reduced emissions.
- Collaboration with public health economists is warranted.

Fuel Consumption Changes and Human Health:

Decreased demand and consumption of fossil fuel in an environment of increasing costs likely affects economic stability which affects human health outcomes (e.g. "drive or eat").

These health determinants and potential health outcomes should be considered as factors affected by CAFE standards and discussed.

Fleet Design Changes and Human Health:

Vehicle safety is a public health concern. Appropriate vehicle design as well as decreasing vehicle fleet disparities in size and weight can act to decrease crash-related injury to those driving lighter-weight automobiles and trucks as well as other modes of transportation such as bicycles, motorcycles, and scooters. Changing CAFE standards will affect fleet design and therefore have the potential to increase or decrease crash-related injury. Potential fleet design and composition by which vehicle manufacturers will comply with new CAFE standards warrants comprehensive analysis. Modeling these projections is critical to an adequate analysis of the impact that new CAFE standards will have on the human environment. To adequately promote and protect human health assuming shifts in the US automobile fleet make-up:

- Analysis of current vehicle fleet composition, prospective fleet composition, and optimal fleet composition with respect to transportation user needs, CAFE standards, and decreasing crash-related injury to transportation system users is also warranted for adequate assessment.

Thank you for the opportunity to review and comment on this proposed action. Please furnish one electronic copy of all NEPA documents related to this proposal to Sarah K. Heaton, MPH at SHeaton@cdc.gov as they become available for review or to the address below.

Sincerely yours,

Andrew L. Dannenberg, MD, MPH
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